PHOTOSYNTHESIS IN RELATION TO SOME SELECTED ENVIRONMENTAL PARAMETERS IN PRAWN CULTURE FIELDS

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of the Cochin University of Science and Technology

November 1986

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To My Parents

CERTIFICATE

This is to certify that this dissertation is a bonafide record of work carried out by Sri K. Madhusudhan Reddy under my supervision and that no part thereof has been presented before for any other degree.

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PREFACE

In recent years aquaculture has gained lot of importance world over because it was found to be more renumerative than agriculture. It helps to supplement the yield to the traditional capture fishery which has reached a stagnation point. At present, prawn or shrimp culture, finfish culture, mussel culture, oyster culture, seaweed culture, etc., have gained importance all over the world. There is vast scope for adopting these technologies on commercial lines by government or by the private agencies which may help in improving the socio-economic conditions of the rural population. Hence this institute has come in a big way to develop various technologies for aquaculture in general and mariculture in particular.

Prawn culture in the low lying fields adjoining backwaters of Kerala and the 'Bheries'of West Bengal are in vogue from ancient times. In Kerala, about 5120 ha. of fields are utilized for prawn culture. The ever-increasing demand for prawns has stimulated countrywide interest in scientific prawn culture and enterpreneurs are coming forward to establish prawn farms. If the farm is to be economically viable, various factors have to be taken into consideration before selecting a suitable site.

The environmental factors play a very important role either directly or indirectly on the productivity of any ecosystem. Estuaries are highly productive and are extraordinarily fertile. The organic matter produced in estuaries is several times more than in the open sea or shelf waters. The various environmental factors such as temperature, salinity, dissolved oxygen,pH, seston, nutrients, alkalinity and chlorophyll are greatly influenced by the tidal rhythm. The low-lying brackishwater areas form a suitable site for culture practices.

The carrying capacity of any culture system depends mainly on its primary productivity. Therefore, it is very essential to assess the biogenic capacity of water to determine the stocking strategies. Growth and production of all culture organisms in a pond vary according to the level of primary production. The primary productivity is the basic link in the chain of events leading to the tertiary production in the ecosystem. In order to attain the requisite productivity, the rate of photosynthesis has to be increased by manipulating the different environmental parameters. An attempt has been made in the present study to investigate the role of some selected environmental factors on the photosynthesis and its effect on the productivity.

I express my deep sense of gratitude to Dr. V.S.K. Chenubhotla, Senior Scientist and my Supervising Teacher for his constant help and guidance during this study. I am greatly indebted to Dr. P.S.B.R. James, Director, C.M.F.R.I., for all the facilities and encouragement given to me during the course of my study. I take this opportunity to place on record my sincere gratitude to Dr. P.V.R. Nair, former Joint Director, C.M.F.R.I., for his valuable guidance, advice and whole-hearted support. I also thank Sri M.S. Muthu, Senior Scientist and Officer-in-Charge, Marine Prawn Hatchery Laboratory, Narakkal, for his valuable suggestions given during this work. I stand in appreciation of Sri Nanda Kumar for his timely help. My sincere thanks are due to Sri Joseph Gilbert, Sri K. Suresh Kumar, Senior Research Fellows and Kum. Usha for helping me during this study. I also thank my seniors as well as juniors and my class mates, especially S/Sri Dipak N. Chaudhari, Sandip R. Ahirrao and A.K.V. Nasser for their timely help rendered to me during this period of study. Last but not least I thank the I.C.A.R., New Delhi for providing me with Junior Research Fellowship during the post-graduate programme in Mariculture.

INTRODUCTION

Photosynthesis is the process by which chlorophyll containing plants convert solar energy into photochemical energy. This energy stored in the form of carbohydrates, provides food for man and all other heterotropic organisms. In addition, it provides the most vitally needed supply of oxygen. It is becoming more and more apparent that, evaluation of the true productive potential of water bodies is necessary for utilization of this most fundamental metabolic activity of green plants. The process of photosynthesis is initiated when light is absorbed by an antenna molecule within the photosynthetic membrane. Although there are several pigments that are involved in the light-gathering process, the fundamental importance of chlorophyll (chl) or bacteriophyll (Bchl) is clear from the fact that this molecule is common to all photosynthesis antenna systems, as well as reaction centre.

The earlier experiment of Ruben *et al*. (1941) provided experimental evidence for Van Neil's argument that H_2O was the source of O_2 in photosynthesis. This concept has been challenged by Warburg (1964), Metzner (1975) and by Stemler (1980). Although there is general agreement that the ultimate source of O_2 is H_2O

(Metzner 1966; Stemler and Radmer, 1975; Radmer and Ollinger, 1980). Metzner et al (1979)and Stemler (1980) believe that the immediate source of O_2 may be HCO_3 or CO_2. The involvement of CO_2 in water oxidation is presently unsettled, although it has been shown that CO_2 plays a role in electron transport between the two photosystems.

Investigations on the production of organic matter in a coastal region were first made in the English Channel. By determining the changes in alkalinity (loss of CO_2) Atkins (1922) estimated the production of dextrose for a unit area. Subsequently Atkins (1923) calculated the annual plankton crop from phosphorous consumption and arrived at figures identical with the earlier calculations. This was followed by Krebs and Verbinskaya (1930), Cooper (1933), Harvey (1950) and Steele (1956). Production was calculated by estimating the oxygen consumption in the vertical water column of western north Atlantic (Seiwell, 1955) and by the distribution of oxygen in the Sagasso Sea (Riley and Gorgy, 1948).

A review of the various aspects of primary production has been given by Steeman Nielsen (1952, 1958a, 1960, 1963 and 1964). Ryther (1956), Laevastu (1958), Steele (1961), Yentsch (1963) and very comprehensively by Strickland (1960, 1965) and Vollenweider (DN) (1969);

Radhakrishna (1969), Koblentz-Michke, Volkinsky and Kabanova (1970).

The first really direct method of estimating the production of organic matter using light and dark bottle was introduced by Putter (1924) and subsequently by Gaarder and Gran (1927), Marshal and Orr (1928, 1930) and Steeman Nielsen (1932, 1937, 1951). A modification of this method was used by Riley in both eutrophic and oligotrophic regions (1938, 1939, 1941a,1941b). Investigations with radioactive carbon and the data on oceanic production were collected by the GALATHEA Expedition (Steeman Nielsen, 1952 and 1954).

During the last decade there has been considerable progress in the study of primary production in the Indian Ocean region and the environmental phenomena that regulate it. During the GALATHEA Expedition primary production was measured by ^{14}C techniques in the western Indian Ocean along the coast of Africa, equatorial part of the Indian Ocean in a section from Mombassa to Ceylon, Bay of Bengal and the Indo-Malayan waters (Steeman Nielsen, 1952, 1954; Steeman Nielsen and Aabye Jensen, 1957). After extensive measurements of primary production on board the ANTON BRUNN, Ryther <u>et al</u> (loc cit) showed that the western Indian Ocean is one of the most productive regions in the world. The observations in the western half of the Arabian Sea are summarised by Worster et al (1967). Newell and Keer (1968) and Kabavano (1968) summarised the results of primary production measurements in the Indian Ocean by the expeditions of various countries. Estimates of primary production in the different ecological zones of the Indian Ocean were presented by Moiseer (1969). Prasad, Banerji and Nair (1970) made a quantitative assessment of the primary production in relation to the potential fishery resources of the Indian Ocean and Cushing (1971) for the upwelling regions.

In hydrobiology, the chlorophyll concentration was originally used for estimating the biomass of phytoplankton, it was also employed later on for estimating the potential rate of photosynthesis, Manning and Juday (1941), Gesner (1944), later Ryther and Yentsch (1959) have recommended the use of the chlorophyll concentration for estimating the rate of primary production in the sea. Reports on phytoplankton pigments of the Indian Ocean by Khimua and Fukushima (1965), Laied et al (1964) Mc Gill and Lawson (1966). Humphrey (1966) and Humphrey and Kerr (1969) provide a sound basis for the estimation of productivity in the Indian Oceans. Some of the notable works in this field are of Qasim and Reddy (1967); Pannikar (1969); C.P. Gopinathan (1972); Krishnamurthy K and V. Sundarajen (1974). Bhattathiri P.M.A and V.P. Devassy (1975) have studied the effect of salinity on pigment concentrations of some tropical phytoplankton. Regarding the occurrence, seasonal fluctuations and the abundance of some of the estuarine phytoplankton contributions were made by Joseph and Nair (1975); Joseph and Pillai (1975) and Gopinathan (1975).

The Cochin backwaters have been studied intensively in recent years for plant pigments (Qasim and Reddy, 1967), light penetration (Qasim, Bhattathiri and Abidi, 1968), organic production (Qasim _et_ _al_ 1969) and nutrient cycle (Sankaranarayanan and Qasim, 1969). Besides the productivity of coral reefs (Nair and Pillai, 1972; Qasim, Bhattathiri and Reddy, 1972) of sea grass beds (Qasim and Bhattathiri, 1971) and liberation of particulate organic matter by coral reefs of an atoll (Qasim and Sankaranarayanan, 1970) have also been investigated.

However, the information on the productivity parameters in the brackish water culture system are meagre and are localised at a few centres only. The only investigation undertaken on the productivity of prawn fields _per se_ is that of Gopinathan _et_ _al_ (1982) who have studied the environmental characteristics of the prawn culture fields in the estuarine system of Cochin from Azhikode in the North to Kumarakam in the South including the Vembanad Lake.

This study forms a supplement to the above investigation and is aimed to fill up the gaps by including productivity parameters such as ammonia and other nutrients which enable the assessment of the stocking potential of a culture system by comparing enclosed system with a semi-enclosed system connected with the backwaters perennially.

MATERIALS AND METHODS

STUDY AREA:

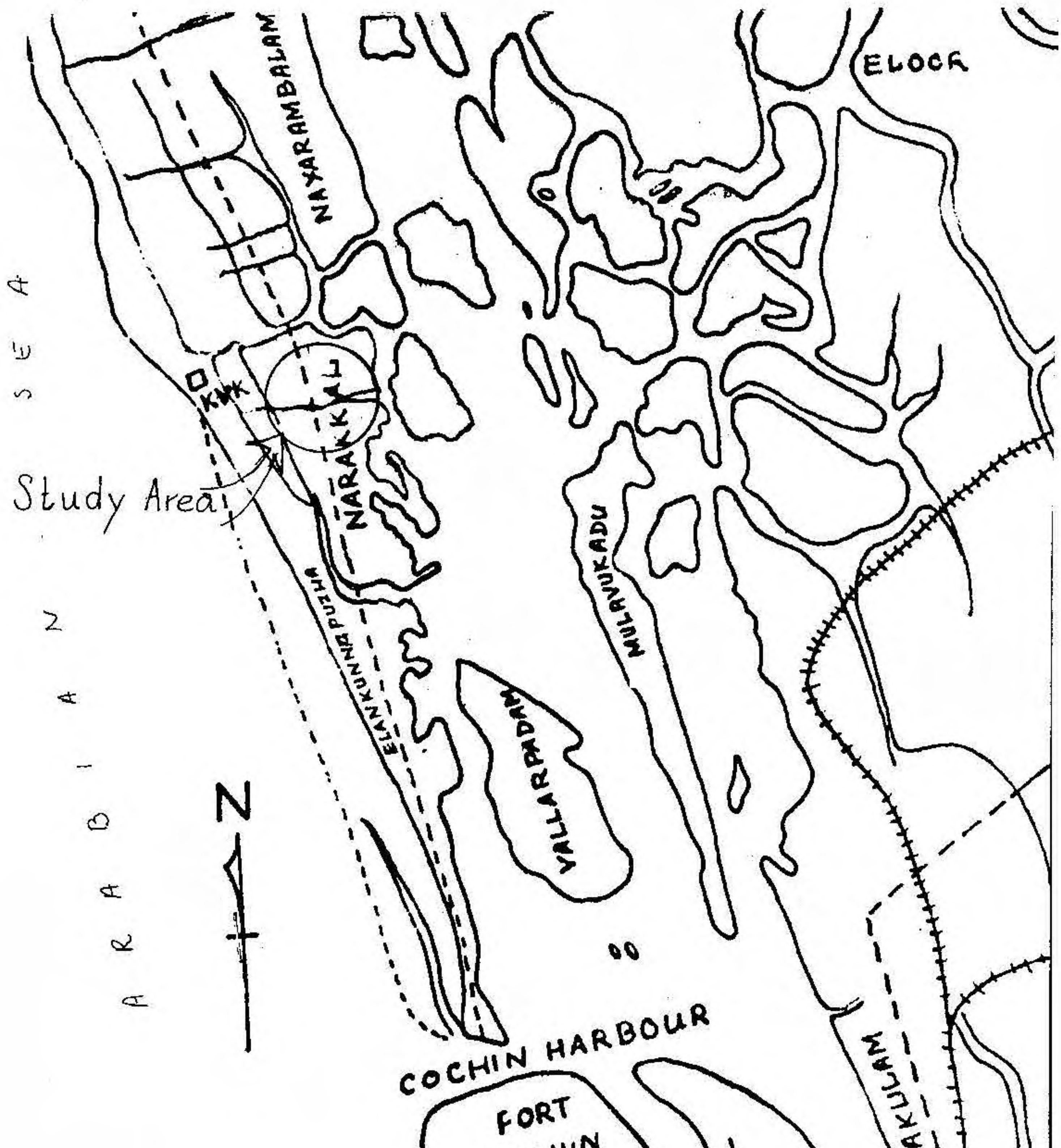
Studies on photosynthesis in relation to environmental parameters were carried out from brackish water ponds at Narakkal, situated in the Vypeen Island located 12 kms northwest of Cochin city on west coast of India (10.01^{o}N - 75.16'E).

The sites of sample collection were two stocking ponds of MPHL (Marine Prawn Hatchery Laboratory) and a coconut groove located approximately 75 m east of MPHL. All the three sampling sites were separated from sea by a narrow stretch of land and were connected to the backwater via channel network.

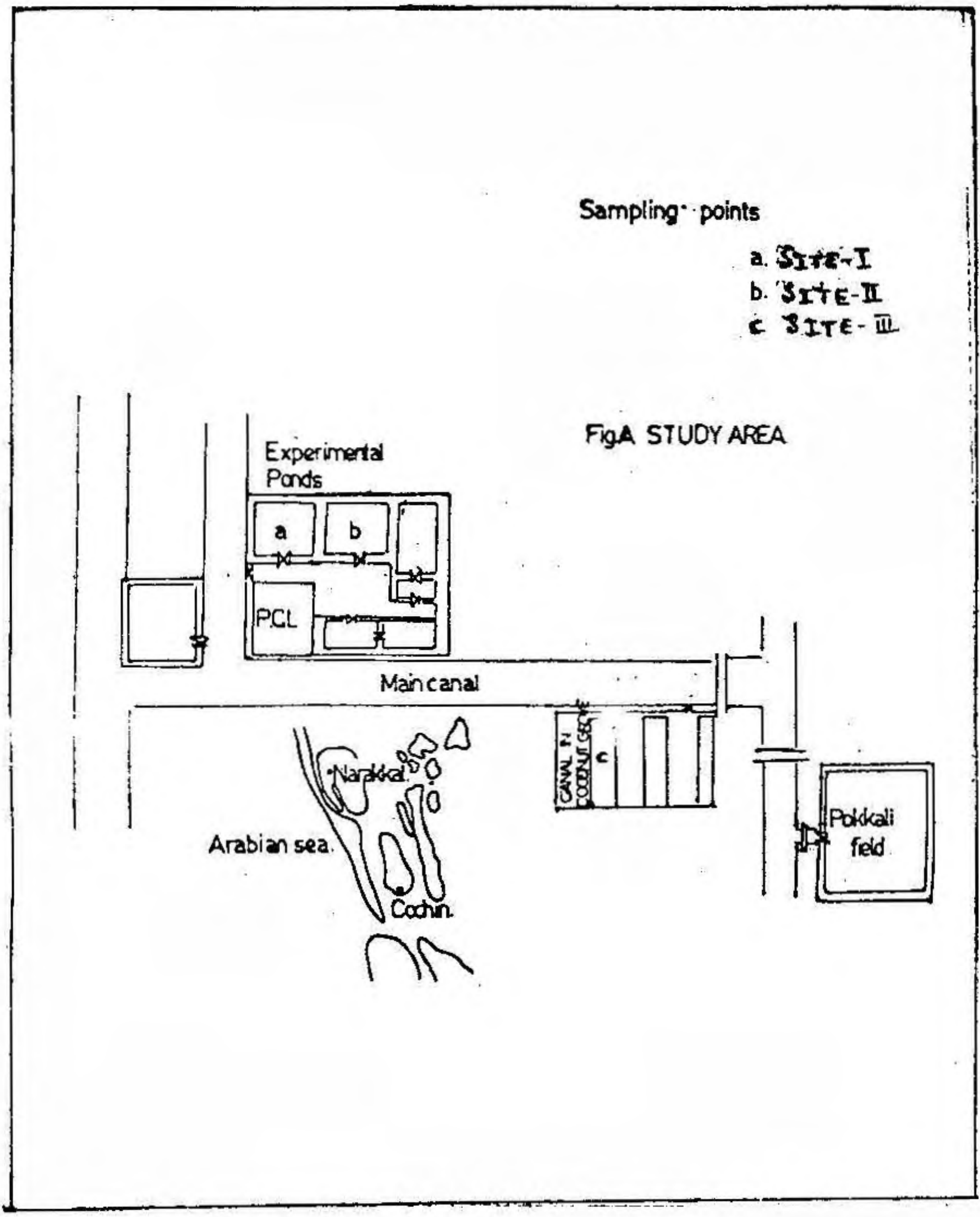
The description of the three sites is as follows:

Site : 1

A stocking pond of 0.2 ha. area, adjacent to the backwater channel was chosen as Site-1. The average depth of the pond was 0.95 ± 0.25 m varying according to the tidal influx. Throughout the study period the tidal exchange of water, for every high and low tide, was maintained through a sluice gate of 1.0 m width. The substratum at the sampling sites, approximately 1 m away from the bund, was mostly muddy.



