STUDIES ON THE PLANKTON OF THE EAST COAST OF INDIA

Part II. Seasonal Cycle of Plankton and Factors Affecting Marine Production with Special Reference to Iron Content of Wate

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INTRODUCTION

IN the following account, the fluctuation of the standing crop plankton over a period of nearly three years (June 1959 to Ap described and its relationship to hydrological factors discussed collections made at a station off Madras coast. The data for 1 be had only for 14 months. This account, in some respects, is com to the studies on the west coast of India carried out for several y of us (Subrahmanyan, 1959). For the first time, for our water content over a period has also been studied. The probable rôle a limiting factor has already been pointed out (Subrahmanyan, *I*

METHODS

Plankton samples were obtained by five different hauls alread in an earlier account (Subrahmanyan and Sen Gupta, 1963).|| Phy was estimated by extract of the pigments by Harvey's metho plankton by displacement volume and dry weight.

Surface water was sampled for analysis at the same time a collection. Internationally accepted methods, the same as thos

content has not been reported for our waters before, the method adop
is briefly given below as also the deviations in the instance of salinity.

As no method has yet been devised to estimate the available iron c
the *total* iron was estimated. It was determined by the wet ashing of
sample with sulphuric acid and liberating the iron, after oxidation of
ferrous to ferric form, by treatment with bromine water, and estimating v
thiocyanate according to the method of Thompson and Bremner (19
Though some workers hold this method as unsuitable, we found that ma
taining optimum conditions in the sample and control and using ammoni
thiocyanate instead of potassium thiocyanate the colour produced to
quite stable for comparison in a Klett-Summerson photoelectric colorim
using blue-green filter No. 50. The results obtained are quite favour
within the limit prescribed by others using different colour producing age

Salinity was calculated according to the Table of Dr. Pickard after e
mating the chlorinity by the method suggested by Strickland and Pars
(1960). Though the Table is yet to be approved by the International Cour
it has been adopted, as the salinity estimations are made hereafter apply
the corrections for density and temperature differences, hence, more accu
than those calculated by using Knudsen's Tables, current even now v
several workers.

RESULTS AND DISCUSSION

1. *Phytoplankton*

In Fig. 1 the data relating to the standing crop of phytoplankton
represented for the period June 1959 to April 1962. Graphs A, B an
represent data from haul I: phytoplankters in terms of Harvey Units, displ
ment volume and dry weight. It may be seen that, in general, the tren
fluctuation of the standing crop is same in all, although the Harvey units
indicative of healthy plankters only, and the volume and weight repre

