column in July, with a maximum of 1800 cells l⁻¹ in the lowermost layer. The density of this diatom in the upper two layers was considerably lower than in the four following layers (Fig. 9). Furthermore, Chaetoceros tended to increase regularly from top to bottom during July, a feature not paralleled by any other alga recorded in this study. The phytoplankton collected from the second and fourth layers in this month was entirely composed of this diatom, whereas Chaetoceros constituted only 60.0, 62.2, 66.7 and 81.8% of the total phytoplankton in the surface, third, fifth and sixth layers respectively (Fig. 7). A drastic decline in density and frequency occurred in August-September, when numbers fluctuated between 200-400 cells l⁻¹ but not necessarily from every layer.

An appreciable rise in the total crop of Chaetoceros was again noted at all layers in October, giving the highest count of 800 cells l⁻¹ at 5 m depth. This diatom was present in higher percentage composition at the successive lower four depths, notably 15 and 25 m where it formed pure stands. The total crop of Chaetoceros from all levels was greater in the following month, reaching a total of 2600 compared to 2400 cells in October, when it was seen at every layer. Number as well as frequency declined remarkably in December, when the total crop declined to 1200 cells. The decline continued in January 1975 to give a total crop of 1000 cells, 200 cells l⁻¹ from each layer except the fourth one. This may indicate an incidence of mixing between the upper three layers and the two lowermost. It is obvious from the above account, as well as from Fig. 9, that Chaetoceros favoured both winter and summer although its preponderance during the latter season was significantly greater. In both seasons the lower water strata harboured greater populations than the surface water.
The other major diatom genus, *Rhizosolenia*, was seen at the beginning of this study in the surface water only, giving a count of 800 cells l\(^{-1}\). It suddenly established its maximum (1000 cells l\(^{-1}\)) in this very layer during the following colder month (February, 1974), as well as exhibiting a density of 200 cells l\(^{-1}\) at the third depth only. This surface-occurrence diminished to 600 and 200 cells l\(^{-1}\) in March and April respectively, while no specimen was recorded from any other layer. In May, a summer month, a density of 200 cells l\(^{-1}\) was also recorded simultaneous with a similar density in the third layer. Conditions seem to have changed in the following summer months (June-August) since the alga was not recorded from the surface samples, but was then encountered in the samples of the third-sixth layer with a density of 200 to 400 cells l\(^{-1}\), not necessarily at each of these layers (Fig. 9). One may infer that with a rise in temperature, *Rhizosolenia* tends to sink down. The diatom was seen to move upward to the second layer in September, a colder month, where 200 cells l\(^{-1}\) were counted simultaneous with a similar density in the fourth and fifth layers. Although the second colder period commenced in October, the surface layer continued to be devoid of this diatom while 600 cells l\(^{-1}\) were counted from the third layer. With the progress of the colder period, a rise in the population density as well as a reoccupation of the surface water were noted in November. Throughout the remaining colder months (December-January), *Rhizosolenia* persisted in the surface water although its presence in other layers was also noticed (Fig. 9).

In contrast to *Chaetoceros*, it appears that the rate of multiplication of *Rhizosolenia* is greater in the colder than in the warmer months, and that it favours the surface water.

iii) Cyanophyceae

This algal group constituted a very minor proportion of the phytoplankton. It was represented by one genus, *Trichodesmium*, which was observed
Fig. 9  Vertical distribution of the major phytoplankton (diatoms)

Chaetoceros

Rhizosolenia

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only during the periods February-April and September-November 1974. However it was absent in the majority of the samples collected during these two periods, and was relatively more common during the former than the latter period. Its maximum density of 1400 cells l\(^{-1}\) was recorded in March and October 1974, at a depth of 15 m and in the surface water layer respectively.

**DISCUSSION**

The best development of *Peridinium* and *Ceratium* (January-March) coincided with a temperature range of 22.1° - 26.1 °C. The maximum attained by the former (2400 cells l\(^{-1}\)) and by the latter (2000 cells l\(^{-1}\)) was associated with a temperature of 23.0° C and 22.1° C respectively, although they occurred at different depths but in the same month, February 1974. The maximal development of these two algae may be attributed to this relatively lower temperature, although similar lower temperatures reoccurred without notable increase in numbers. During April 1974 - January 1975 when the temperature was higher (24.4-32.8° C), both taxa exhibited comparatively much lower cell counts, except in June when *Peridinium* gave high simultaneous counts of 1000 and 1400 cells l\(^{-1}\) in the upper two layers coincident with a temperature of 29.0° C. This may suggest that *Peridinium* tolerates higher temperatures than *Ceratium*. Temperature may not be the only factor which governs the fluctuations in their numbers although Graham (1941) and Wood (1964) detected an apparent correlation between temperature and the vertical distribution of these organisms.

The pH and salinity at the different layers oscillated in a very narrow range (8.4-8.6 and 39.93-40.04% respectively). The difference between any pair of layers was always found to be insignificant. Therefore, the authors are hesitant to correlate either of them with the vertical fluctuation in numbers of these flagellates. In harmony with the present study Harvey (1934) and Hasle (1969), working on temperate or tropical
waters, observed no influence of pH on the vertical distribution of these two algae. On the other hand, their vertical oscillations in relation to the oxygen content were not all similar although their highest population coincided with relatively high oxygen (5.17-5.49 ml l⁻¹). Nevertheless, Peridinium was reported to an appreciably high count during summer (June 1974) when oxygen concentration was relatively low (4.38 ml l⁻¹). Hasle (1959), Sukhanova (1969) and Kimor (1973) found both dinoflagellates to concentrate in tropical waters in zones of maximum oxygen content.