Map showing Sampling Site



FigA STUDY AREA

Site : 2

Another pond of 0.2 ha. area adjacent to the first pond farther east, was chosen as Site-2. This pond had an average depth of 1.05 ± 0.25 m varying with the tidal influx. The substratum was clayey. Water exchange was similar to site - 1.

Site : 3

In order to get a better comparison, the third site selected was a coconut groove. This site was characterised by very shallow water (0.5 ± 0.25 m) and plenty of vegetation. The coconut groove was open to the channel and exchange of water during high and low tide was accomplished naturally.

SAMPLING PROCEDURE

Weekly sampling was carried out from late June to early October. Sampling was done during the early hours between 0600 hrs and 0700 hrs. From site - 1 and site - 2, surface and bottom samples were collected. But from site-3, only one sample was collected as the depth was very low to differentiate surface and bottom significantly.

Water samples, for nutrient analysis, were collected in narrow mouth, air tight plastic bottles of 500 ml capacity. For chlorophyll, the water collected in 1 litre plastic cans was used. These samples were immediately transferred to freeze.

SITE :I: Culture Pond

SITE :II: Culture Pond

SITE :III: Coconut groove

For oxygen, the samples were fixed on the spot in 125 ml capacity bottles. For productivity, light and dark bottle method was used. The dark bottle was made dark by wrapping in a double layered black rexine bag. Precaution was taken to place light and dark bottles horizontally at the site. The experiment was carried out for a period of 12 hrs.

Analysis of the nutrients was carried out on the same day but chlorophyll was analysed next day spectrophotometrically.

ANALYTICAL PROCEDURE:

The following parameters were analysed:

a) Temperature:

The in situ temperature was measured with the help of an ordinary mercury thermometer (0-100°C).

b) pH:

pH was measured using a pH paper.

c) Salinity:

Salinity was established for Mohr-titration method (Strickland & Parsons, 1968).

d) Dissolved oxygen:

Dissolved oxygen was estimated by Winkler method (Strickland and Parsons,1968) with necessary precaution.

e) Ammonia:

Determination of ammonia in water was estimated by phenol hypochlorite method (Solarzano, 1967).

50 ml of the sample was transferred into a 250 ml conical flask and to which 2 ml of phenol solution, 2 ml of sodium nitroprusside and 5 ml of oxidizing reagent was added successively. The colour is allowed to develop at room temperature for 1 hr and the absorbance recorded at 640nm i a spectrophotometer. Precaution has been taken to wash all glass wares initially with warm dilute Hcl and then rinsing thoroughly with distilled water.

For calculating the ammonia content different concentrations of the standard solution (Ammonium sulphate 0.100 g in 1000 ml) were made and with the help of a standard graph the same was calculated in $/^{u}g\text{-at-}l^{-1}$.

f) Inorganic Phosphorous:

Inorganic phosphorous was estimated following the method given in the Technical Paper No. 137 of FAO (1975).

Two 35 ml portions of the sample were transferred into 100 ml conical flasks. One of the portion is regarded as the sample and the other turbidity blank. To each of the portions 1 ml of the acid-molydate solution is added and to the sample also 1 ml of the ascorbic acid solution. After five minutes the sample was measured against the turbidity blank in the spectrophotometer at 882 nm.

For calibration, phosphate working solution was prepared by taking 10 ml of the standard stock solution (Pottasium di-hydrogen phosphate) with 1000 ml distilled water. From this a series of working standards are prepared and with the help of a standard graph, inorganic phosphorous was calculated in $/^{u}g\text{-at-}l^{-1}$.

g) <u>Nitrate</u>:

Nitrate-Nitrogen was estimated by the method of Morris and Riley as described by Strickland & Parsons (1968) with slight modifications.

50 ml of the sample was transferred into a 250 ml conical flask to which 2 ml of buffer reagent (phenol sol + sodium hydroxide sol) and with rapid mixing 1 ml of reducing agent (Copper sulphate + Hydrazine sulphate) were added. The flasks were kept in dark for 20 hours. Later 2 ml of acetone, and after 2 minutes 1 ml of sulphanilamide solution was added. After 2 minutes and not later than 8 minutes 1.0 ml of NNED was added and mixed thoroughly. After 10 minutes the

absorbance was measured at a wave length of 545 nm in a spectrophotometer.

Standard nitrate stock solution was used to prepare different concentrations and standard graph is plotted and nitrate is expressed in $/^{u}g\text{-at-}l^{-1}$.

h) Nitrite:

Nitrite-nitrogen was estimated by the method of Morris and Riley as described by Strickland & Parsons (1968).

50 ml of water sample was taken into a conical flask. 1 ml of sulphanilamide solution was added and after 2 minutes but not later than 8 minutes 1 ml of NNED was added and mixed thoroughly. The optical density was measured at 545 nm.

Standard graph was prepared by using the standard nitrite solution (0.345 gms in 1000 ml) and nitrite is expressed in $/^{u}g\text{-at N } l^{-1}$.

i) Dissolved Silicon:

Silicon in sea water was estimated by the method of Cirow N Robinson as reported by Strickland & Parsons (1968).

3 ml of the acid-molybdate reagent, 15 ml of water sample and 5 ml of distilled water were taken in a conical flask. After 10 minutes, 15 ml of reducing agemt (metol-sulphite + oxalic acid + 25% sulphuric acid) was added and the solution made upto 50 ml. The solution was allowed to stand for 3 hours. The optical density of the sample was measured at 812 nm.

For calibration, standard solution (silicic acid) was taken with different concentrations and a standard graph plotted. Silicon is represented in $/^{u}$g-at Si l^{-1}.

j) Chlorophyll a:

For chlorophyll 'a' estimation, Timothy.R. Parsons et al (1984) method was followed with slight modifications.

One litre of water sample is filtered through a membrane filter paper of 47 mm dia. The filter paper was soaked in 10 ml Acetone (90%). The Acetone stored in screw cap bottles were wrapped with black paper. The bottle was kept in refrigerator in dark for 24 hrs. Later, the sample was centrifuged for 15 minutes at 3,500 r.p.m. and the readings were taken in a U.V.Spectrophotometer (ECIL).

Chlorophyll 'a' was calculated using the following formula.

(C) Chlorophyll a = $11.85\ E_{664}-1.54\ E_{642}-0.08\ E_{630}$

Mg chlorophyll/m^3 = $\frac{C \times V}{V_1\ 10} \times 10$

V = volume of acetone

V_1 = volume of water filtered.

k) Productivity:

For productivity studies, light and dark bottle technique introduced by Gaarder and Gran (1927) was adopted.

Productivity was calculated as follows:-

Gross production = Light bottle - dark bottle

Net production = Light bottle - initial bottle

Respiration = Initial bottle - dark bottle

Production (mg C/m^3/hr) = A = $\frac{O_{2(ml)} \times 0.536}{PQ \times T} \times 1000$

Production in mg c/m^3/day = A x 10 (assuming that photosynthesis takes place for 10 hrs during a day)

PQ = 1.25

T = Duration of the experiment conducted.

l) Statistical Analysis:

Different parameters were subjected to statistical analysis for linear correlations. The significance of the correlation coefficient was tested at 5% level by student's 't' test.

RESULTS

The study period was mainly restricted to the monsoon period from June to October. The monsoon has a direct effect on the environmental parameters which in turn affect the photosynthetic process.

TEMPERATURE

Site 1:

The water temperature varied from 27°C to 31.5°C as shown in the Fig. 1. The temperature decreased slightly during June-July with an increase in the later half of July. In the first week of August a steep fall is recorded which reduced the temperature to 27°C. Thereafter a peak was observed and till late September, the temperature fluctuated within a range of 30°C and 31°C. In the last week of September there is a slight decrease in temperature.

Site 2:

The water temperature of site-2 did not show much variation from that of Site-1. The temperature values ranged between 27.5°C and 31.5°C. The trend in temperature fluctuation was quite similar to that of the site-1.

Site 3:

The water temperature of site-3 ranged between 25°C and 29°C. The trend in temperature variation was similar

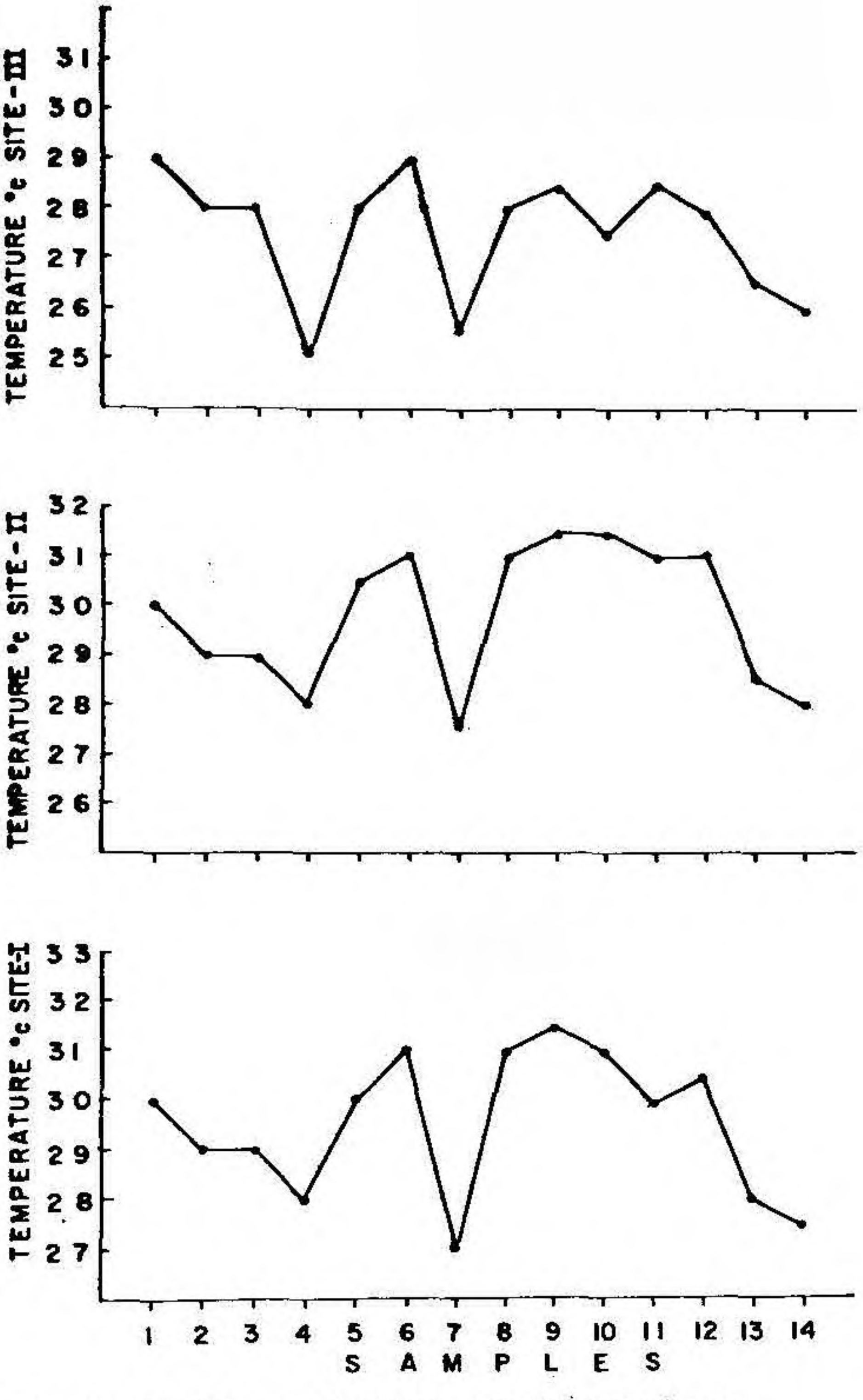


FIG.1: Weekly variations in Temperature.

with the other two sites with an exception of steep fall in temperature in mid July which was the lowest temperature recorded during the study period.

pH:

The water pH of all the sites was tested and it ranged between 6.5 and 8.5.

SALINITY

Site - 1:

The salinity of the sample water ranged between 3.15 and 9.85 x 10^{-3}. The figure (2) shows a decreasing trend till August and then an increasing trend upto the last week of September with a fall by October first week. The highest salinity recorded was in late June.

The bottom water salinity has shown a similar trend as that of the surface water with slightly higher values.

Site - 2:

Salinity of surface water ranged between 2.75 and 10.38 x 10^{-3} and 3.02 to 10.56 x 10^{-3} in bottom layer. In most of the cases the bottom salinity values exceeded the surface values.

Site - 3:

Here the range was about 1.27 and 10.56 x 10^{-3}. The variation was irregular but when compared to the other sites the same trend was observed.

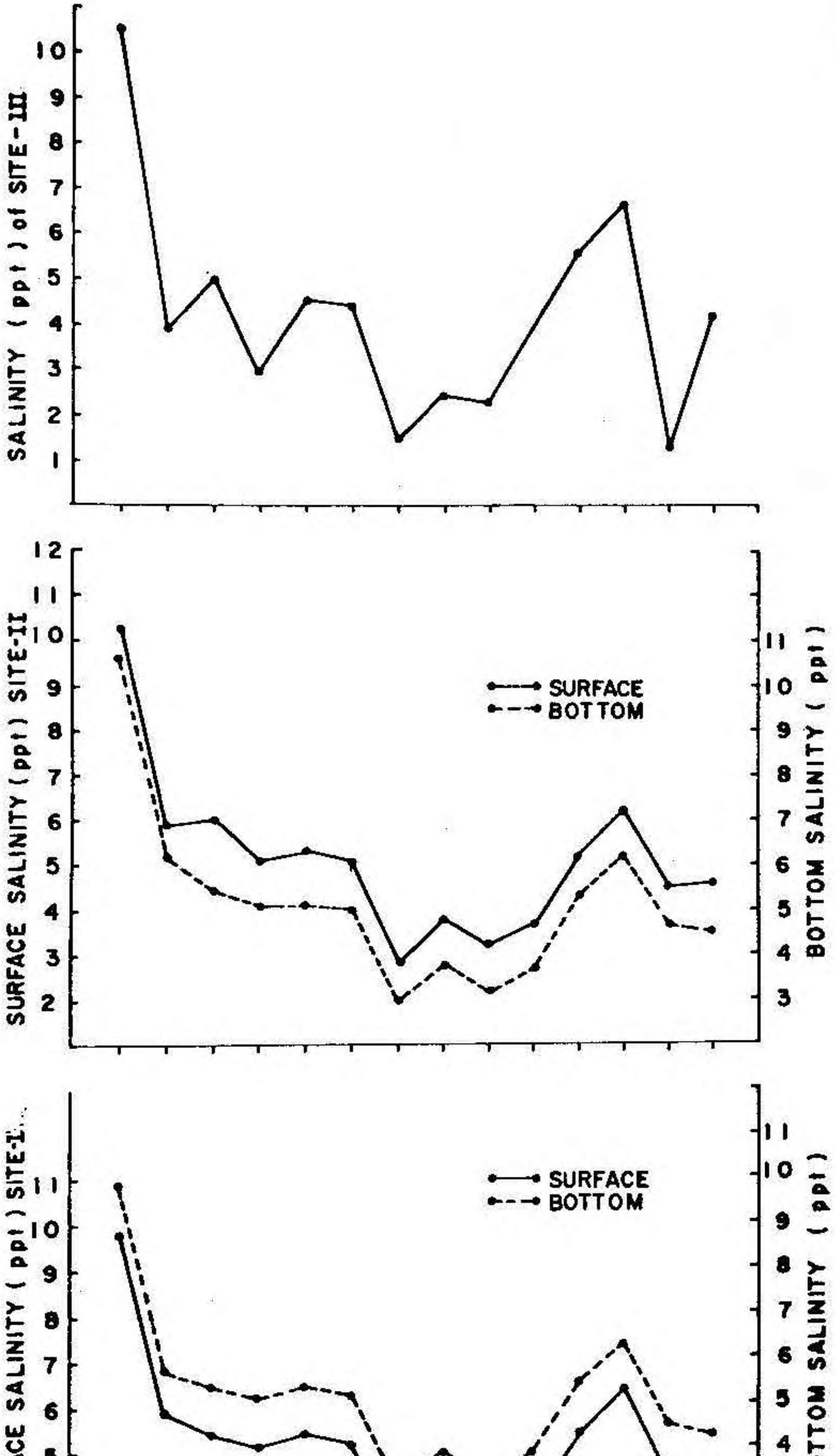


Fig. 2: Weekly variations in salinity.

DISSOLVED OXYGEN

Site - 1:

The dissolved oxygen values varied throughout the period of study and ranged between 0.95 and 5.65 ml l^{-1}. As per the Fig. (3) in June and July the values did not vary much. A peak was observed during early August and later the trend did not show much variation. In the last week of September the values reached a maximum with a value of 5.65 ml l^{-1}.

The dissolved oxygen in the bottom region did not show much of variation with that of surface water but the values varied between 0.95 and 7.8 ml l^{-1}.

Site - 2:

The oxygen values ranged between 0.018 and 6.2 ml l^{-1} in the surface water and 0.7 and 7.0 ml l^{-1} in bottom waters. There was no remarkable variation in the oxygen levels when compared with Site-1 and the same trend was observed.

Site - 3:

The oxygen values varied between 0.75 and 4.62 ml l^{-1}.