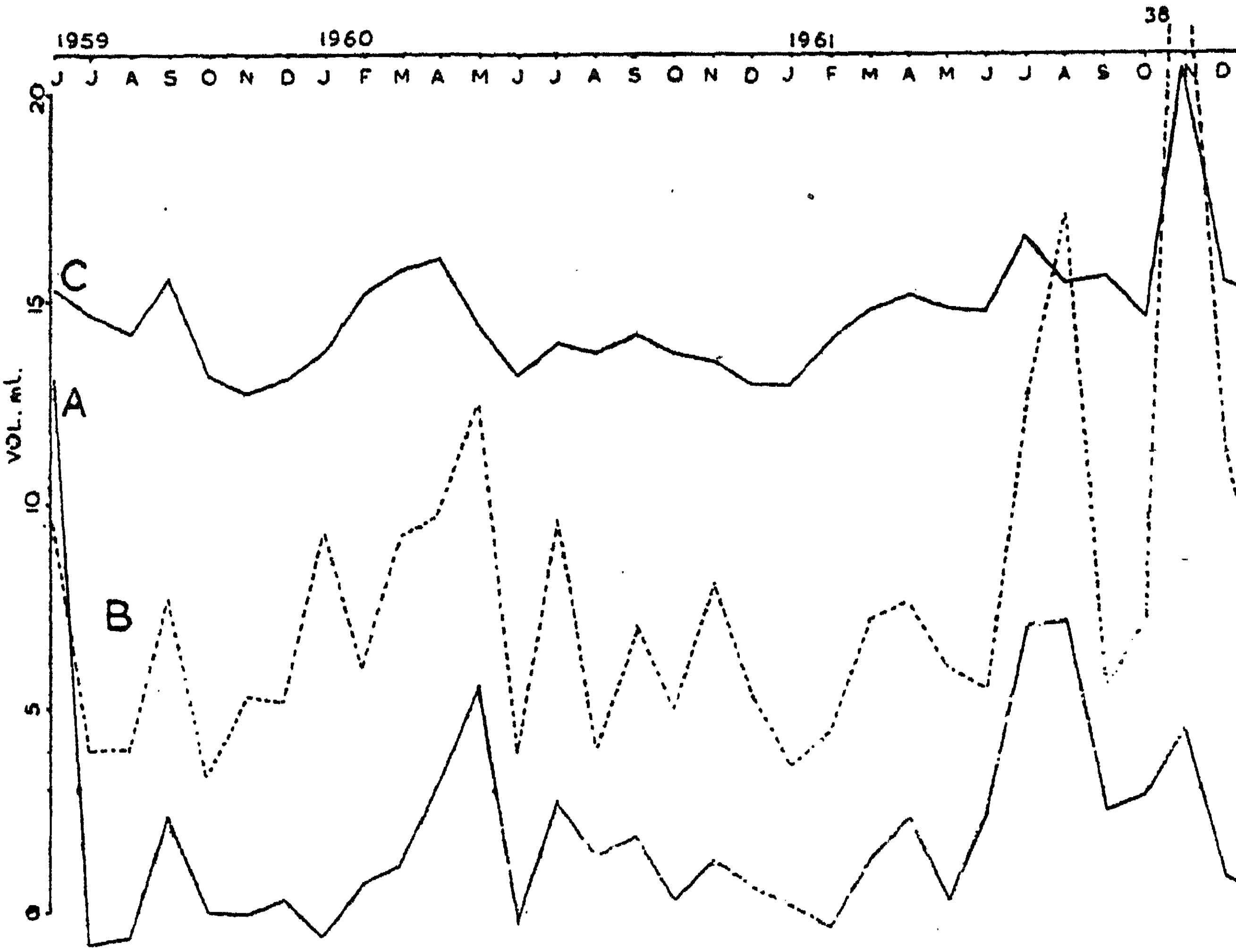


FIG. 1. Seasonal fluctuation in the quantity of phytoplankton. Harvey uni
volume and dry weight. For period June 1959 to April 1962.

It may be noticed that the pigment values are of a higher o
nate years. Such a fluctuation has been noticed on the west
well as changes in the peak periods which appear to depend
and period of expression and intensity of the monsoons (Su
1959, 1960).

2. *Total Plankton*

Figure 2 represents the data relating to displacement volu
weight respectively of the plankton obtained in hauls II, III, IV a
of haul II consists of smaller zooplankters and a few of the
plankters; catch of III (surface haul) and IV (oblique haul

plankters indicating a parallel relationship which is indicative of the d
dance of zooplankters on the floral elements.

