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PHYTOPLANKTON OF THE WATERS OF THE WEST COAST OF INDIA AND ITS BEARING ON FISHERIES*

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Investigations on marine phytoplankton, the prime synthesizers of all organic matter in the sea has assumed great importance since over half a century. As these microscopic organisms fluctuate in response to climatic changes, water movements, nutrient content of the water and so on, they form an important and convenient link in the assessment of the stock of fish. Very little work has been done on these aspects in any of the warmer regions of the world and particularly in India. Since 1949, the author has been engaged on a continuous and intense study of phytoplankton in particular and plankton in general on the west coast of India from several aspects including its relationship to fisheries. It may be mentioned here that nearly 80 per cent of marine fish landed in India is on the west coast.

ENVIRONMENT

The west coast of India is a tropical area under the influence of the south west and north east monsoons. The sea bottom from about a mile from the shore out to 30 fathoms consists of soft grey mud with dead shells. A very interesting feature about this coast, particularly the southern half, is the occurrence of mud banks, composed of fine mud in an unconsolidated state, which shift from place to place under certain influences not clearly understood. Ocean currents are more or less constant with a clockwise coastal circulation during the SW monsoon period and an anticlockwise circulation during the period of NE monsoon. Under the influence of the former especially, there is considerable upwelling of the waters of the Arabian Sea.

PHYTOPLANKTON BLOOM

The maximum production of phytoplankton, as seen from the magnitude of the standing crop estimated by enumeration and pigment content, takes place during the SW monsoon months of May to September, after which the crop declines. Later on, during the NE monsoon also, there is a secondary peak of production which, however, is of a much lesser intensity compared with the first. The first bloom is comparable to the spring bloom and the latter to the autumnal bloom occurring in the temperate waters. The magnitude of the first bloom is of a very high order, surpassing those known from some of the most fertile regions of the world (*refer*, Subrahmanyan, 1958*a*, 1959*a*).

The Diatoms form the main bulk of the phytoplankters, the Dinophyceae, the Cyanophyceae, the Silicoflagellatae and certain other groups occur in lesser quantities in the order mentioned. Numerically the zooplankters attain an abundance comparable with the Dinophyceae.

As the Diatoms form the bulk of the flora, they determine the trend of fluctuation of the total phytoplankton crop; the peaks of production

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being mainly due to their multiplication. The Dinophyceae also show two peaks of abundance, one during the SW monsoon as a result of the bloom of the unarmoured forms, particularly of *Noctiluca miliaris*; the armoured forms develop towards the end of the SW monsoon or later, when one or two peaks may be observed. The Cyanophyceae, composed chiefly of *Trichodesmium* spp. occur in abundance during the warmer months of the NE monsoon.

The nature of the flora changes frequently and each species appears to have its own peak periods of occurrence and associations. The species which contribute to the bulk during periods of maxima also vary from year to year though a few appear to be common. The occurrence of several species seems to be cyclical and governed by their periodicity of principal reproductive season; and, this is also reflected in the total standing crop, the magnitude of whose fluctuation from year to year is cyclical, somewhat identical peaks occurring at intervals of years. It has generally been the practice with plankton workers to assess the constituents of the flora to the genera level only. The investigations show that this would be highly misleading where the object of the studies is to make full use of this important link in the food chain as biological indicators (Subrahmanyan and Sarma, in press.)

A total of over 350 species of phytoplankters have been recorded from the region, the majority of them belonging to the Diatomaceae and Dinophyceae (Subrahmanyan, 1958*b*). Of these only 34 species of the former and 15 of the latter occur in appreciable quantities (Subrahmanyan, M. S.; Subrahmanyan and Sharma, *l.c.*).