The increase in numbers of Peridinium and Ceratium which occurred during the first colder period was associated with a relatively lower phosphate range of 0.32-0.60 µg-at l⁻¹. The maximum ever reached by each of them was in this period, i.e. February, and it coincided with 0.60 and 0.52 µg-at l⁻¹ for the former and the latter alga respectively. During periods of lower and higher phosphate values, counts of either alga decreased noticeably and both tended to be sparse in the majority of water layers, with the exception of Peridinium which showed high cell concentration (in June) at a phosphate level of 0.30-0.40 µg-at l⁻¹. This may suggest that Peridinium tolerates a wider phosphate range than does Ceratium although both were found to multiply at moderate phosphate content. Contrary to this, Graham (1942), Hasle (1969) and Kimor (1973), working on tropical or temperate dinoflagellates, found a direct correlation between these organisms and phosphate concentration. Similarly, their maximal counts coincided with a moderate silicate value of 27.0 for Peridinium and 36.0 µg-at l⁻¹ for Ceratium. In the present study there was no discrete relationship between the vertical distribution of these algae and silicate content. Similarly, Lebour (1925), Graham & Bronikovsky (1944) and Vinogradov & Voronina (1962), working on temperate or tropical dinoflagellates, found no definite correlation between these organisms and silicate content. Conversely, El Sayed & Jitts (1973) found an inverse relationship between these
algae and silicate.

Of the diatoms, *Chaetoceros* was noted to abound in July when temperature fluctuated at the six depths between 28.1 and 31.0° C. Its maximum count (1800 cells l\(^{-1}\)) in this month was recorded from the lowermost layer and coincided with a temperature of 28.1° C. The alga remained at low concentration or became sparse during the following warmer months. Its frequency and numbers tended to increase during the succeeding colder period so as to attain a submaximum of 1200 cells l\(^{-1}\) in the fifth layer in November coinciding with a temperature of 24.6° C. Although a similar temperature was recorded from the fourth layer in this very month the number of *Chaetoceros* was 600 l\(^{-1}\). Similarly, *Rhizosolenia* was noted to increase during both seasons. Its maximum count was attained in February 1974 at a temperature of 24.0° C. The minimal count for both diatoms was in August and was associated with the highest temperature in all water strata. However Lebour (1930), Riley (1957) and Wimpenny (1966), studying temperate or tropical waters, found no direct relationship between these diatom genera and temperature.

Since salinity and pH varied throughout this study over only a very narrow range, it cannot be claimed that their variations are responsible for fluctuations in numbers of these two diatoms. However, *Chaetoceros* attained its best development at a pH range of 8.5-8.6 and a salinity range of 40.02-40.04% while *Rhizosolenia* reached its maximum at a more or less similarly high pH but at a relatively lower salinity, i.e. 39.95%. Pronounced development of *Chaetoceros* in July was associated with a generally low oxygen content (4.66-4.60 ml l\(^{-1}\) ). Although a more or less similar oxygen range was reported in the other summer months without a similar preponderance in *Chaetoceros* population. *Rhizosolenia*, on the other hand, attained its optimum growth (1000 cells l\(^{-1}\) ) synchronous with an oxygen concentration of 5.25 ml l\(^{-1}\). This oxygen level reoccurred on several other occasions but without any
concomitant marked increase in the numbers of Rhizosolenia. It can be assumed, therefore, that no relationship can be discerned between oxygen and the variations of these diatoms. In contrast, Lebour (1930), Cupp (1943) and Braarud (1962) found direct correlation between these organisms and oxygen content in temperate and tropical waters.

The greatest counts reached by Chaetoceros (1000-1800) cells l⁻¹ were associated with phosphate values of 0.25-0.60 μg-at l⁻¹. At maximal phosphate range (0.65-1.5 μg-at l⁻¹), the population density of this diatom was only 200 cells l⁻¹ (minimum). This may indicate that very high phosphate is inimical to the development of Chaetoceros and moderate levels may favour its multiplication. Similarly, Rhizosolenia built its maximum at moderate phosphate values of 0.45 and 0.40 μg-at l⁻¹. These values, recurred several times but were concomitant with very sparse or minimal cell counts. Despite this, no further correlation between the two is warranted from the present data. However, it may be broadly stated that Chaetoceros tolerates a wider phosphate range than Rhizosolenia. Several authors working on temperate or tropical seas and oceans detected either a direct relationship (Cupp, 1943; Goldberg et al. 1951) or a linear correlation (Kimor, 1973) between phosphate and the vertical distribution of these two diatoms.

With regard to silicate, Chaetoceros tended to be more frequent when silica declined to relatively low values. Its maximum density (1800 cells l⁻¹) was associated with a narrow lower silicate range (18.0-29.0 μg-at l⁻¹) while Rhizosolenia density was reduced to 50%. However, at the lowest values (14.0-20.0 μg-at l⁻¹) either diatom tended to increase both in numbers and frequency, especially Chaetoceros which rose to a peak of 1200 cells in the fifth layer. In the last two months of this investigation when silica climbed again to the highest range (54.0-75.0 μg-at l⁻¹), Chaetoceros numbers decreased significantly but those of Rhizosolenia remained constant. Therefore, it is tempting from the above description to
suggest that *Chaetoceros* favours an appreciably lower silicate content than *Rhizosolenia*. Atkins (1926), Humphrey (1963) and Davis (1976), studying some temperate or tropical areas, found direct as well as indirect correlation between the vertical distribution of these diatoms and silicate.

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