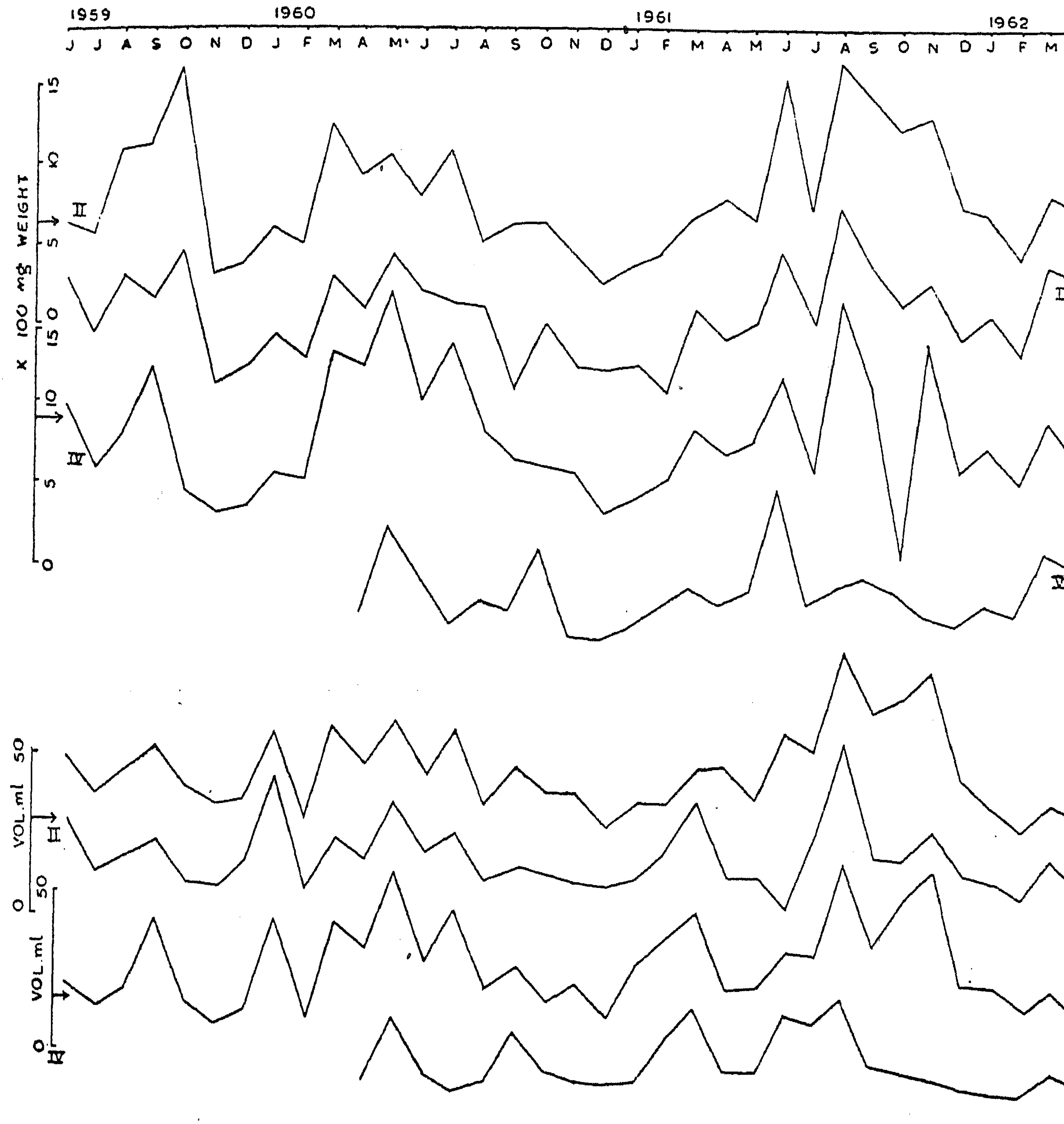


FIG. 2. Seasonal fluctuation in the quantity of total plankton. Displacement volur
dry weight for 4 different hauls (*vide* text).

As the technique employed at other centres and workers for the may also be mentioned that the lipid content of the plankton als the west coast material showing a higher fat content. These aspe been discussed in detail elsewhere (Subrahmanyan, 1959; 1960; manyan and Sarma, 1960; and Subrahmanyan and Sen Gupta, 19

3. *Hydrological Conditions*

Estimations have been made of phosphates, nitrites, silicates, iron and dissolved oxygen in the water. As the fluctuation of most of dependent on the mixing up of the water layers, data for wind forc the factors responsible, is also dealt with.