Sometimes, the sea water becomes discoloured owing to the intense bloom of a single species, the colour of the water depending on the pigmentation of the organisms concerned. Thus, *Noctiluca miliaris*, on certain occasions, particularly during the SW monsoon months blooms so intensely as to colour the water pink; another *Noctiluca* which is green on account of the presence inside of it of an euglenoid flagellate, *Protoeuglena noctilucae* Subrahmanyan (1954*a*) discolours the water green; *Hornellia marina* Subrahmanyan (1954*b*) a Chloromonadine flagellate occurs infrequently in such large quantities discolouring the water green; and, an yellow discolouration was noticed during the bloom of a Chrysophycean palmelloid alga on a few occasions. Similar records are known from other parts of the world also (*see* Subrahmanyan, 1959*a*). Such outbursts of some of these organisms are known to bring about certain changes in the hydrological conditions and also at times mortality of marine organisms including fish, owing to the effect of toxins, presumably liberated into the water (*see* Subrahmanyan, 1959*a*). It may be mentioned here that generally, during occurrences of blooms of these organisms, the normal constituents of the plankton are found to be absent or scarce. It is believed that such " exclusion " is caused by the excretions of the organisms which excercises a deleterious effect on the environment (*see* Subrahmanyan, 1959*a*). It is possible that such effects may also ultimately determine the seasonal fluctuation and succession of the species in the water mass and their associations.

The phytoplankters contribute to the bulk of the plankton during the SW monsoon season and the zoophlankters to the bulk during the NE monsoon season.

In terms of dry weight, the fluctuation of the quantity of plankton is not so marked by such large oscillations as seen in the estimations of the number or pigment units. A striking point noticed was that of a close approximation between the ratio of the standing crop during the SW monsoon season with the bulk consisting of phytoplankters, and the NE monsoon season with the bulk of zooplankters. The ratio was found to be 1:0·9.

PHYTO- AND ZOO-PLANKTON RELATIONSHIP

The relationship of phyto- and zoo-plankton has been described by many workers (*see* Subrahmanyan, 1959*a*). It is held that (1) that the standing crop of phytoplankton is controlled by the grazing effect on it of the zooplankton leading to an inverse relationship; (2) that the grazing effect will not have much effect if the factors conducive to the production of phytoplankters remained favourable in which case as a result of the slower development of zooplankters a direct relationship will occur and on account of water movements and so on, the maxima for the two may occur in different places leading to an apparent inverse relationship; (3) that a non-predatory relationship is possible in which instance an intense development of phytoplankton will so condition the medium so as to exclude or repel the animal population; (4) that a swarm of Copepods, for example, is the result of weeks of growth and is dependent on the quantity of phytoplankton available throughout the growth period, the relationship being a direct one; and (5) that the inverse relationship met with may be accounted for by a combination of migration and grazing and that the exclusion mechanism as a means of producing the inverse relationship is operative only in instances of monospecific blooms of toxic flagellates such as *Gonyaulax*.

On the west coast of India, we have a predominantly phytoplankton period succeeded by a predominantly zooplankton period; however, zooplankters tend to increase gradually with the increase of phytoplankters from the beginning of the SW monsoon season and the former attain their peak at the same time as or immediately following the peak of phytoplankton production. The trend shows a direct relationship. But, sometimes, when setoid species like those of *Chaetoceros*, *Bacteriastrum* and *Rhizosolenia* occur, a fall in the number of zooplankters is noticed, perhaps due to the deleterious influence or unpleasantness induced by the processes on the species concerned, leading to a patchy distribution of the two plankton elements as the zooplankters appear to avoid such species of phytoplankters. In contrast, when non-setoid forms occur, such as, *Coscinodiscus*, *Thalassiosira* and so on, an increase of zooplankters is noticed. Plenty of developmental stages observed during this season would indicate abundance of food available for growth.

During the NE monsoon season, both direct and inverse relationships were observed; however, the bulk of the plankton was of animal matter, which had obviously increased at the expense of phytoplankton.

In this connection, the dry weight relationship mentioned earlier between the plankton content of the two main seasons may be recalled here; this shows a close approximation indicating a balance in the biological content of the water as between plant and animal life. Too much emphasis appears to have been placed on the *number* factor in judging relationships of phyto- and zooplankters in the past. It would appear that the bulk also needs to be considered.