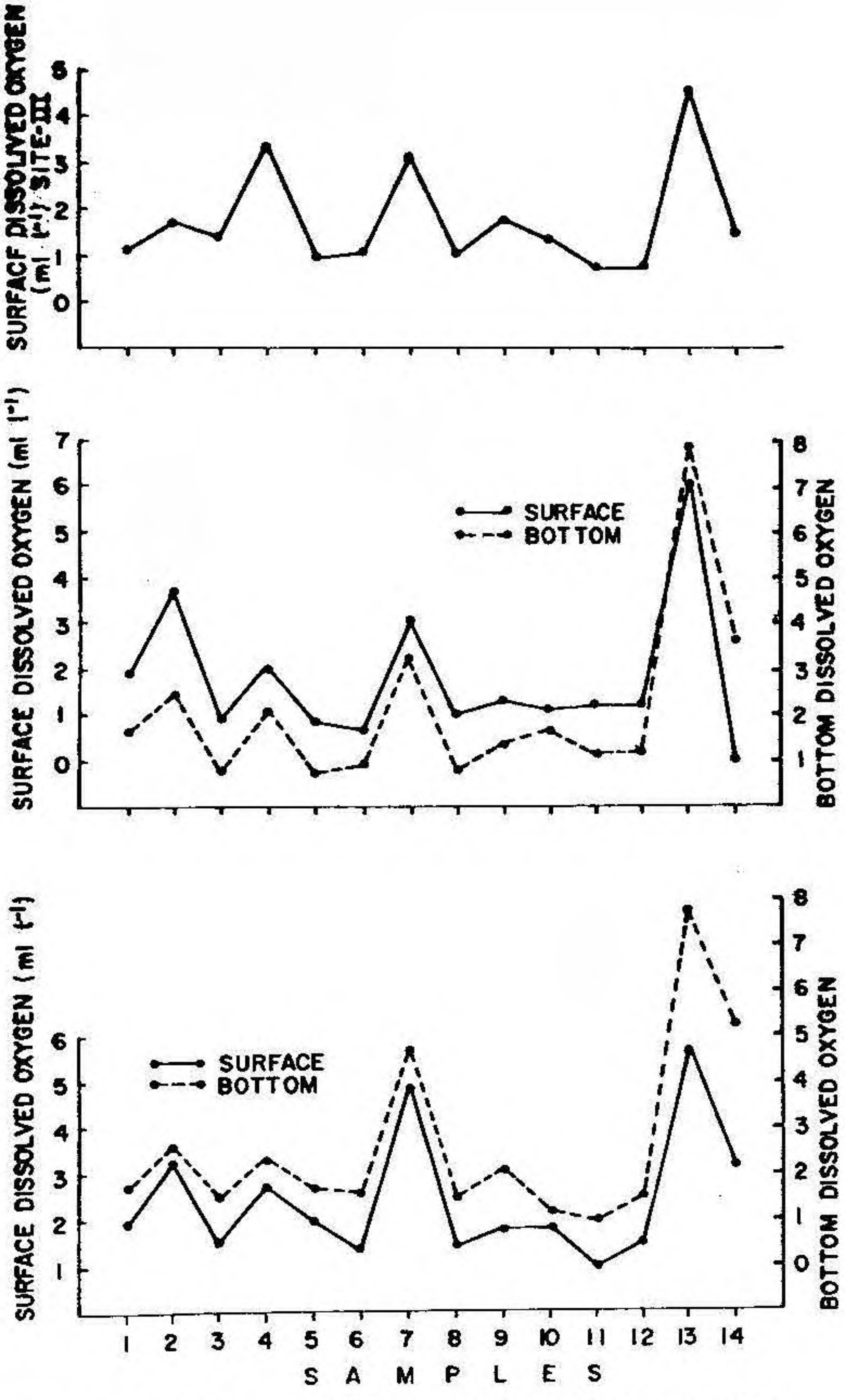


Fig.3: Weekly variations in Dissolved oxygen.

AMMONIA

Site - 1:

Variations in the ammonia content in surface waters was very wide and the range was between 0.8 and 41.6 ug-at. N l^{-1} with a mean of 24.36 ug-at N l^{-1}. Fig. (4) showed an increasing trend initially and later a decreasing trend was observed.

The bottom waters showed a range between 3 and 38.4 ug-at N l^{-1} with a mean 22.4 ug-at N l^{-1}.

Site - 2:

In surface waters a maximum of 54.6 and a minimum of 1.8 ug-at N l^{-1} were recorded with a mean value of 26.4 ug-at N l^{-1}.

The bottom water showed a maximum of 51.4 and a minimum of 7.4 ug-at N l^{-1} with a mean value of 28.14 ug-at N l^{-1}.

Site - 3:

The values ranged between 18 and 82.6 ug-at N l^{-1} with an average of 50.46 ug-at N l^{-1}.

INORGANIC PHOSPHORUS

Site : 1

The concentration of Inorganic Phosphorous in the surface waters ranged between 8.39 in early August and

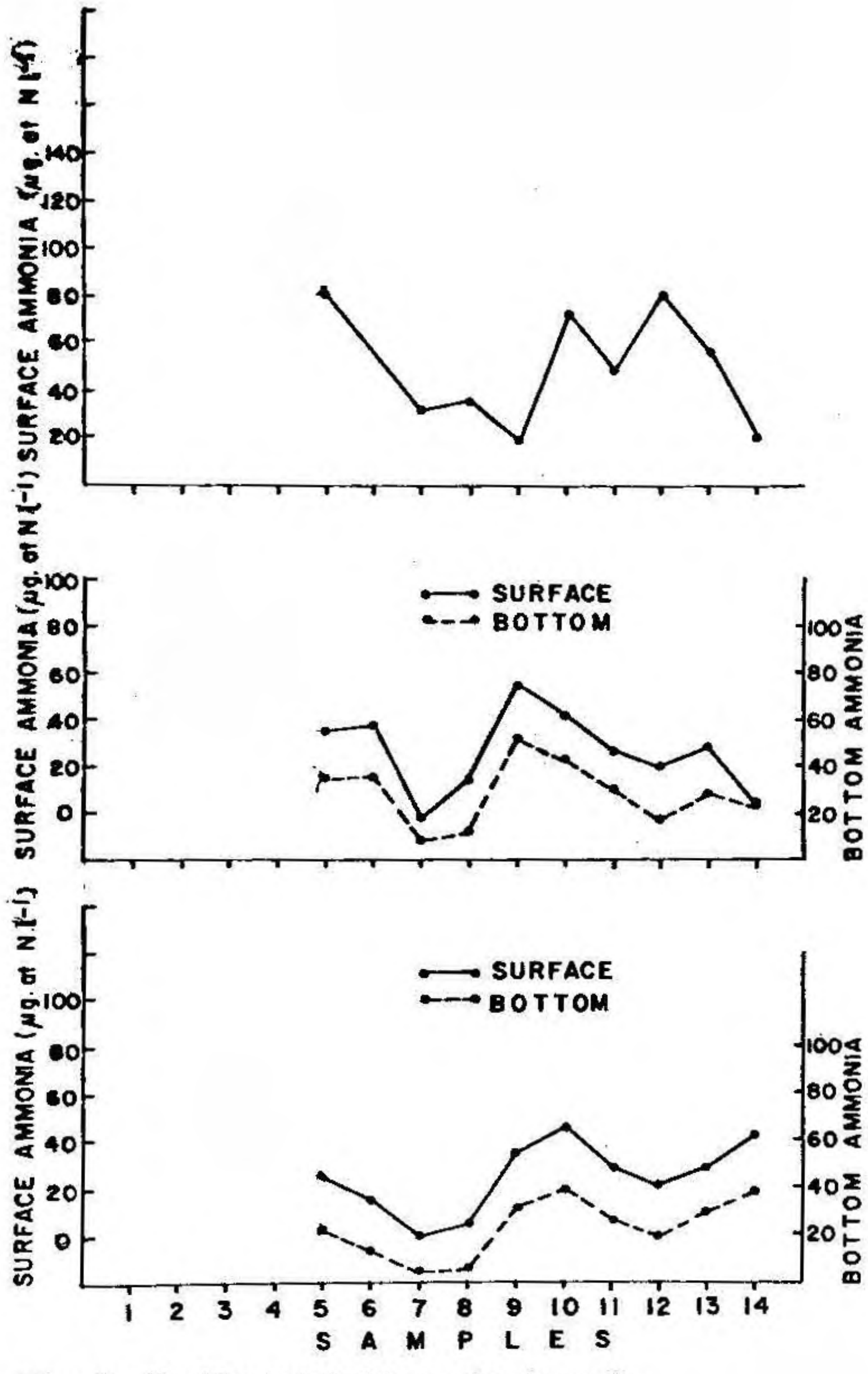


Fig.4: Weekly variations in Ammonia.

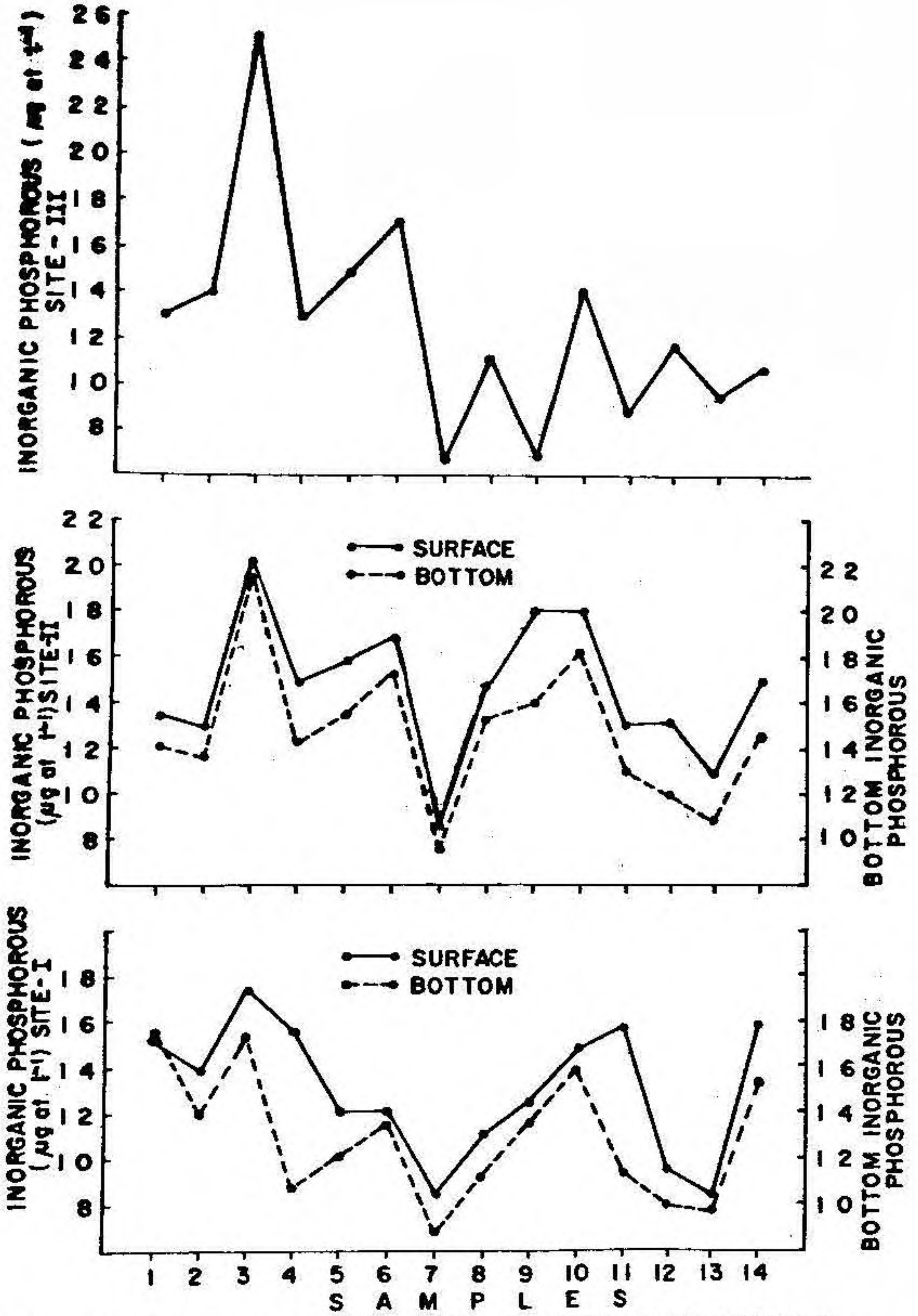


Fig.5: Weekly variations in Inorganic phosphorus.

17.37 in early July. The figure (5) showed a wide fluctuation in the phosphorous content. The average value noted was 13.01 /ug-at 1^{-1}.

Variation in bottom water for Inorganic Phosphorous was between 8.56 and 17.48 /ug-at 1^{-1} with a mean of 12.84 /ug-at 1^{-1}. No marked difference was noted from surface and bottom waters.

Site - 2:

In surface waters a range of 7.43 to 20.33 /^{u}g.at/lt was recorded with a mean value of 14.6 /^{u}g.at/lt.

In the bottom waters the range was between 9.98 and 21.46 /^{u}g.at/lt with a mean of 14.69 /^{u}g.at/lt.

Site : 3

Values ranged between 6.69 and 25.16 /^{u}g.at/lt with an average value of 12.59 /^{u}g.at/lt. The variation in the concentration of inorganic phosphorous showed a similar trend to that of site-1 and site - 2.

NITRITE

Site - 1:

A range of 1.6 and 13.6 /^{u}g.at N 1^{-1} was recorded in surface water. The mean value for the same was 5.8 /^{u}g.at.N 1^{-1}. In the bottom water the nitrite concentration ranged between 2.2 and 12.8 /^{u}g.at N 1^{-1}, with a mean value of 5 /^{u}g.at.N 1^{-1}. Figufe (6) showed

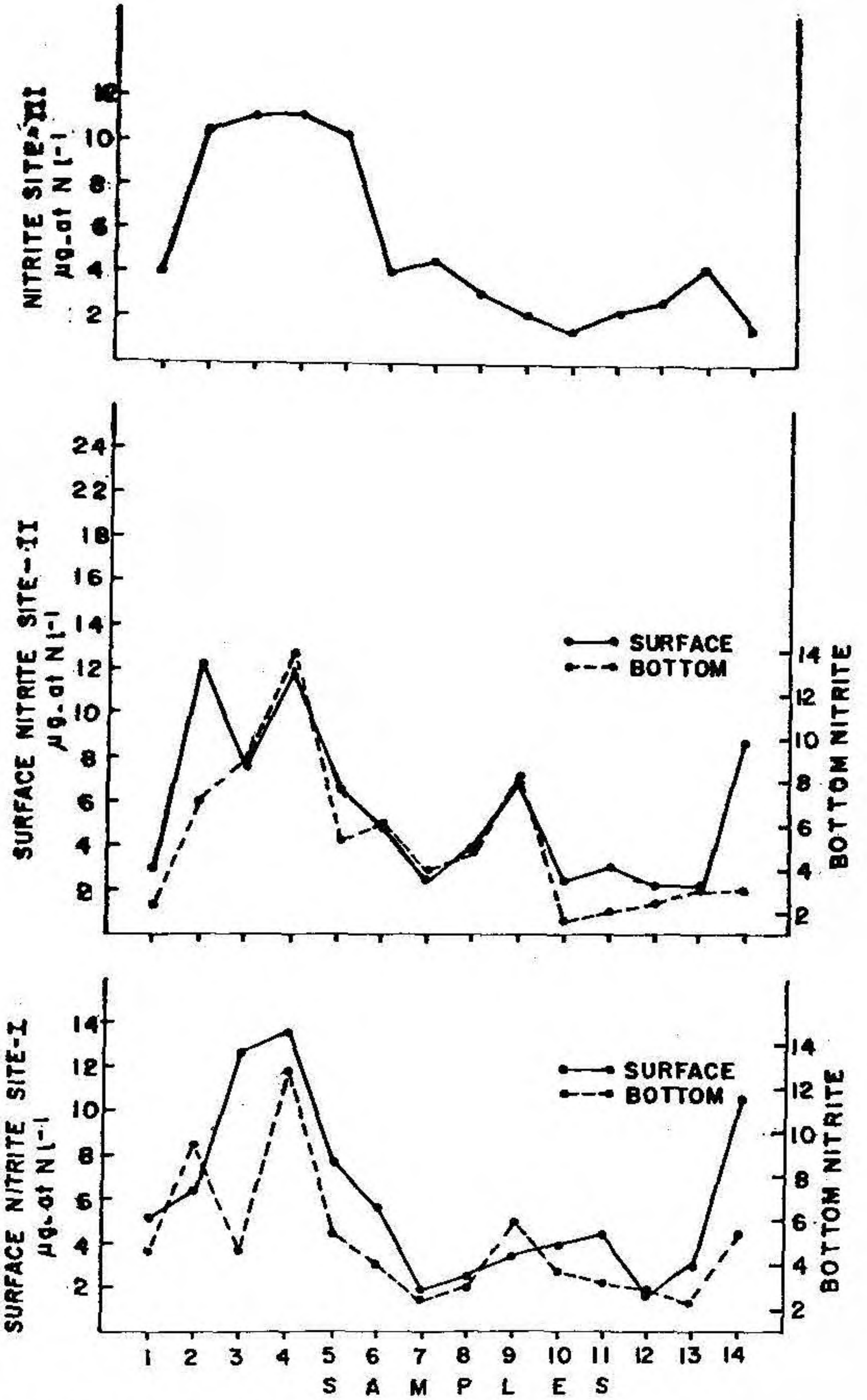


Fig.6: Weekly variations in Nitrite.

distinct peaks and the first peak was observed in mid July and the second one in October.

Site - 2:

In the surface water the nitrite concentration ranged between 2.2 and 12.22 /ug.at.N l^{-1} with a mean of 6.4 /ug.at.N l^{-1}. Nitrite concentration in bottom waters ranged between 1.6 and 13.6 /ug.at.N l^{-1} with a mean value of 5.2 /ug.at. N l^{-1}. The fluctuation in the nitrite concentration was similar with that of site - 1.

Site - 3:

The nitrite concentration in the water ranged between 1.4 and 11.2 /ug.at.N l^{-1} with a mean of 5.24 /ug.at. N l^{-1}. Figure (6) showed only one distinct peak in the month of July and the second peak; in October as observed in site-1 and site - 2 was not noticed.

NITRATE

Site - 1:

In surface water the nitrate values showed a range of 5.8 to 17.8 /ug.at N l^{-1} with a mean of 9.8 /ug-at.N l^{-1}. Fig.(7) showed a decreasing trend throughout the sampling period with a small peak in late August.

The nitrate content in the bottom water ranged between 5.4 and 20.4 /ug.at.N^{-1} with a mean value of 9.8 /ug.at.N l^{-1}.