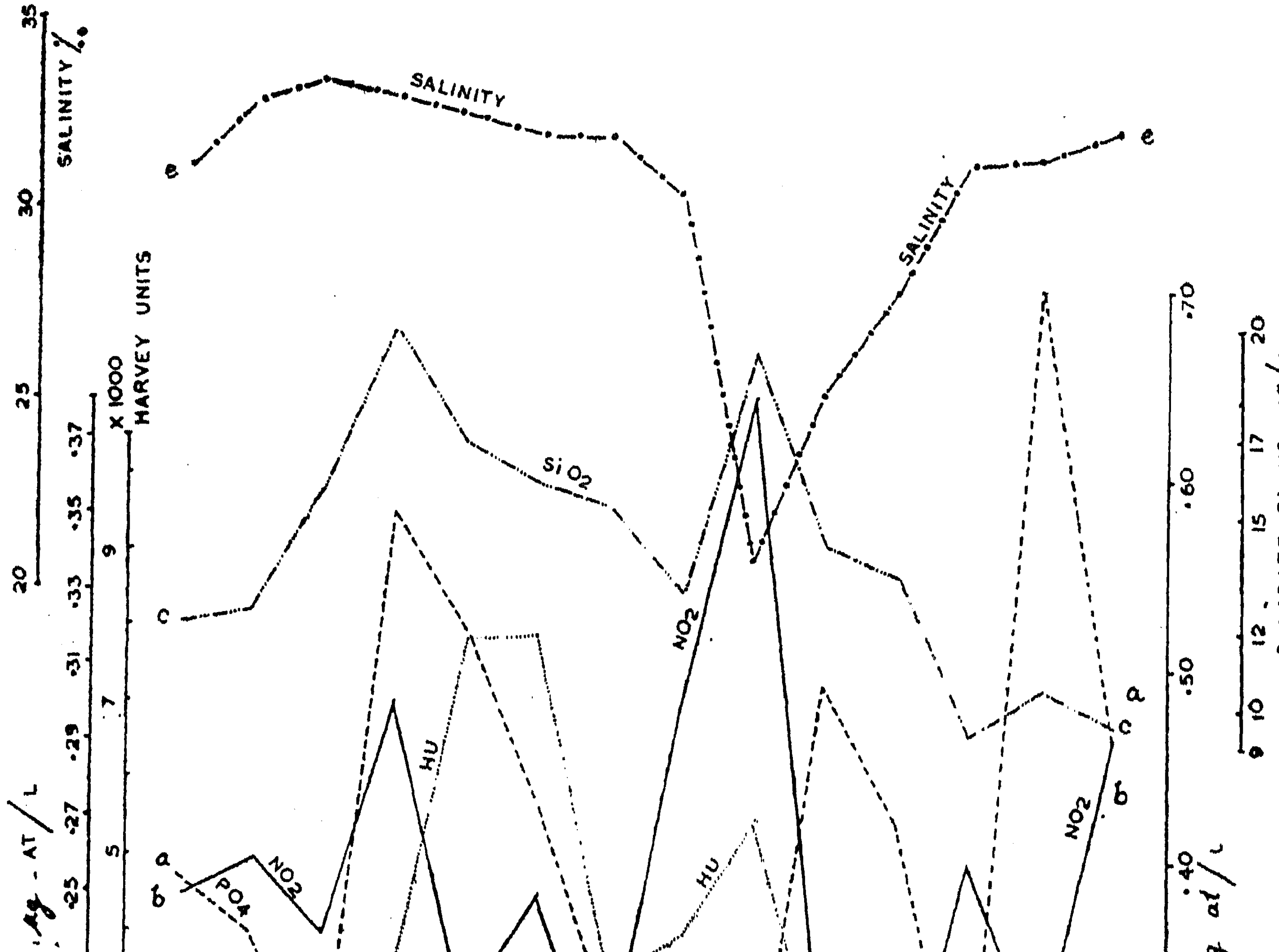
Temperature readings could not be made owing to certain difficulties. It may be pointed out, however (*vide* Subrahmanya p. 191), that a bimodal or double oscillation of sea surface tempera been found to be common for the several of the warmer areas inv in the waters around India. Observations made by Ganapati and (1954) off Vizagapatanam coast show a triple oscillation of the surf perature. Ramamurthy (1953) could record no such oscillation in perature off Madras; his values vary from 27·16 to 31·10° C., from to October.

In drawing upon the temperature data mentioned here, we wish t clear they are not meant to apply to the period of present investigation for, it is found from the accounts for the same region by earlier wo 1951, 1953 and 1959 (Jayaraman, Ramamurthy, Varma and Reddy tively) that data and seasonal fluctuation for no two years are ide any of the factors involved, mentioned in the present account.