The relationship of phyto- and zooplankton as it obtains here, therefore, may be considered to be *direct* in terms of number and bulk during the SW monsoon months and *direct* in terms of number and *inverse* in terms of bulk during most of the following season.

FACTORS INFLUENCING PRODUCTION OF PHYTOPLANKTON

Some of the factors involved in the production of phytoplankters may be briefly examined next. Data collected on temperature of sea water, salinity, phosphate- nitrate- silicate- and oxygen-content during a period of over six years on the west coast and the results obtained by workers in other parts of the world on some of these aspects have made it possible here to obtain an integrated picture of the conditions in the sea for the first time. Details relating to all these aspects have been discussed by Subrahmanyan (1959*b*).

Though the optimum temperature for growth varies for different species, for most forms the value lies between 24 and 25° C. It is interesting to note that the maximum production of phytoplankton on the west coast of India also takes place when the temperature of the water is between 24 and 25° C. Pulses of production also occur when temperature is between 27 and 28° C but this is due to local flowering of some species owing to the stimulus provided by some nutrient factor. Very high temperature such as 30° C and above affects the production adversely.

In the present region light does not appear to be a limiting factor at any time as it happens in the temperate and polar waters.

Salinity is important for maintaining the proper osmotic relationship of an organism. Species of phytoplankton have their own range of toleration to salinity, however, not much is known about the osmotic relationship of diatoms, the main constituent of the flora; it has been shown that these changes are not governed by laws of osmotic equilibrium as far as some species are concerned. It would appear that the diatom cell has a peculiar reaction to changes in the salinity depending on its own physiological state.

One reaction of the diatoms to changes in the salinity has great significance to the life-history of the organism, viz., a fall in the salinity under certain conditions. Prof. M. O. P. Iyengar and the writer working at Madras found that in cultures when the diatom cells no longer showed signs of vegetative multiplication, a transfer of the cells to a slightly diluted medium, not exceeding 20 per cent, 10 per cent being ideal, with distilled water, brought about sexual reproduction and auxospore-formation after which the new cells resulting from the above process showed rapid vegetative multiplication. In nature, similar dilution occurs during heavy downpours as in the tropical areas, or melting of snow and ice in the colder regions, discharge of flood waters and so on. On the west coast of India, during the south west monsoon months, there is a fall in the salinity by 3 to 5 parts per mille i.e. 10-12 per cent, from the highest values obtaining earlier, which provides the stimulus for many species for rapid reproduction as mentioned earlier, and other factors also being favourable, which also are, an outburst of plankton production occurs. The blooms during the NE monsoon months also at times were found to be due to such a fall in the salinity, caused by the influx of Bay of Bengal water into the Arabian Sea; the species concerned, however, are different.

The reaction of different species to variations in salinity may also determine the floral composition of the plankton which is never alike for any length of time and the species responsible for the peak blooms also change from season to season and year to year.

The values for phosphates, nitrates and silicates recorded here, when compared with data from other areas of the world, are fairly high indicating a high fertility rate for the waters. They also show a seasonal fluctuation. The peak in their concentration is attained during the SW monsoon months at the same time as or immediately following that of the phytoplankton, unlike in the temperate waters where an inverse relationship is the rule, the phytoplankton bloom succeeding a depletion of the nutrients. It has been found that the ratio of P:N:Si in the waters of the west coast is the same as that recorded in the temperate waters, viz. 1:15:20 which indicates an equilibrium in the concentration of these elements in the waters. It may be mentioned here that the bottom sediment on the west coast plays a very important role in the nutrient cycle acting as a regeneration centre where organic detritus is broken down to inorganic salts useful for plant growth and the mud appears to be a storehouse for such salts as found in one instance, that of phosphates, where there was an inverse relationship between the phosphate content of the water and bottom mud (Seshappa, 1953).