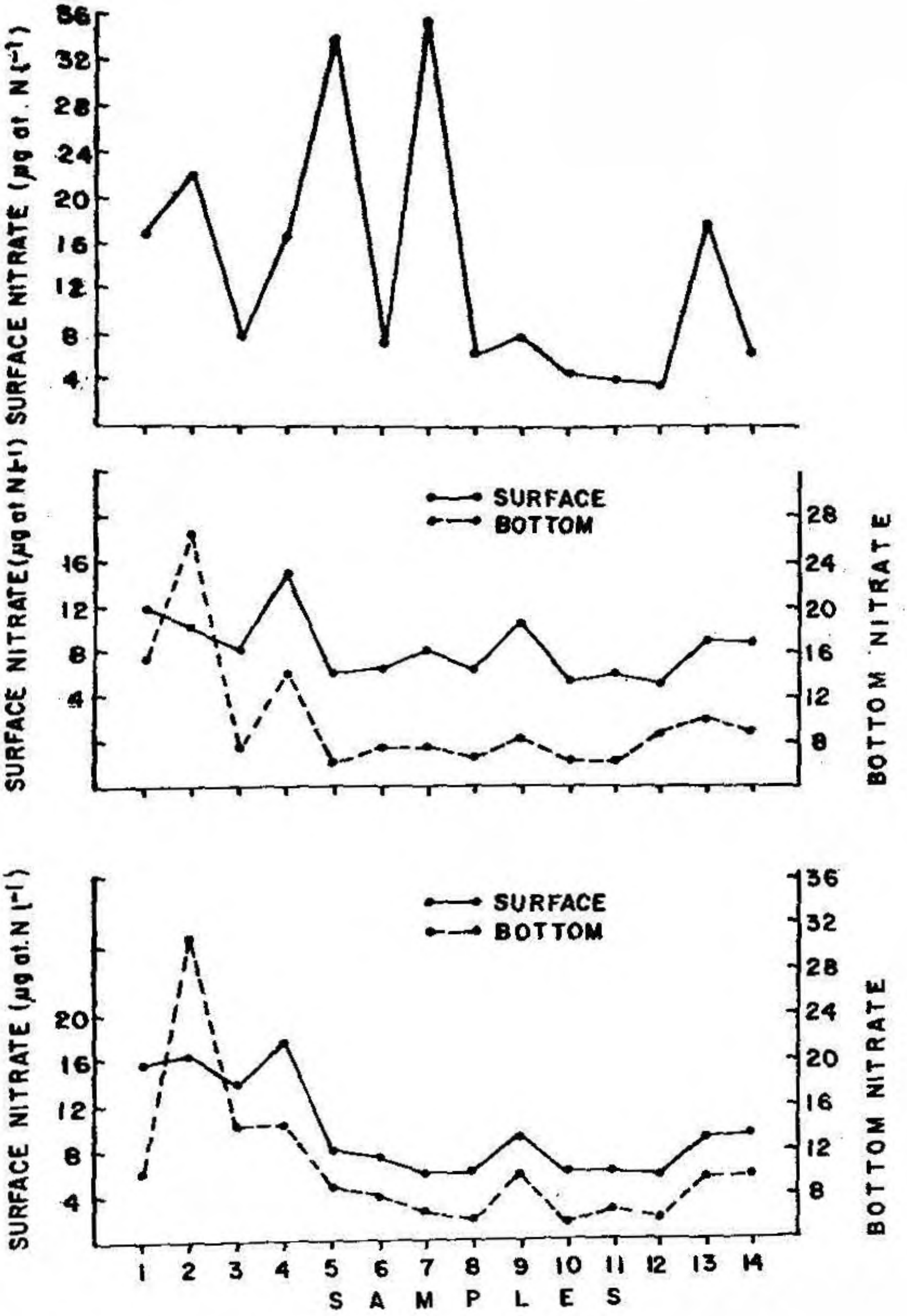


Fig.7: Weekly variations in Nitrate.

Site - 2:

The surface water showed a maximum of 15 and a minimum of 5.2 μg.at. N l^{-1} with a mean of 8.4 μg.at.N l^{-1}. In the bottom water the maximum was 26.8 and the minimum 6.0 μg.at. N l^{-1} with a mean value of 9.8 μg.at.N l^{-1}.

Site - 3:

The nitrate concentration showed a range between 3.8 and 35.6 μg.at.N^{-1} with a mean of 14.3 μg.at. N l^{-1}. Fig (7) showed two distinct peaks one in the mid July and the other in early August.

SILICATE

Site - 1:

The surface water showed a range of 9.37 and 100.86 μg.at.Si l^{-1} with a mean of 50.64 μg.at.Si l^{-1}. In the bottom water the silicate concentration showed a range of 8.6 and 103.75 μg.at.Si l^{-1} with a mean value of 50.33. Figure (8) showed a rise in the silicate content as the study progressed. A sudden increase in silicate content was observed during early August and a second peak at the end of September.

Site - 2:

Silicate concentration in the surface water ranged between 8.65 and 95.1 μg-at.Si l^{-1} with an average value of 50.31 μg-at.Si l^{-1}. The bottom waters showed a

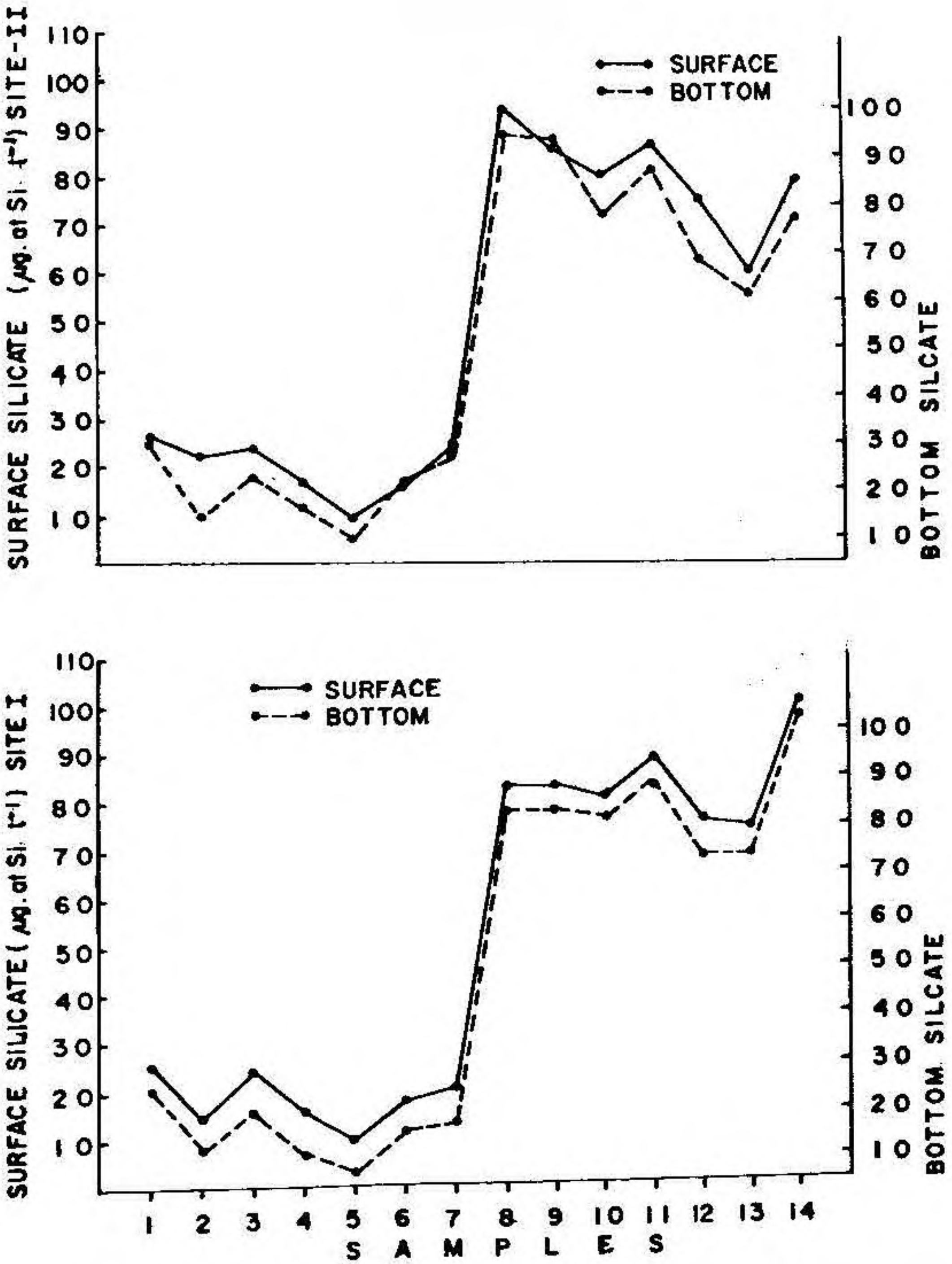


Fig.8: Weekly variations in Silicate.

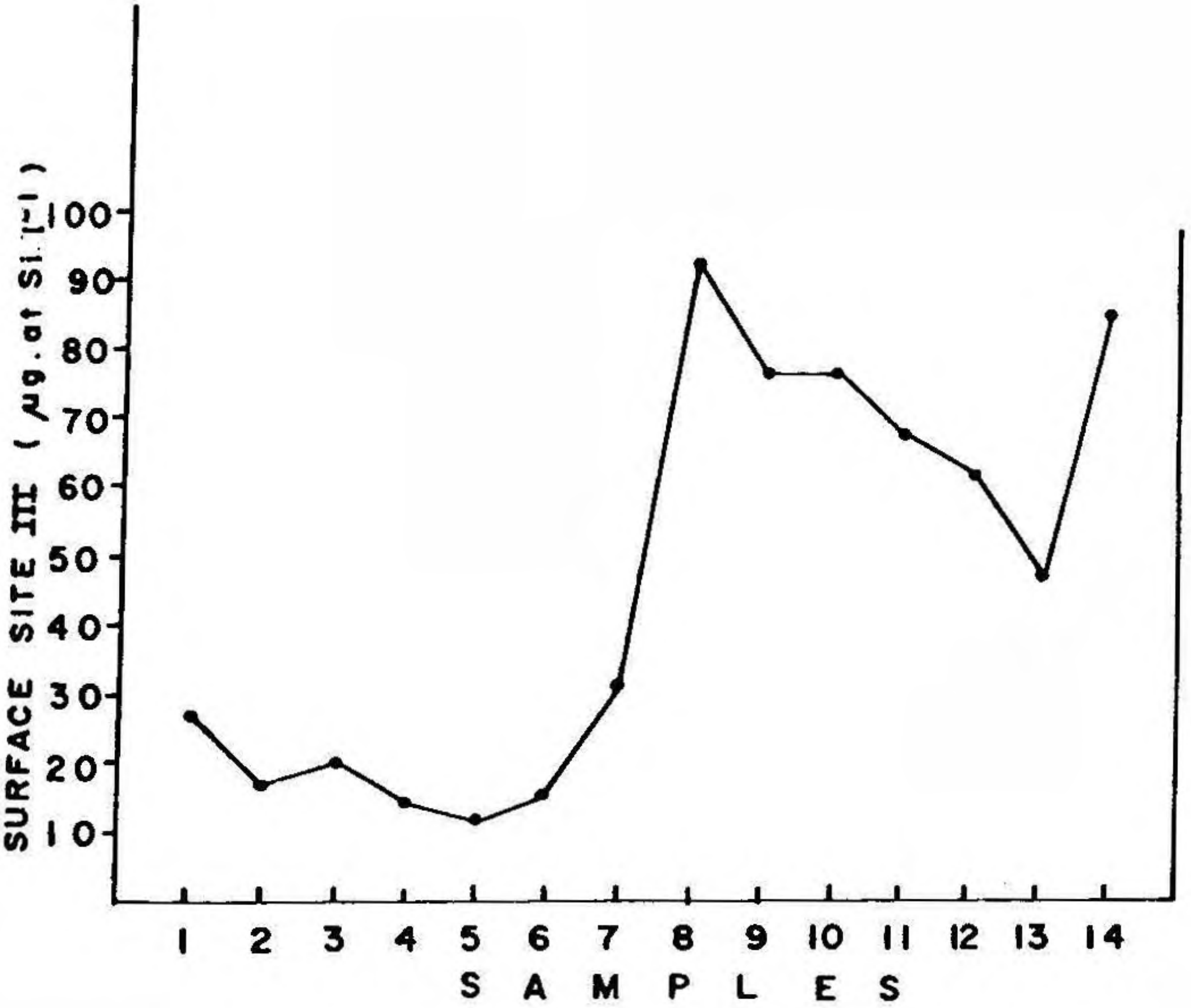


Fig.8a: Weekly variations in Silicate.

variation of 10.09 to 95.1 μg-at.Si l^{-1} with an average of 49.12 μg-at.Si l^{-1}. Figure (8) showed the same trend as that of site-1 but the maximum values were recorded in the middle of August.

Site - 3:

A range of 12.25 and 93.66 μg-at.Si l^{-1} was observed with a mean of 46.73 μg-at.Si l^{-1}. Figure (8) showed the same trend as that of site - 2.

CHLOROPHYLL *a*

Site - 1:

Variation in chlorophyll 'a' content ranged from 7.67 and 77.5 mg.chl m^{-3} with a mean of 29.07 mg.chl m^{-3}. Fig. (9) showed a decreasing trend. Three minor peaks one in the middle of July and the other two in August and in the middle of September were observed.

Site - 2:

Chlorophyll 'a' concentration ranged from 3.91 and 108.3 mg.chl m^{-3}. Figure (9) showed the same trend as in that of site - 1.

Site - 3:

A range of 1.19 to 34.91 mg.chl m^{-3} was observed. The figure (9) showed a decreasing trend from late June to late August. A small peak was seen in the middle of September as in the case of site-1 and site - 2.

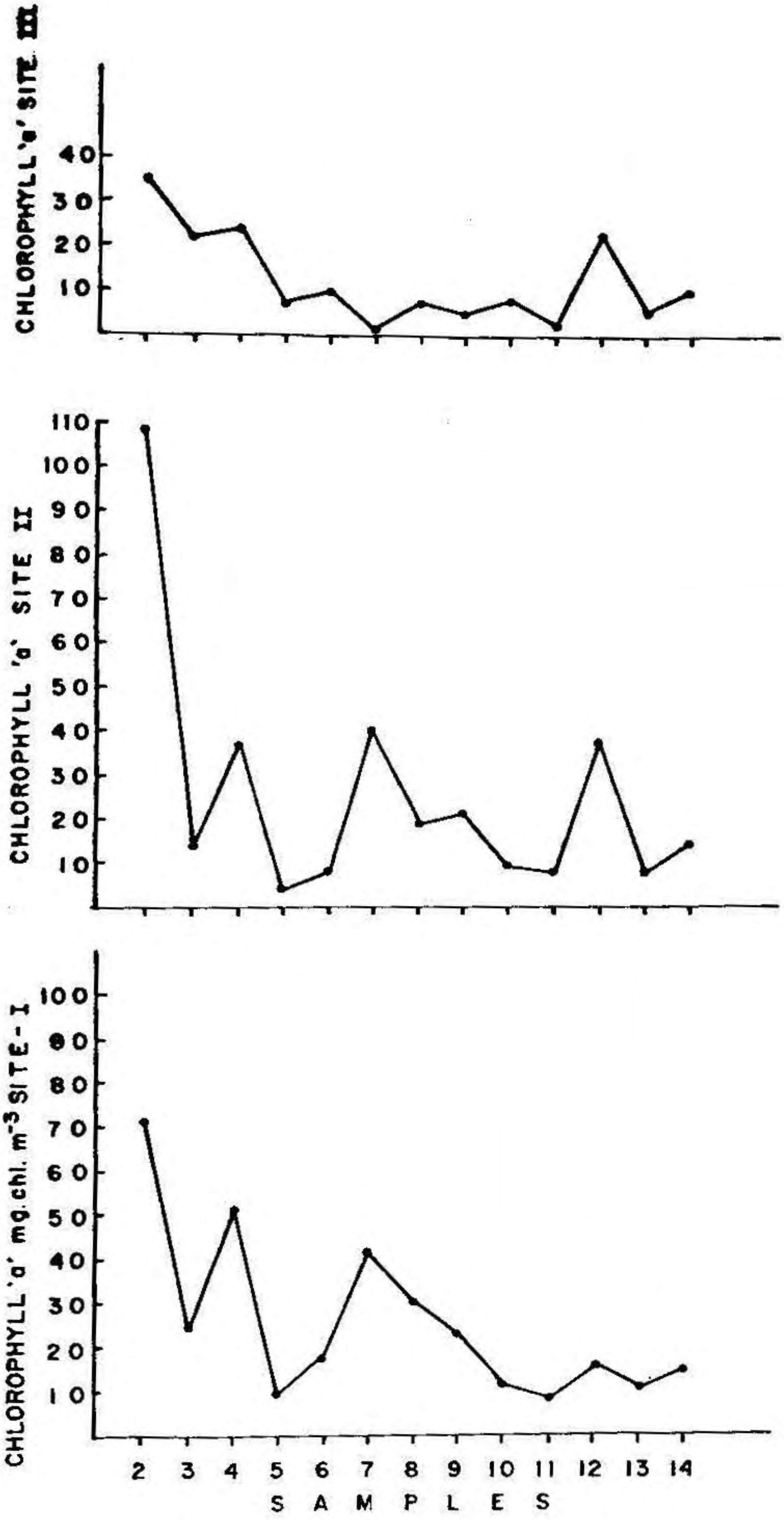


Fig.9: Weekly variations in Chlorophyll-a.

PRODUCTIVITY

The productivity values obtained during the study period, were plotted in the Fig. (10). The productivity in site - 1 ranged from 0.45 $gm^{-3}d^{-1}$ to 3.76 $gm^{-3}\ d^{-1}$. While the productivity at site - 2 showed a variation of 0.66 $gm^{-3}\ d^{-1}$ to 3.38 $gm^{-3}\ d^{-1}$ and the site 3 had the production range of 0.05 to 3.02 $gm^{-3}\ d^{-1}$.