In Figs. 3 and 4 the several hydrological factors, wind force an plankton content of the water are graphically represented. In the d that follows, we have attempted to bring out the relationship of thes not only to the plankton bloom but also amongst them.

(*a*) *Phosphate-Phosphorus*.—The course of the phosphate fl

It may be seen that phosphate values rise steeply from May, proba effect of wind mixing up the water; for, the wind force is on the incre during the period (Fig. 4 *g*.). The value reaches a peak in June and, the after, with the consumption by phytoplankters, the phosphate content reco a fall reaching a minimum value in November, at which time also, there i minor bloom of phyto elements. Subsequent to this, the values keep oscill ing, with an inverse relationship probably reflecting regeneration a replenishment of phosphate at the surface layers and the same sinking lower levels, to be brought up again with the onset of the following monso The oscillations may also reflect the shortened cycle of regeneration throu the faecal pellets of profusely feeding zooplankters which exhibit diur movements owing to which some phosphate is left at the surface at vario levels.

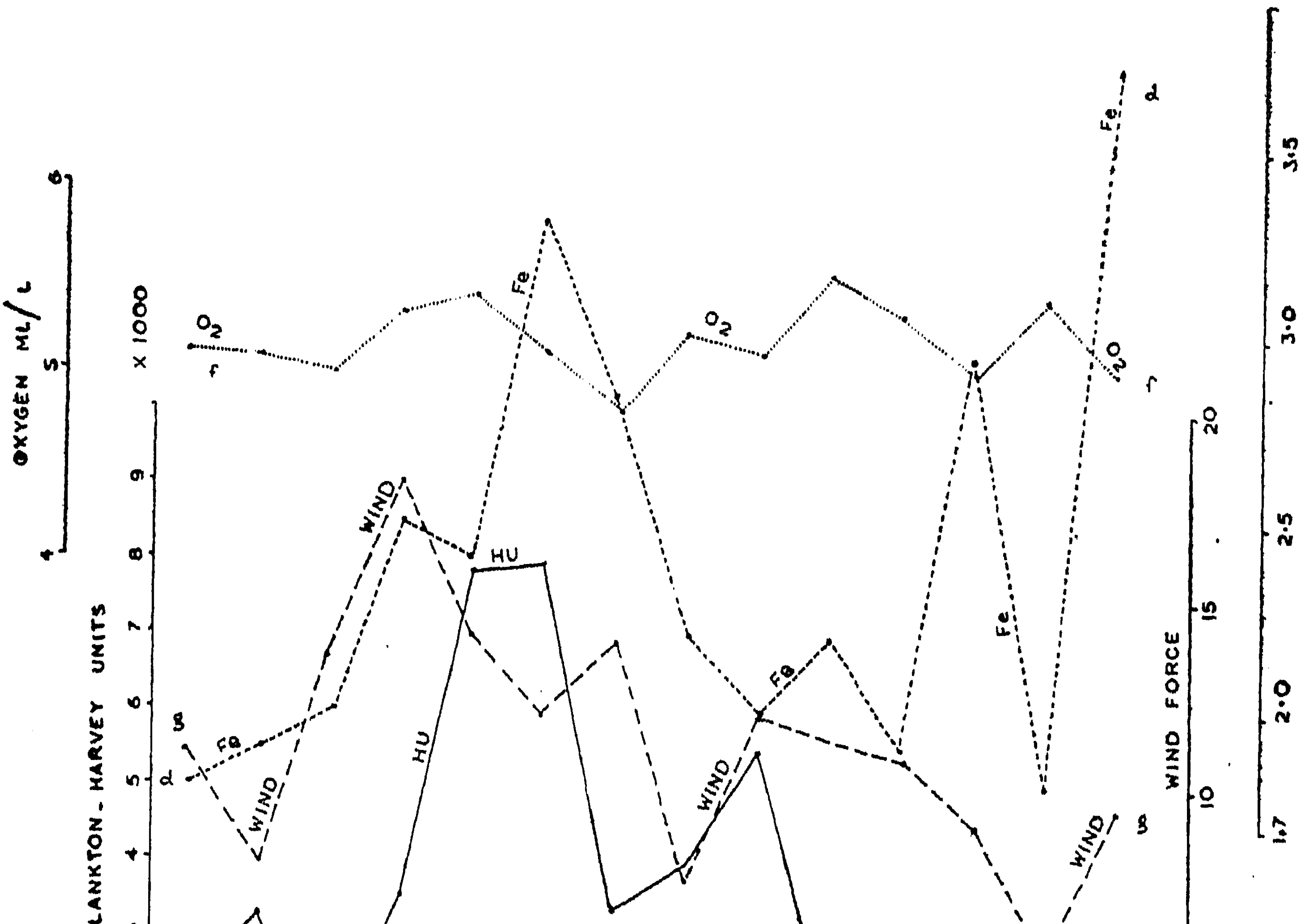


(*b*) *Nitrite-Nitrogen.*—Owing to limitations of equipment, nitra
could not be determined. Figure 3 *b* shows the fluctuation of nitri
It may be seen that nitrite content shows sharp oscillations; the
between 0·177–0·387 μg. at./L. It would appear that it bears a
relationship to dead elements present in the water (*e.g.*, Nove
than conforming to a pattern of a nutrient. It is known from cul
ments (*vide* Harvey, 1955, pp. 75–77) that during breakdown
ammonium is liberated which is immediately acted upon by bacte
ing it into nitrite and then nitrate step by step. It is very prob
similar cycle obtains here. The concentration of nitrite here is
order compared with the west coast of India (Subrahmanyan, *l.*

(*c*) *Silicate-Silicon.*—The silicate content (Fig. 3 *c*) of the w
from 9·1–19·89 μg. at./L. Silicate value increases from Marc
and reaches a maximum in June; with the peak production
in July and August, when it is consumed, the values fall. A seco
in November coincides with the minor bloom of plankton. This i
of local rains and considerable influx of land drainage and low salini
factors conducive to higher silicate content. In addition, it may
that plankton often contains a large quantity of dead elements,