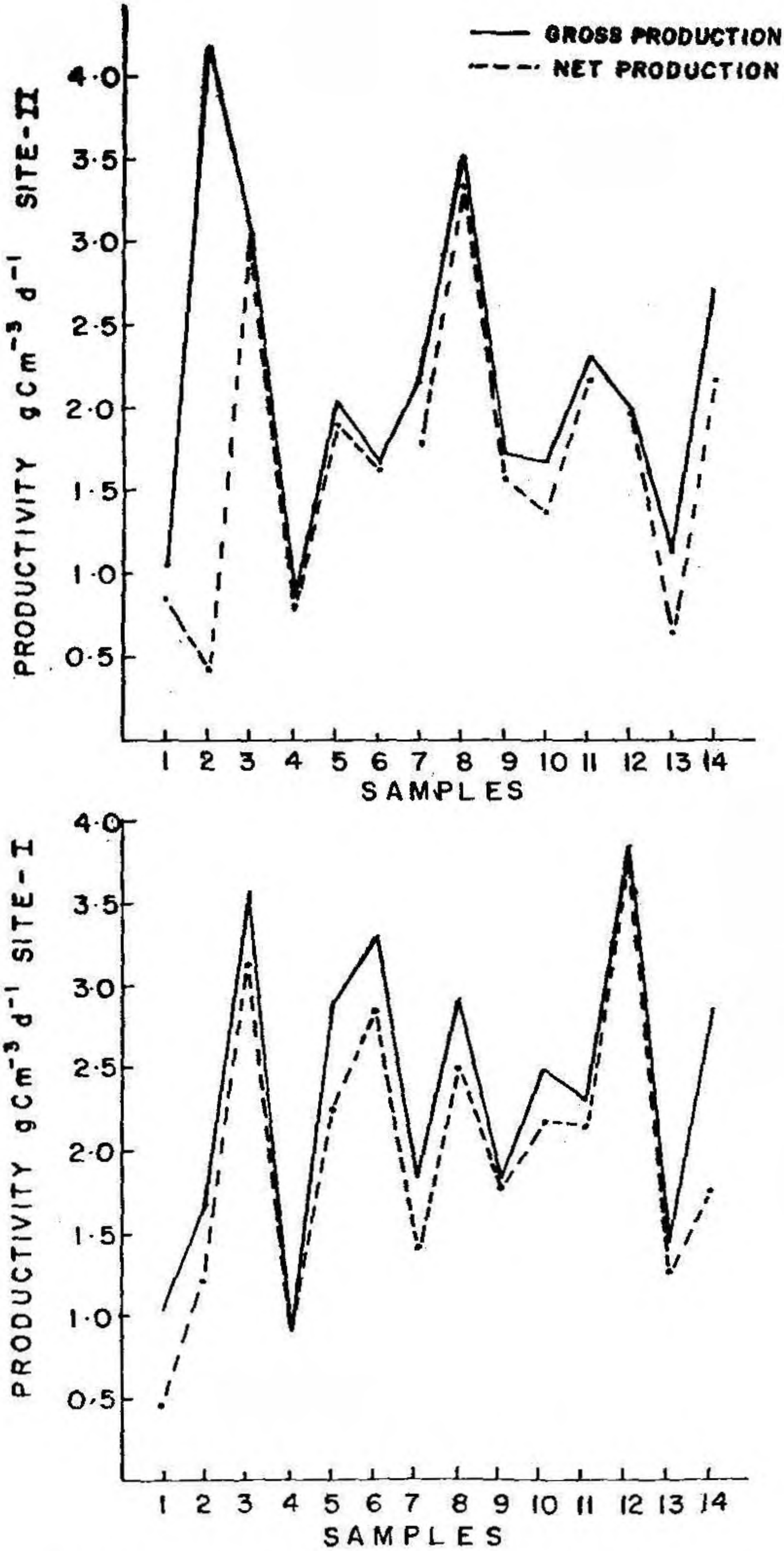


Fig. 10: Weekly variations in Productivity.

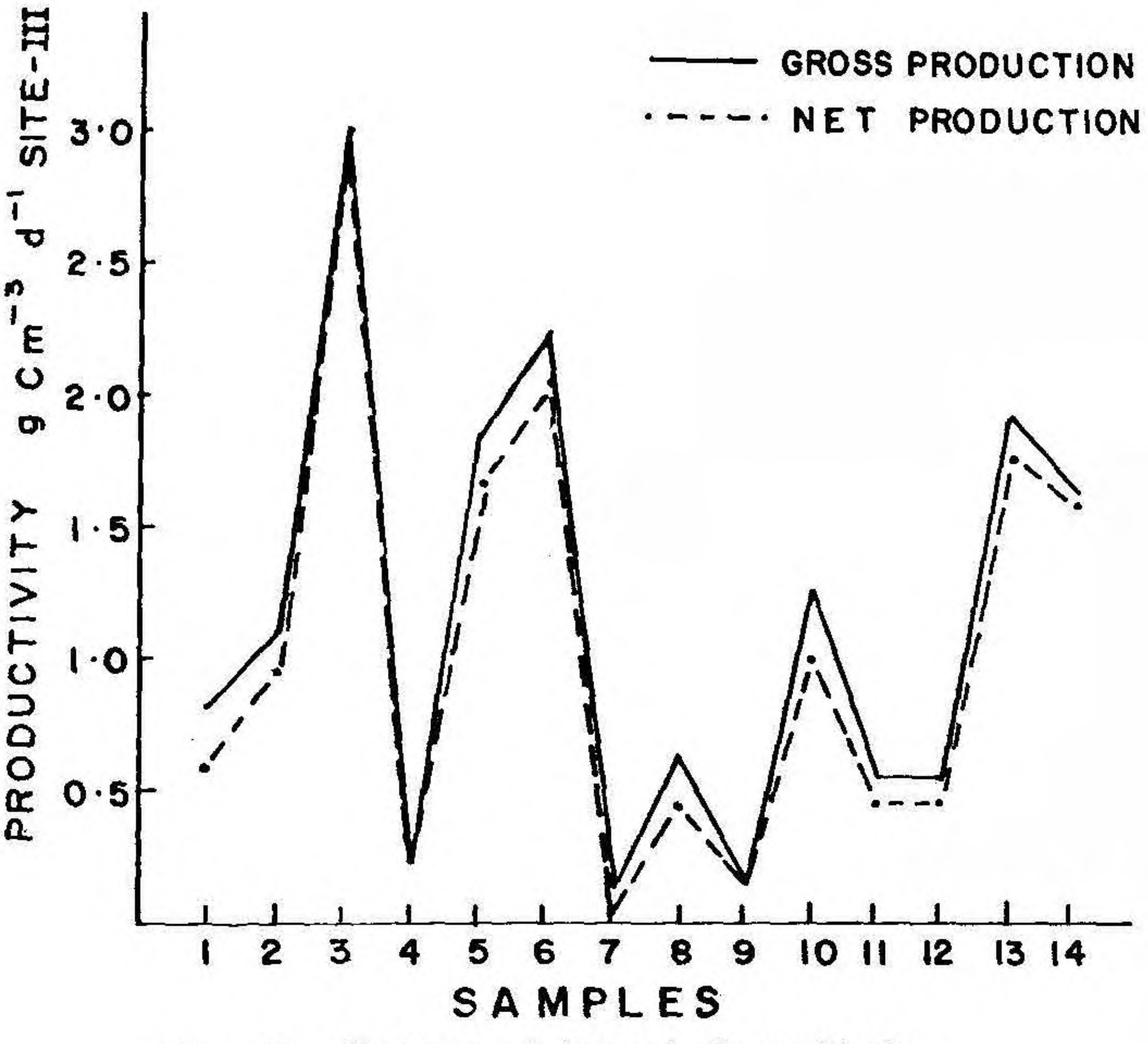


Fig. 10a: Weekly variations in Productivity.

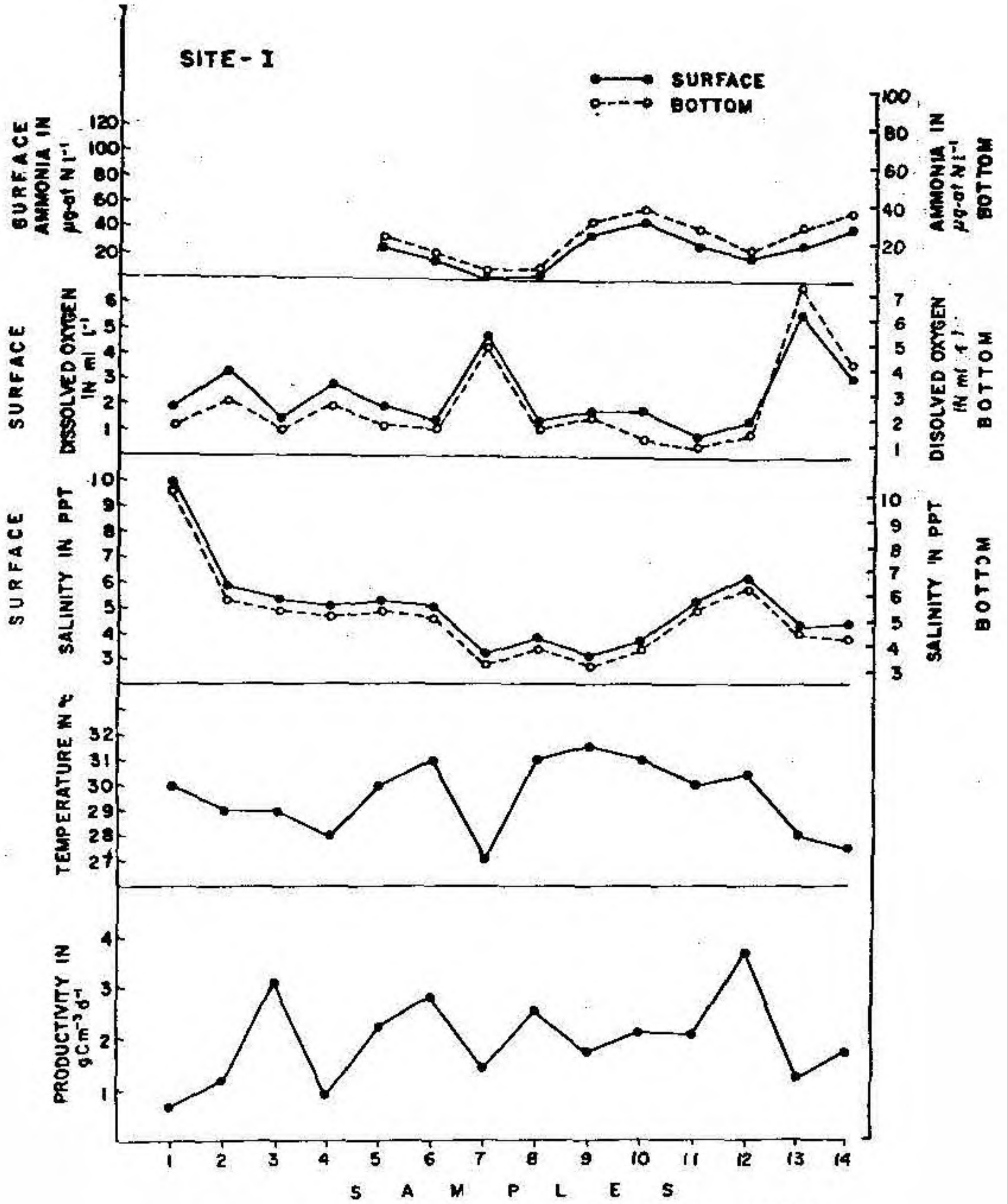


Fig. 11: Weekly variation in Productivity in relation to Temperature, Salinity, Dissolved oxygen and Ammonia.

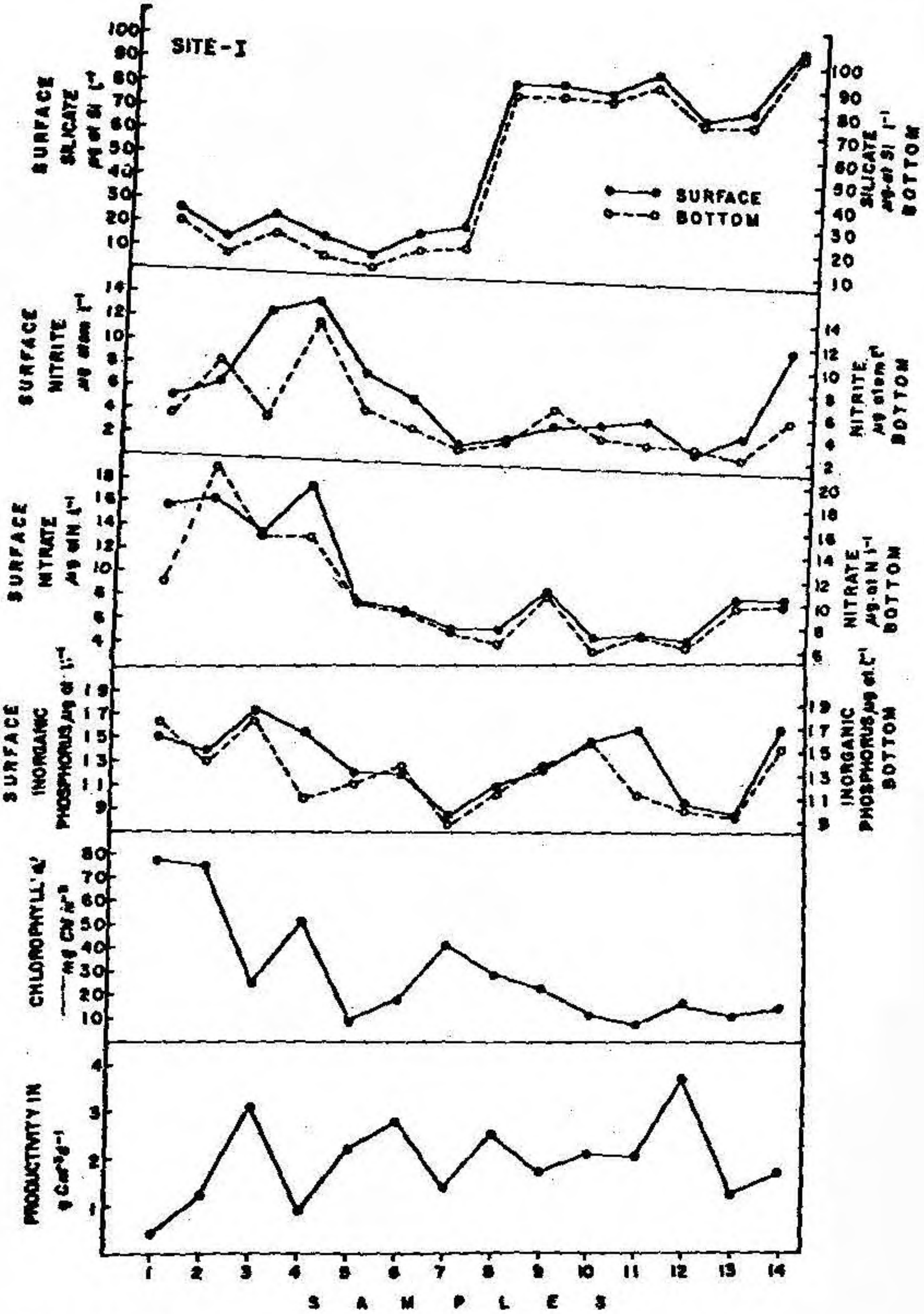


Fig.12: Weekly variation in Productivity in relation to chlorophyll-a and nutrients.

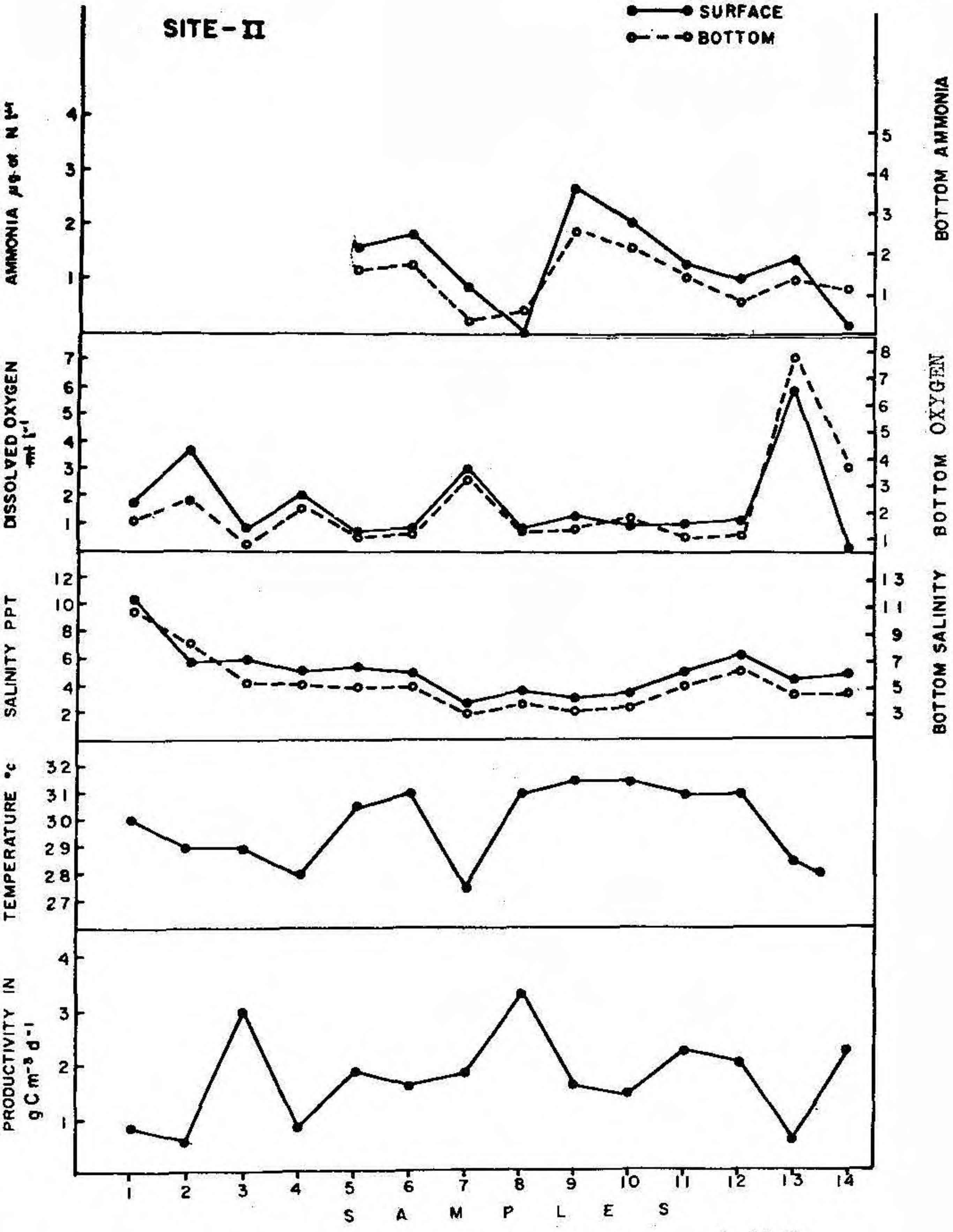


Fig. 13: Weekly variarion in Productivity in relation to Temperature, Salinity, Dissolved oxygen and Ammonia.

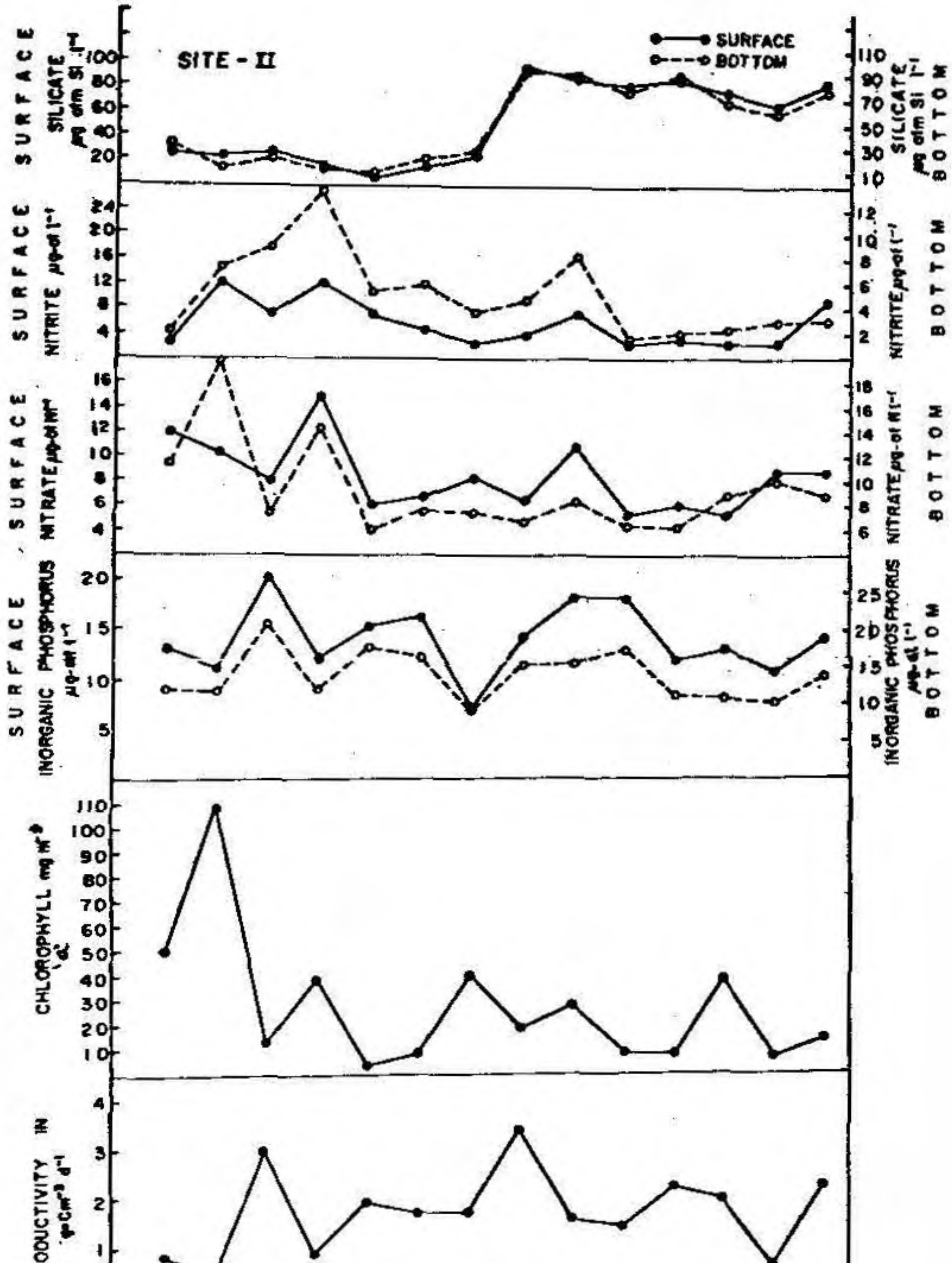


Fig.14: Weekly variation in Productivity in relation to chlorophyll-a and nutrients.

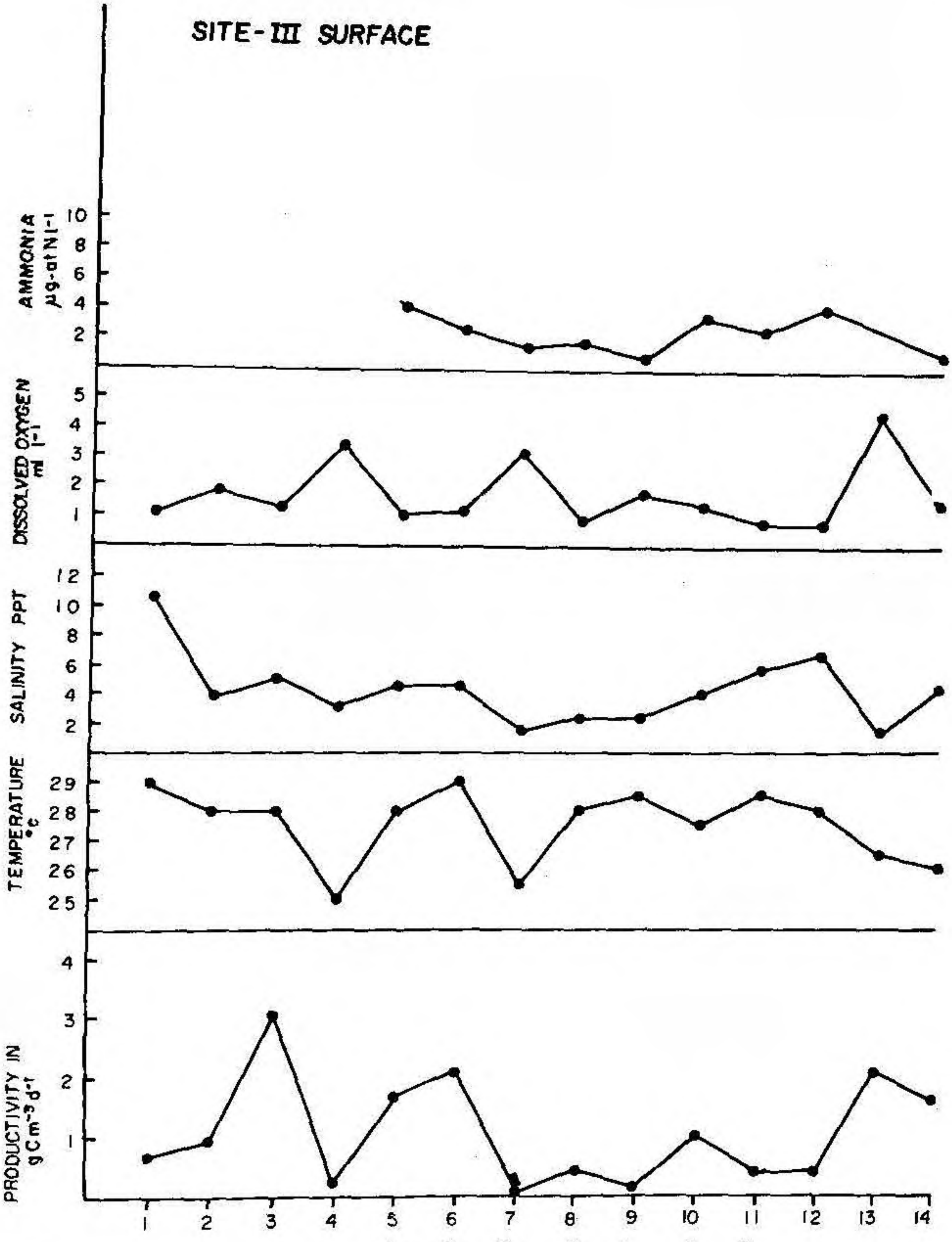


Fig. 15: Weekly variation in Productivity in relation to Temperature, Salinity, Dissolved oxygen and Ammonia.

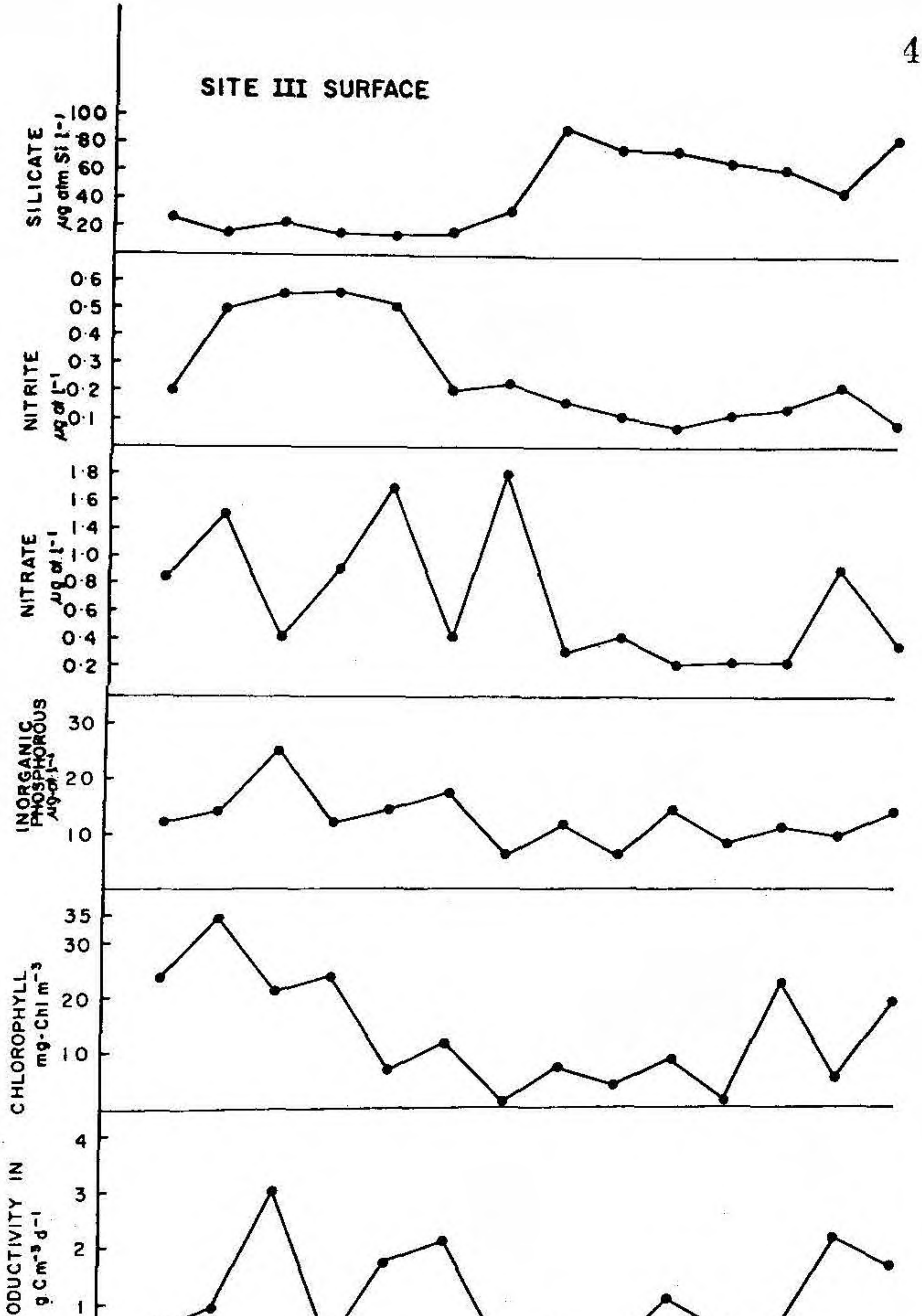


Fig. 16: Weekly variation in Productivity in relation to Chlorophyll-a and nutrients.

TABLE No. 1

SITE-I (SURFACE)

S.No. Samples	Date	°C Temperature		pH (Paper)	Salinity (%)	Dissolved Oxygen ml l^{-1}	Ammonia (ug-at N l^{-1})	Inorganic phosphorus (ug-at l^{-1})	Nitrate (ug-at l^{-1})	Nitrite (ug-at l^{-1})	Silicate (ug-at sil^{-1})	Chlorophyll a mg-chl/m^3
		Atm	Water									
1	24-06-86	26	30	7.5	9.85	1.87	-	15.21	15.6	5.2	25.22	77.5
2	01-07-86	25	29	7.0	5.82	3.31	-	13.79	16.4	6.4	14.409	70.5
3	08-07-86	27	29	7.0	5.37	1.48	-	17.37	13.6	12.6	24.5	24.84
4	15-07-86	25	28	6.5-7.0	5.19	2.78	-	15.5	17.8	13.6	15.85	51.22
5	22-07-86	26.5	30	7.0	5.37	1.96	24.4	12.09	8	7.6	9.37	9.11
6	29-07-86 (05-08-86)	26	31	7.5(8.0)	5.19	1.44	15.8	12.09	7.4	5.6	17.29	17.83
7	12-08-86	24	27	7.0(7.5)	3.2	4.85	0.8	8.39	6	1.8	20.17	41.206
8	19-08-86	27	31	7.5	3.92	1.43	4	10.95	6	2.4	83.57	29.68
9	26-08-86	27.5	31.5	8.0	3.15	1.76	35.2	12.37	9.4	3.4	83.57	23.39
10	02-09-86	27	31	8.0-8.5	3.83	1.76	46	14.93	5.8	3.8	80.69	12.26
11	09-09-86	28	30	7.5	5.27	0.95	28	15.78	6	4.4	89.34	7,67
12	16-09-86 (23-09-86)	27	30.5	7.5-8.0	6.29	1.46	20	9.53	5.8	1.6	70.61	15.64
13	30-09-86	24	28	8.0	4.33	5.65	27.8	8.39	12.	3	73.49	11.21
14	07-10-86	24	27.5	7.5	4.42	3.09	41.6	15.78	9.4	10.6	100.86	14.9

TABLE NO. 2

SITE - II (BOTTOM)

S.No. Samples	Date	Temperature	pH (paper	Salinity (%)	Dissolved oxygen ml 1^{-1}	Ammonia g-at 1^{-1}	Inorganic Phosphorus(g-at 1^{-1}	Nitrate g-at 1^{-1}	Nitrite g-at 1^{-1}	Sillicate (g-at Sil^{-1}
1.	24.6.86		7.5	10.03	1.7	-	17.48	10.2	4.6	25.22
2.	1.7.86		6.5-7.0	5.82	2.57	-	13.79	20.4	9.4	12.97
3.	8.7.86		7.0	5.37	1.48	-	17.43	14.2	4.6	21.61
4.	15.7.86		6.5-7.0	5.19	2.35	-	10.07	14.4	12.8	12.97
5.	22.7.86		7.0	5.37	1.7	-	12.09	8.8	5.4	8.65
6.	29.7.86		7.5	5.19	1.57	13.8	13.51	8.2	4	15.85
.	(5.8.86)									
7.	12.8.86		7.5	3.2	4.8	3	8.56	6.6	2.4	18.01
8.	19.8.86		7.5-8.0	3.87	1.52	3	11.23	5.8	3	85.57
9.	26.8.86		8.0	3.24	2.09	31.[illegible]	13.5	10	6	83.57
10.	2.9.86		8.0	3.87	1.2	38.4	15.78	5.4	3.6	82.13
11.	9.9.86		7.5	5.36	0.95	25.8	11.23	7	3.2	89.34
12.	16.9.86		7.5	6.29	1.46	18	9.81	6	2.8	73.49
.	(23.9.86)									
13.	30.9.86		7.5-7.0	4.5	7.8	29.8	9.53	9.4	2.2	73.49
14.	7.10.86		7.5-8.0	4.33	5.2	37.4	15.21	9.8	5.4	103.75

TABLE No. 3

SITE-II (SURFACE)

S.No. Samples	Date	Temperature °C		pH (Paper)	Salinity (%)	Dissolved Oxygen ml l^{-1}	Ammonia ug-at l^{-1}	Inorganic phosphorus(ug-at 1-1	Nitrate (ug-at l^{-1})	Nitrite (ug-at l^{-1})	Silicate (ug-at Sil^{-1})	Chlorophyll a mg-chl/m^3
1	24-06-86	26	30	7.0-7.5	10.38	1.78	-	13.5	12	2.8	25.65	50.0
2	01-07-86	25	29	7.0	5.91	3.74	-	12.94	10.2	12.2	21.61	108.3
3	08-07-86	27	29	7.0	6.0	0.91	-	20.33	8	7.6	23.78	13
4	15-07-86	24	28	7.0(6.5)	5.1	2.13	-	14.93	15	12.0	17.29	37.35
5	22-07-86	26.5	30.5	7.0-7.5	5.28	0.78	33	15.78	6	6.6	8.65	3.91
6	29-07-86 (05-08-86)	26	31	7.5(8.0)	5.1	0.74	37.4	16.92	6.6	4.8	15.85	8.18
7	12-08-86	24	27.5	7.0-7.5	2.75	3.14	1.8	7.43	8.2	2.4	24.5	40.05
8	19-08-86	26.5	31	7.0-7.5	3.78	0.95	13.8	14.64	6.4	3.8	95.1	19.06
9	26-08-86	27	31.5	7.5-8.0	3.2	1.33	54.6	18.05	10.8	7	86.46	20.71
10	02-09-86	26.5	31.5	8.0	3.65	1.05	43.8	18.05	5.4	2.4	80.69	9.19
11	09-09-86	27	31	7.5-8.0	5.23	1.15	26.6	12.94	6	3	87.9	8.27
12	16-09-86 (23-09-86)	28	31	7.5	6.2	1.2	20.6	13.22	5.2	2.2	76.37	37.71
13	30-09-86	24	28.5	7.5-8.0	4.5	6.2	28.8	10.67	8.8	2.2	60.52	7.65
14	07-10-86	24	28	7.5-8.0	4.51	.018	3.6	14.93	8.8	8.8	80.69	14.84

TABLE NO.4

SITE II (BOTTOM)

Sl.No. Samp-less	Date	pH (Paper)	Salinity (%)	Dissolved Oxygen (ml l^{-1})	Ammonia g-at l^{-1}	Inorganic Phosphorus (g-at l^{-1}	Nitrate (g-at l^{-1}	Nitrite (g-at l^{-1}	Silicate (g-at Sil^{-1}
1.	24.6.86	7.0-7.5	10-56	1.6	-	14.07	11.4	2.2	30.26
2.	1.7.86	6.5	6.18	2.48	-	13.51	26.8	7.2	14.4
3.	8.7.86	7.0	5.37	0.78	-	21.46	7.4	9	23.05
4.	25.7.86	6.5-7.0	5.1	2.13	-	14.19	14.4	13.6	15.85
5.	22.7.86	7.0-7.5	5.1	0.7	33	15.5	6	5.2	10.09
6.	29.7.86 (5.8.86)	7.5	5.01	0.87	35.2	17.48	7.6	6	21.61
7.	12.8.86	7.0-7.5	3.02	3.28	7.4	9.98	7.6	3.8	27.38
8.	19.8.86	7.5-8.0	3.83	0.76	12.6	15.21	6.6	4.6	95.1
9.	26.8.86	7.5	3.2	1.38	51.4	15.89	8.2	8.2	89.34
10.	2.9.86	8.0	3.69	1.71	42.8	18.34	6.4	1.6	77.51
11.	9.9.86	7.0-7.5	5.32	1.15	29.8	12.94	6.2	2	87.9
12.	16.9.86 (23.9.86)	7.5	6.20	1.15	18	11.8	8.8	2.4	67.72
13.	30.9.86	7.5-7.0	4.59	7.9	27.8	10.67	10	3	60.52
14.	7.10.86	8.0(7.5)	4.51	3.6	23.4	14.64	8.8	3	77.81

TABLE No. 5

SITE-III.