silicified forms of which might also contribute to replenishment
dissolution. In some respects the relationship seen here is the
that on the west coast—a direct relationship during south-wes
months owing to continuous replenishment (here an inverse
during this period) and an inverse relationship during October to
more or less a direct relationship).

(*d*) *Iron.*—Though the importance of iron as a nutrient for phy
growth has been recognized since long, there have been only few
for iron-content of water or its seasonal fluctuation, and the latt
short periods only (Braarud and Klem, 1931; Cooper, 1935,
Thompson and Bremner, 1935 *a*, *b*; Lewis and Goldberg, 1954;
1957; *refer* also Sverdrup *et al.*, 1942; Harvey, 1955; and Raym
The values recorded by these workers are, except Armstrong, ver

and the influx of river water into the Bay in the latter half of the period a
result of the south-west monsoon precipitation at the sources of the ri
systems. With the waning of the wind force, considerable quantities a
utilized and an inverse relationship may be seen with the November bloo
and later on a sample to sample basis, a feature prevalent before the wi
velocity increases tending to mix up the water layers. The sharp and freque
fluctuation might also reflect quick regeneration through the faecal pell
of the herbivores feeding on the floral elements. A certain quantity m
sink with the dead plankton, for, iron tends to get adsorbed on the surfa
of the plankton (Harvey, 1955; Raymont, 1963). The lowest value record
in March 1962 coincides with the minimum for wind force which lends supp
for the view stated above. With the plankton bloom waning later a
increase of wind force, iron content rises again.



It may be mentioned here that Cooper (1935) has recorded in the quantity of iron succeeding the spring out burst of dia English Channel. It has been found that analysis of plankton y iron than phosphorus (Cooper, *l.c.*; Harvey, 1955, p. 144; Arms which indicates a higher consumption of iron by the plankters. the variation in the concentration of the four mineral nutrients it may be seen that the variation in concentration of iron is of a than that of phosphorus as also of the rest. It is, therefore, p iron apparently is not a limiting factor; however, assimilable act as a limiting factor if at all, besides some of the other subst discussed in an earlier account by one of us (Subrahmanyan, 19