S.No. Samples	Date	Temperature °C		pH (Paper)	Salinity (%)	Dissolved Oxygen ml l^{-1}	Ammonia ug-at l^{-1}	Inorganic phosphorous (ug-at l^{-1})	Nitrate (ug-at l^{-1})	Nitrite (ug-at l^{-1})	Silicate (ug-at Sil^{-1})	Chlorophyll a mg-chl/m^3
1	24-06-86	26	29	6.5(7.0)	10.56	1.09	-	12.94	17	4	26.66	23.5
2	01-07-86	25	28	6.5(7.0)	3.85	1.7	-	14.07	30.2	10.4	16.57	34.91
3	08-07-86	27	28	7.0	5.01	1.35	-	25.16	7.6	11	20.17	21.81
4	15-07-86	24	25	6.5	3.04	3.35	-	12.94	17	11.2	14.41	24.34
5	22-07-86	26	28	7.0	4.57	1.0	81.4	14.93	34.4	10.2	12.25	7.15
6	29-07-86 (05-08-86)	27	29	7.5(8.0)	4.48	1.13	53.4	17.2	7	4	15.85	10.28
7	12-08-86	24	25.5	6.5(7.0)	1.53	3.18	31	6.69	35.6	4.6	32.42	1.19
8	19-08-86	25.5	28	7.0(7.5)	2.48	0.95	35.2	11.23	6.4	3.2	93.66	7.44
9	26-08-86	26.5	28.5	7.0(7.5)	2.34	1.76	18	6.69	8.2	2.2	77.81	4.7
10	02-09-86	27	27.5	7.0(7.5)	4.01	1.36	74	14.07	4.6	1.4	77.81	8.38
11	09-09-86	26.5	28.5	7.0	5.68	0.75	50.2	8.68	4	2.4	69.16	1.8
12	16-09-86 (23-09-86)	26	28	7.0(7.5)	6.80	0.8	82.6	11.8	3.8	2.8	63.4	22.78
13	30-09-86	23.5	26.5	7.0(7.5)	1.27	4.62	58.8	9.53	18	4.4	47.55	5.28
14	07-10-86	23.5	26	7.5	4.33	1.46	20	10.38	6.4	1.6	86.46	19.76

TABLE No. 6

PRODUCTIVITY (in g $Cm^{-3}d^{-1}$)

S.No. Samples		SITE-I			SITE--II			SITE-III		
		Gross	Net	Respiration	Gross	Net	Respiration	Gross	Net	Respiration
1)	24/6	1.04	0.45	0.59	1.06	0.86	0.20	0.80	0.59	0.21
2)	1/7	1.68	1.23	0.45	4.38	0.39	0.45	1.12	0.96	0.16
3)	7/7	3.54	3.12	0.29	3.05	3.01	0.26	3.02	3.02	-
4)	15/7	1.03	0.9	0.12	0.93	0.84	0.09	0.36	0.26	0.10
5)	22/7	2.89	2.25	0.64	2.07	1.92	0.14	0.19	1.69	0.17
6)	29/7	3.31	2.87	0.44	1.68	1.64	0.03	2.25	2.07	0.18
7)	12/8	1.83	1.41	0.43	2.20	1.84	0.27	0.12	0.05	0.07
8)	19/8	2.92	2.51	0.41	3.54	3.38	0.17	0.63	0.44	0.19
9)	26/8	1.85	1.77	0.09	1.75	1.60	0.17	0.19	0.16	0.04
10)	2/9	2.48	2.19	0.29	1.69	1.41	-	1.28	1.02	0.25
11)	9/9	2.31	2.15	0.16	2.35	2.21	0.14	0.56	0.45	0.11
12)	16/9	3.83	3.76	0.07	2.00	1.99	0.02	0.56	0.45	0.11
13)	30/9	1.42	1.23	0.10	1.16	0.66	0.25	2.21	2.06	0.08
14)	7/10	2.86	1.76	0.55	2.77	2.22	0.28	1.92	1.62	0.15

TABLE NO. 7

CORRELATION CO-EFFICIENT

		SITE I		SITE II		SITE III
		Surface	Bottom	Surface	Bottom	Surface
Prod (Net)	Temp	0.4455	-	0.2433	-	0.1408
"	Salinity	0.2012	-0.2175	-0.2691	0.3385	0.0057
"	DO_2	-0.533*	-0.413	0.6219	-0.4706	0.0083
"	NH_3	-0.3693	-0.4266	-0.3979	-0.4878	0.4201
"	PO_4	-0.1022	-0.04369	0.3068	0.3774	0.7415*
"	NO_3	-0.5616*	-0.3749	-0.544*	-0.6429*	-0.0863
"	NO_2	-0.1289	-0.4225	-0.2919	-0.1089	0.3154
"	Si	-0.1975	-0.2025	0.3684	0.3863	-0.3166
"	Cl.a	-0.6299		-0.5064		0.1201

* Values significant at 5% level.

DISCUSSION

While comparing the productivity and related parameters in the three sites which have been studied for a period of three to four months, the conclusions that can be derived are as follows:

Site - 3 which has got a greater influence from the backwater system shows a better correlation between the various parameters that have got a significant bearing on productivity. All the three areas have got a uniformily high rate of gross and net production reaching over 3 g $C/m^{-3}d^{-1}$ which is equivalent to the highest productivity that is normally observed in estuarine and inshore environments. Qasim et al (1970) have observed that the gross production in this estuarine system is 280 g $Cm^{-2}yr^{-1}$ and net production is approximately 195 g $Cm^{-2}yr^{-1}$. While studying the plankton production in the Vembanad Lake, Pillai et al (1975) reported the highest production rate of 245 mg Cm^{-3} hr^{-1}. Nair et al (1975) found gross production varying from 150 to 650 g $Cm^{-2}d^{-1}$ in the prawn culture fields on adjacent to Vembanad lake.

Qasim (1970) has further suggested that the bloom of phytoplankton and growth of zooplankton in estuarine system are some what out of phase and that the phytoplankton production far exceeded the rate of consumption by the zooplankton herbivores which occur in the system as surplus. This surplus production from a minimum during February reaches its maximum quantity during July to October period. This surplus basic food is obviously a function of enrichment during the monsoon period when large quantities of macro and micro nutrients are carried into the estuaries.

From the results give in Table (6) it may be observed that the respiration as compared to the gross production forms only 6 - 18% in site-1, 2 - 10% in site -3 and 8.2% at site - 3 through once in a while it has exceeded 58%. So on the whole respiration is comparatively of a low rate which further confirms Qasim's observation. If we examine phytoplankton production alone a fairly large surplus is available in the estuarine system of Cochin.

In order to examine the relation between productivity parameters, scatter diagrams (Fig. 17-20) have been made and correlation coefficients (Table- 7) have been worked out. A considerable scatter in the points and a low correlation coefficient are probably because of inadequacy of sampling over a limited period. Perhaps more number of samples spread over a whole year would have shown a better relationship. Some of the puzzling findings are that there is no expected relation between primary production, either gross or net production, with ;chlorophyll a except in site -3 which is more akin to the natural system. The negative relation is perhaps indicative of the fact that other accessory pigments such as phycocyanin and other plant pigments may be more significant in these areas depending on the occurrence and species variation of phytoplankton populations.

Chlorophyll a is the major pigment in algae which is able to transform light energy directly into chemically bound energy. According to Rabinowitch (1951) light energy absorbed by other pigments including chlorophylls 'b' & 'c' may be converted via chlorophyll 'a'. When the plankton is dominated by green algae the light absorbed by chlorophyll 'a' & 'b' is by far the most important source of energy for photosynthesis. However, when blue green algae dominate in the plankton, which may very often be the case in brackish-water culture systems where the experiments have been carried out, phycocyanin may be present far larger quantities than the chlorophyll 'a'. In fact Steeman Nielsen and Jørgensen (1962) point out that phycocyanin is the only pigment that is present in this taxanomic class of algae. Experiments by Myers and Kratz (1955) indicated that in blue-green algae the light energy absorbed in phycocyanin is of more importance for photosynthesis than is the light energy absorbed by chlorophyll. This conjecture could not be confirmed since no qualitative studies on the species abundance and their relative variations have been studied.

Krishnamurthy and Sundaraj (1974) studying on phytoplankton pigments in Portonovo waters reported chlorophyll a values between 2.91 and 65.56 ug l^{-1} The same authors have observed that the temporal variation in the occurrences of the main peak were not significant and the maximum occurrence in summer at all places which was interpreted as due to an interplay of various factors amongst which the effects of shifts in water currents, prevailing wind conditions transporting large volumes of waters and the movement of water masses.

While recognising that phytoplankton crop and primary production are closely related, the factor concerning size of standing crop with reference to chlorophyll has to be examined. Algal cells may disappear by sinking but in most areas a great majority is consumed by the grazing of the herbivorous zooplankton. The biomass of zooplankton, especially of herbivorous in the Cochin estuarine water is low and hence grazing pressure is not severe. However, Vinogrado (1966) suggests, as a generalization for open oceans, that 80% of the primary production is consumed by zooplankton, with only 10% sedimented in the bottom deposit. Even though the trophic structure of the tropical plankton community differs from that of high latitudes, heavy grazing pressure is also regarded as typical of the warm waters by Tranter (1975).

In this connection it may be pointed out that Qasim _et al_ (1969) have not found a close relation of phytoplankton counts and chlorophyll _a_. On the contrary a plot of chlorophyll against seston gives some evidence that an increase in seston is followed by a corresponding increase in chlorophyll _a_. This indicates that seston contributes a fairly large extent to the chlorophyll concentration. But this may not be reflected in primary production because seston will be containing a lot of physiologically inactive chlorophyll. Another factor which requires special mention is that daily variations in chlorophyll concentration can be brought about by interchange of water masses.

As discussed earlier sites 1 & 2 are enclosed environments where the tidal influx and consequent replenishment are almost nil except perhaps through percolation through the bunds. The thermal condition is dependent mostly on the monsoon precipitation. It has already been established that in Cochin backwaters and adjacent areas temperature has little significance in the production of Organic matter (Qasim _et al_ 1969).

The dissolved oxygen content of the water in the prawn culture fields showed little variation. Although the dissolved oxygen content has no direct role in the production of organic matter in the estuary, it is an index of the

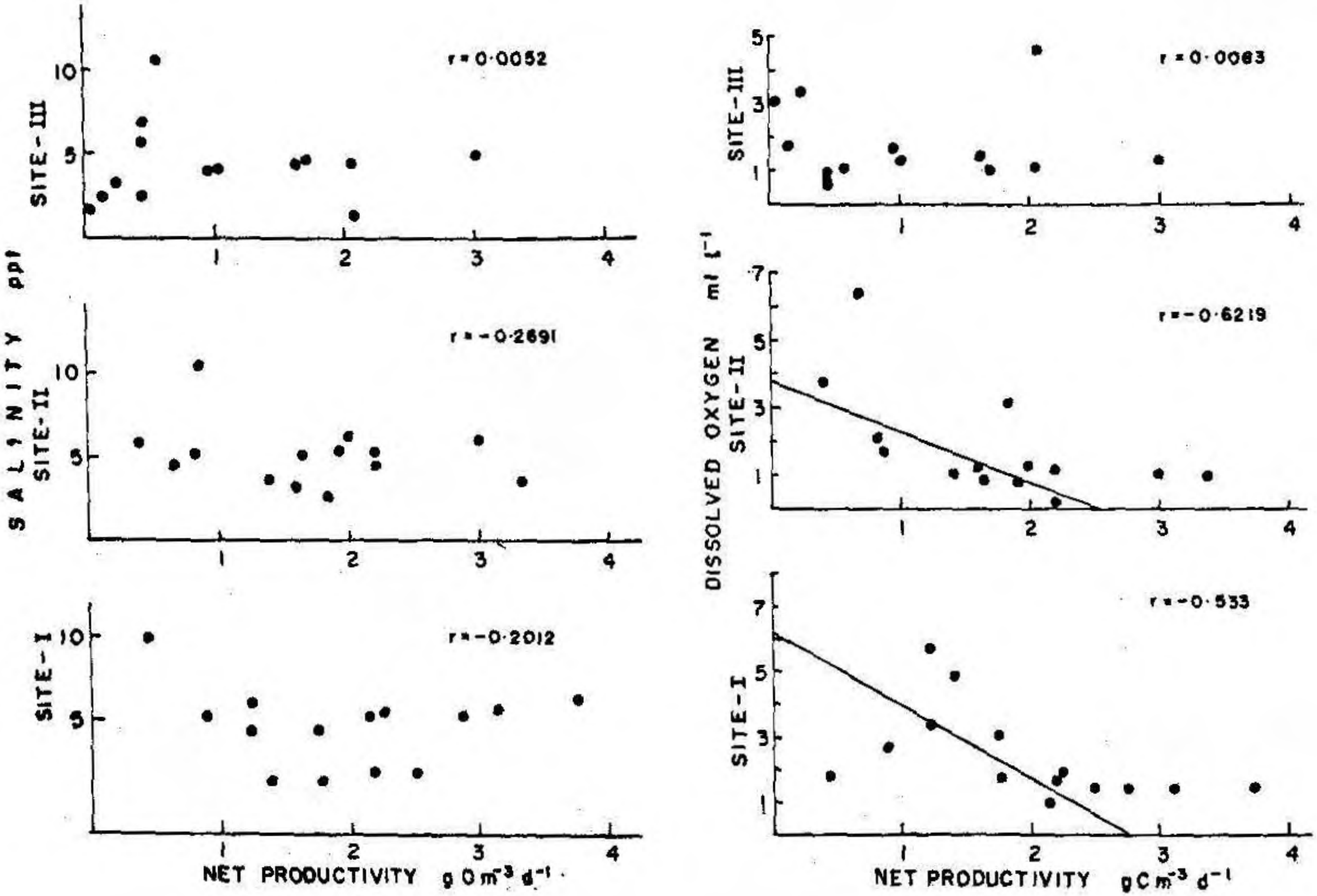


Fig.17: The relationship between net productivity, salinity and dissolved oxygen; 'r' denotes the correlation coefficient.

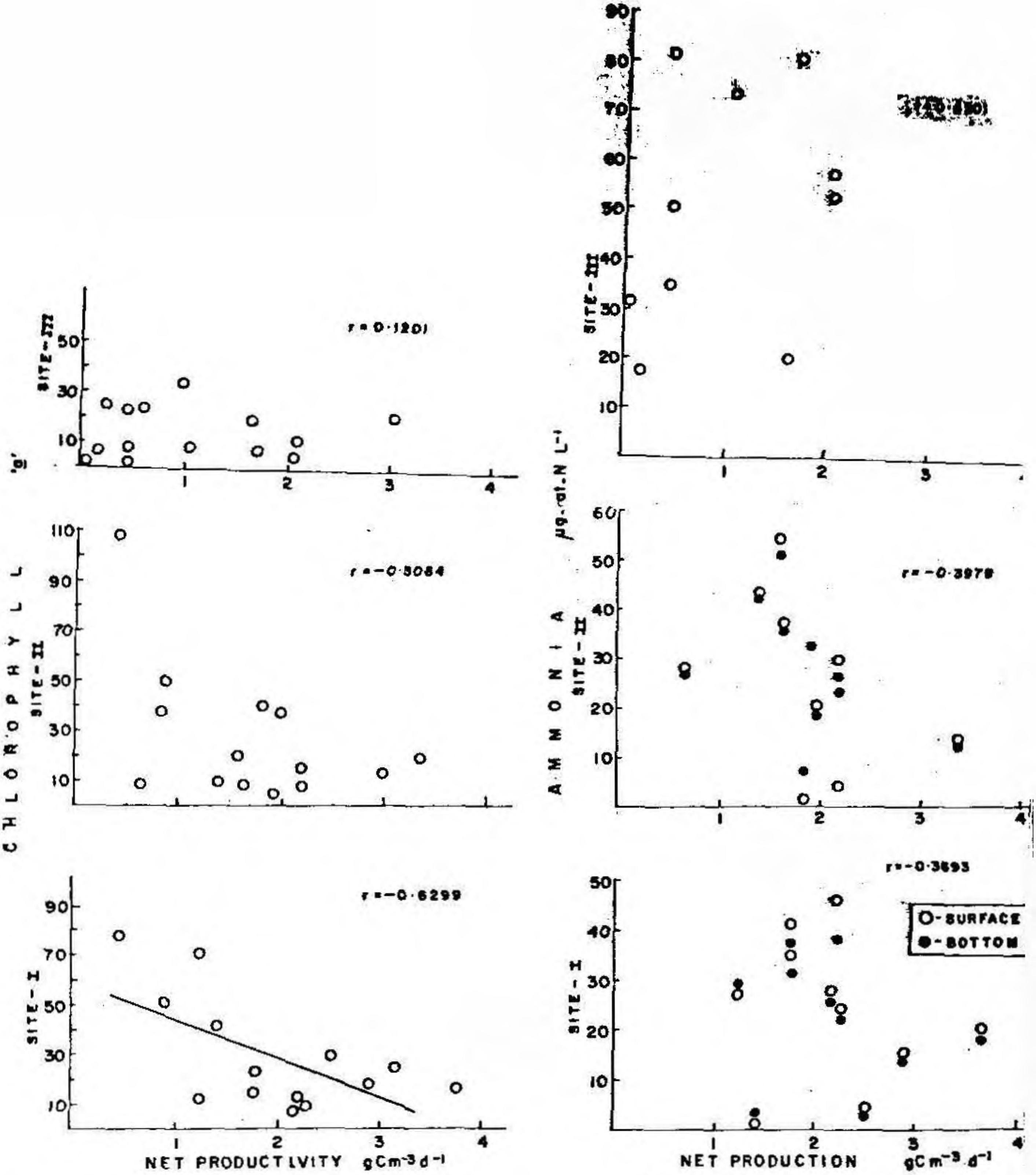


Fig.18: The relationship between net productivity, chlorophyll a and ammonia; 'r' denotes the correlation coefficient.

metabolic activities of the entire community comprising producers as well as consumers (Gopinathan et al. 1982). Pillai et al (1975) observed that high values of dissolved oxygen were found during monsoon and pre-monsoon periods, which can be due to combined effect of photosynthesis and water movement.

The photosynthetic rates of several organisms at varying salinities, have been investigated by Qasim et al (1972). It was found that *Asterionella*, *Chaetoceros* and *Coscinodiscus* showed maximum photosynthesis at salinity range 10-20 ppt. Similar results were observed by Bhattathiri and Devassy (1975) also. The pH variation is also not significant as it is fairly constant around 7 and does not show either strong acidic or alkaline characteristics. So most of the CO_2 supply for the photosynthesis might be as bicarbonates. Though an attempt was made to estimate the bicarbonate, due to the inadequacy of the technique used and as the values obtained are some what suspect these values bicarbonates have not been included in the discussion.

Another significant productivity parameter is the occurrence of free ammonia in the water. The values obtained are fairly high. Venugopal and Rajendran (1975) observed that there is an increase in levels of ammonia during the monsoon periods and have suggested that the major factor responsible for the addition of ammonia might be non-biogenic i.e. from rainfall and terrestrial run off However, the ammonia is removed from natural water by phytoplanktonic and heterotrophic and chemoautrophic microorganisma and the system is enriched by the addition from the excretion of organisms and by the decomposition of organic nitrogenous materials. The negative correlation, though not of significant magnitude, observed in site-1 and site-2 and fairly significant correlation observed in site-3 are indicative of the non-biogenic origin and utilization by phytoplankton and other organisms.

The accumulation of nitrite in estuarine environment could be due to the excretion by phytoplankton, oxidation of ammonia and reduction of nitrate. Rajendran <u>et al</u> (1973) have found that oxidation of ammonia and reduction of nitrate are the chief sources of nitrite in Vellar estuary.

A scrutiny of the nutrients indicate that inorganic phosphorous is significantly higher to that of nearshore environment or in normal brackish water environment. Pillai <u>et al</u> (1975)working on the plankton production in Vembanad lake reported similar high values. Sankaranarayanan and Qasim (1969) have reported very low values which are at variance with the values found in the present study. The same authors have observed that the inorganic phosphorous increases during the monsoon months and progressively decreases during the post-monsoon months. No such trend

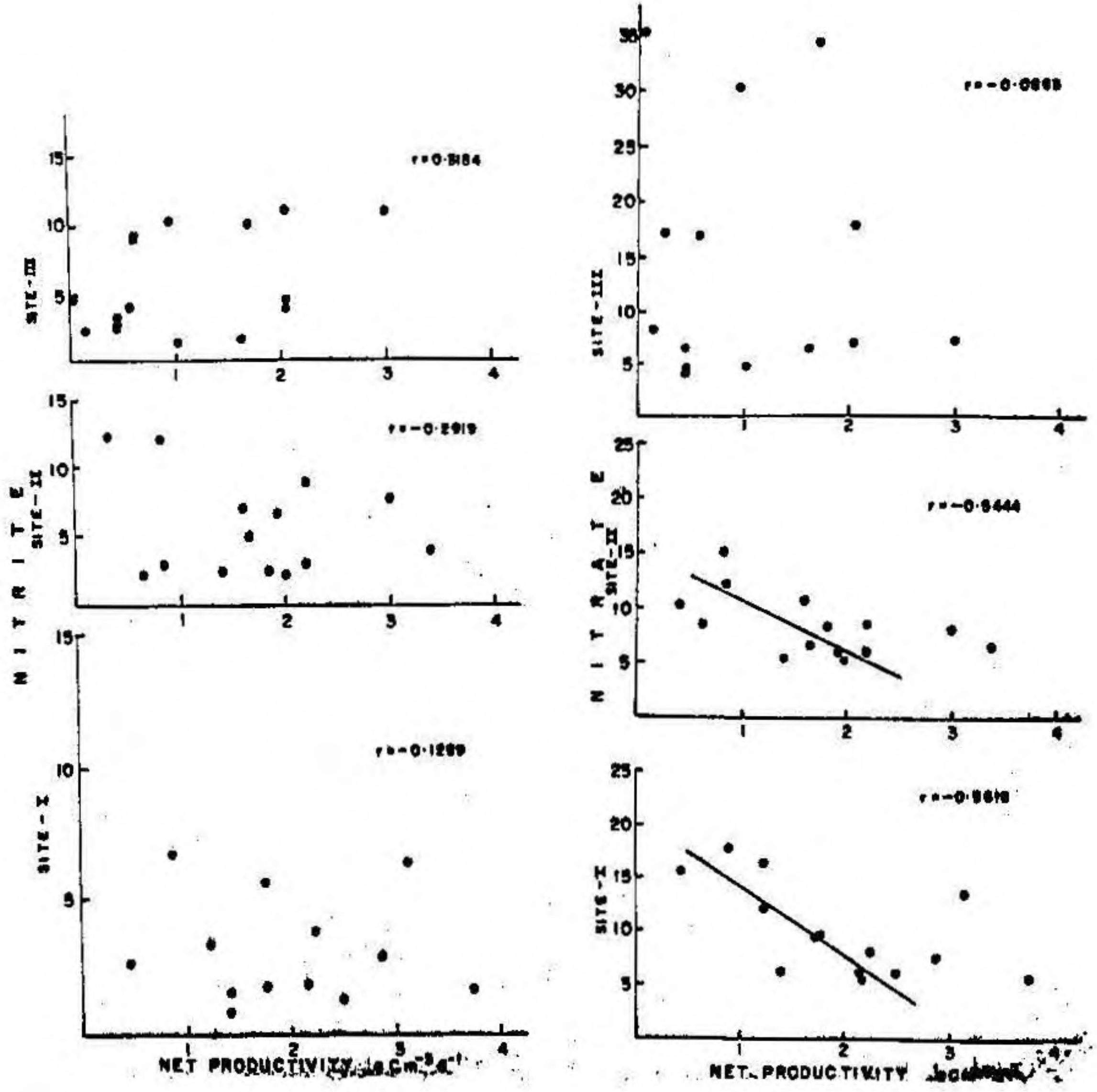


Fig.19: The relationship between net productivity, nitrite and nitrate; 'r' denotes the correlation coefficient

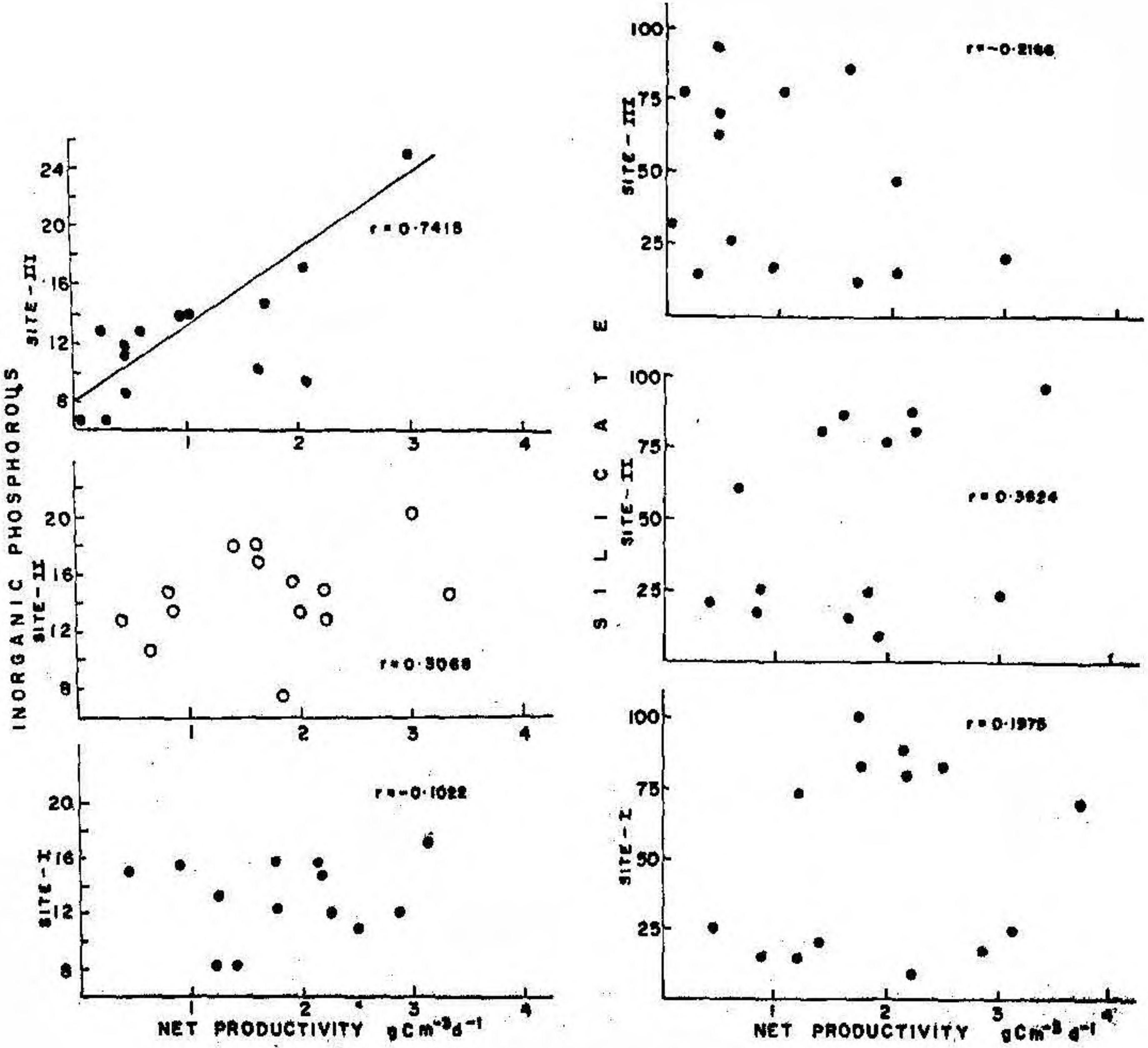


Fig.20: The relationship between net productivity, inorganic phosphorus and silicate; 'r' denotes the correlation coefficient.

has been observed in the present study. The high content of inorganic phosphorous may be perhaps attributed to leaching from agricultural fields around the culture ponds when there is considerable imput by way of fertilisers coinciding with the advent of monsoon. It is possible that a large part of the fertilizers leach into the environment which accounts for the high phosphorous and nitrate content. Simpson et al (1975) have concluded that the phosphate distribution is dominated by the balance between sewage and water transport within and out of the system, and that biological activity has little influence on phosphate distribution in an estuary. Mackay and Leatherland (1976) contended that if there is significant biological removal of phosphate in the estuary, this would be accompanied by nitrate removal. Sankaranarayanan and Qasim (1969) observed that there is no firm basis, for believing that the instantaneous concentration of nutrients as inorganic salts in the estuary provides a significant source of phytoplankton bloom.

The sampling undertaken from June end to October first week is the period when maximum agricultural activity coupled with leaching due to the monsoonal rains take place. This perhaps leave quite large quantities of unutilised phosphorous and nitrogen which may result in even incongruous ratios in contrast to the accepted N : P ratio in such environment. The N : P ratio by atoms has been found to be highly variable in an early study also (Qasim et al. 1969). The normal ratio, though, is 16:1 during the monsoon months the ratios were remarkably high reaching 40:1 in July. When there is no rain water run off it was 0.53 to 1. This is clearly indicative that the leaching and run off have got a significant bearing on the occurrence of phosphate and nitrate. In other estuarine areas similarly highly erratic ratios of Nitrogen and Phosphorous have been recorded even though phytoplankton organisms showed remarkable consistency (Jeffery, 1962). Purushotham and Bhatnagar (1976) reported the primary productivity of protonovo waters have given the N:P rations varying from 12:1 (February) to 1:1 (April). Maximum productivity in the same study was observed in the month of April, when the concentration of nutrients was minimum whereas the temperature and salinity were high.

The uptake of nutrients in the environment is affected not only by their concentration but also by interactions with other variables, particularly temperature and light. For example, uptake of either nitrate or ammonium under conditions where the concentrations is not limiting shows an approximate hyperbolic increase with light intensity (Mac Issac and Dugdale, 1972). Steponson and Richards (1963) found an almost linear relationship between dissolved nitrate and salinity in a riverine estuary. Butler and Tibbits (1972) reported an increased relationship between salinity and total dissolved combined nitrogen.

The agricultural activity also tend to increase the silicate values which are found to range from 12 to almost 94 μg-at t^{1}. The average values of the silicate in the present study are comparable to that of Sankaranarayanan and Qasim (1969). There has been considerable disagreement between the results of the various investigations of silicon behaviour. Dissolved silicon has particular importance potentially only in coastal upwelling regions where diatoms form a dominant part of the phytoplankton. Hence the silicon concentrations in the environments under study has not much significance since diatoms do not form a major component in the phytoplankton population in this area.

So the above studies have again confirmed the fact that in such estuarine systems where there is considerable anthropogenic activity the expected relationship between macronutrients and production may not be applicable. One thing that holds good in this aquatic ecosystem is that it is highly productive leaving a surplus production in excess of respiration. Taking into the view of the zooplankton requirements computed by earlier workers, it is possible that the the entire primary productivity is never consumed fully in the estuarine ecosystem. Hence, in enclosed waters or in areas which have got influx from the adjacent open areas there is a large amount of surplus food which can be fully exploited by stocking at a higher density than the accepted norms and with less input. Gopinathan *et al* (1982), while studying the environmental parameters of prawn fields in and around Cochin, have categorised the culture fields into three groups namely high productive ($>$ 1.5 g $Cm^{-3}d^{-1}$); moderately productive (0.5 to 1.5 g $Cm^{-3}d^{-1}$) and low productive ($<$ 0.5 g $Cm^{-3}d^{-1}$). Among the areas studied by the above authors the seasonal fields are seen to be more productive than the perennial ones. In the perennial ones the time lag for recuperation of the ecosystem by nutrient influx and consequent increase in primary productivity does not exist resulting in the depletion in the magnitude of the potential productivity. According to this classification this area of study falls under the highly productive group. However after one or two culture operations during the summer months it may be desirable to leave the culture system to rejuvenate by itself.

SUMMARY

1. The present study was carried out in two prawn culture ponds and a coconut groove at Narakkal to find out the variability of productivity parameters in enclosed and contiguous ecosystems.

2. Environmental factors such as water temperature, pH, dissolved oxygen, salinity, ammonia, inorganic phosphorous, nitrite, nitrate and silicate were investigated. Photosynthetic measurements were conducted by 'light and dark bottle' method. Chlorophyll 'a' was also determined.

3. Weekly samples were taken and the results are graphically presented and discussed.

4. The water temperature did not show much variation pH was around 7.5; salinity and dissolved oxygen did not vary much, their mean values were 5.1×10^{-3} and 2.2 ml l^{-1} respectively.

5. A scrutiny of the nutrients showed high values, inorganic phosphorous content was high with a mean value of 13.0 /ug-at l^{-1}; values of nitrite and nitrate were also high; silicate ;with a mean value of 50 /ug-at l^{-1} was recorded. The values are much

higher than the rates occurring in backwaters which is attributed to agricultural activity around and subsequent run off.

6. Studies on correlation of primary production with chlorophyll 'a' have not revealed any positive relationship in the experimental sites of 1 & 2.

7. Studies at site -3 showed better relations between productivity and related parameters as it is more akin to natural systems in view of its contiguity with the backwater area.

8. The present study revealed that the culture ponds are highly productive ($>$ 1500 mg $Cm^{-3}d^{-1}$) and can be considered as a part of the highly productive region of the ecosystem of Vembanad Lake, which can be used for culture practices without artificial fertilization.

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