TABLE I

Variations in the concentration of nutrients in terms of μg. a

Phosphorus	0·246– 0·697
Nitrite	0·177– 0·387
Silicon	9·100–19·890
Iron	1·750– 3·720

(*e*) *Salinity*.—The seasonal fluctuation of salinity is shown During the period under discussion, March 1961 to April 1962 value of 33·4‰ was recorded in May; thereafter, a gradual fa September after which a sudden fall to 20·8‰ occurs in Novem tend to rise again steeply, for, as it happens on the west coast, the of offshore water following the influx of river discharge. With of the north-east monsoon and rise of temperature and diminu force, salinity rises again and tends to attain an equilibrium, this in the south-west monsoon months by the entrance of oceanic diatoms, the main constituent of the flora. The secondary maximum November is very low in intensity, the salinity values being at their lowes the bloom constituents are more estuarine in character and the marine el ments are found mostly dead. This is reflected in the very high displaceme volume and lower pigment values for phytoplankton (compare A and B Fig. 1).

(*f*) *Oxygen.*—The oxygen content is of a higher order than that record for the same region by Jayaraman (1951) and Ramamurthy (1953). C the west coast, the maximum value recorded goes beyond that recorded he now. The oxygen content fluctuates between 4·79–5·55 ml./L. (Fig. 4 *f*).

It is generally expected that solubilities of gases like oxygen and nitrog which do not react chemically with the water or its dissolved salts decrea with increasing temperature and that agitation of water tends to increa the solubility of the gases in it; and, during phytoplankton bloom, oxyg concentration is expected to increase and even exceed saturation poi (Sverdrup *et al.*, 1942).

An examination of the curves for oxygen, salinity, wind force and phyt plankton in Figs. 3 *e* and 4 *f*, *g*, shows: that in March and April, both wi force and salinity tend to lower oxygen content; temperature also is again an increase of oxygen, these months being the warmer months. The slig increase in phytoplankters is unable to raise the oxygen concentration. Fro May, increase in the wind force, fall in salinity and increase of phytoplankte are favourable for an increase of oxygen content and the value goes up; b even with the phytoplankton bloom at its height and lower salinity value wind also being not unfavourable, oxygen values continue to drop to t minimum in September. There is again a tendency for oxygen concentrati to increase with increase of phytoplankters; but, with wind force, salini (considerable fall) and secondary bloom of phytoplankters, all bei favourable, oxygen content decreases in November. It rises again aft plankton bloom wanes in December, from when on a parallel relationsh in conformity with the data collected over a period of 10 years b for the west coast, part of which covering the years 1949–54 ha lished (Subrahmanyan, 1959). The apparent contradictions n been explained there in detail to which reference is invited. say here that, if the physiology of the floral elements, the bulk c the diatoms, as well as certain other facts are taken into con oxygen given off during photosynthesis not only being consume ration but for assimilation of silica of which the cell walls of composed, respiratory requirements of increasing number of coinciding with phytoplankton increase, increasing bacterial accompanying phytoplankton development, demand of oxygen b decomposing organic matter, a part of the nutrient cycle—th of oxygen fluctuation may be understood. Further, it is also p iron which remains in the ferrous state only for a short time m taking up available oxygen and get converted into the ferric s already pointed out, considerable quantities of iron are involved of life in the sea.

4. *Wind Force*

The effect of wind has been referred to frequently above. in its velocity is shown in Fig. 4 *g*. The continental shelf off th being steeper than on the west coast, its effect is not so well en on the west coast though, in fact, its force is of a lesser order the west coast (Subrahmanyan, 1959) an increase in the wind force followed by a bloom of phytoplankton which is very characteris led to the inference that some factor, probably iron, locked up i layers or bottom mud is released favouring growth of the floral e

5. *Physiological State of the Floral Elements*

Finally, it may be mentioned, that the physiological state c elements is an important factor, probably the deciding factor, to the bloom the intensity of which will depend on the rate of th

The peak production occurs during the south-west monson month cycle of physical and chemical factors and their relationship to pl production are discussed. Data for iron content, estimated for t time for our waters, are presented. It is concluded that, in Indian it is the physiological state of the floral elements that finally deci magnitude of plankton production on which ultimately depends fish p tion.

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