Brief mention may also be made of the oxygen content of the water whose behaviour is unique on the west coast. Unlike data from other areas, it shows here a positive correlation with temperature and salinity from September to November and a very diverse behaviour during May to September which is at first puzzling, particularly because, values for oxygen appear rather low during a period when, normally, one would expect very high values owing to the very rich floral elements present. Data obtained from phytoplankton studies here and investigation of workers on the silica metabolism throw light on the curious behaviour of the oxygen content of the waters on the west coast; the fact that oxygen is consumed during silica assimilation also besides in respiration, and that an increase of Diatom elements brings about an increase of bacterial elements, consumption of oxygen thus going up further, would explain the apparently lower values during the SW monsoon season. In other words, it may be stated that had the organisms concerned been not Diatoms, but say, green algae, the increase of oxygen during such an intense bloom would be far more than that recorded, and instances are not wanting where such an increase had led to injurious effect on other organisms of the plankton and higher forms of life like fishes. The presence in fair quantities of Diatoms appears to act as a check on supersaturation of the waters.

It is found that phytoplankton blooms succeed periods of high winds which is very pronounced during the SW monsoon. The main bloom of phytoplankters in the Indian waters, could also be correlated with the monsoons directly or indirectly (Subrahmanyan, 1959c). The effect of wind is not direct; wind brings about a vertical mixing up of the different layers of water and on the West coast this effect reaches the bottom sediment also and thus supply of nutrients to the upper layers is replenished during periods of high winds. That such a mixing takes place may be seen from the presence of bottom living forms in the upper layers during such periods of high winds. However, in the present area, even during calm weather, most of the common nutrients (such as phosphates, nitrates, silicates) are never deficient for growth of phytoplankton. It would appear that some other factor, organic substances such as vitamin B_{12}, or organic matter containing elements like iron, cobalt, molybdenum, manganese and so on may be acting as a limiting factor; evidence for such a view are available from culture experiments on different elements of plankton flora. Lastly, it may be mentioned that the senescense of the floral elements themselves, following a period of intense growth under very favourable conditions, might be acting as the limiting factor. The grazing effect by the developing zooplankters and of plankton feeding fishes may contribute to a delpetion of the floral elements, apparently giving the impression of a scarcity of phytoplankters in the water during certain periods.

PHYTOPLANKTON AND FISHERIES

The object of fishery research is mainly to devise a method for the forecasting and controlling of future fish supplies; in other words, a rational exploitation of the available resources. As the phytoplankters, the main synthesizers of all food in the sea, fluctuate in relation to definite environmental factors as pointed out already, they form an important and convenient basis for assessing the stock of edible fish.

The importance of a rich phytoplankton crop for survival of larval fish and the role of increased plankton production by fertilizers in fish production and so on have been stressed by several authors (*see* Subrahmanyan, 1959*a*).

Studies on the west coast of India showed that there are some intimate relationships between plankton production and fish production.

The Indian oil sardine, *Sardinella longiceps* Cuv. et. Val. and the Indian mackerel, *Rastrelliger kanagurtha* Cuv. constitute the bulk of the fishery resources of the west coast of India. The total landings of fish for an extent of the west coast of India, about 150 miles of the coast line, north of Ponnani to Mangalore, shows that the quantity landed goes up following the bloom of phytoplankton or even, sometimes, during the height of the bloom itself as in June 1953. A closer examination of a specific fishery and the food of the fishes concerned brings out the relationship better.

In the course of his investigations on the oil sardine, Nair (1952) established that the fish is a plankton feeder, feeds mainly on phytoplankters and amongst them shows a preference to the diatom, *Fragilaria oceanica* Cleve. According to the present writer (MS) this diatom has a life-span of three to four years, during which the quantity of this diatom in the water fluctuates, there being outstanding peaks of production at intervals of three to four years or so, brought about by its mode of reproduction. A study of the fluctuation in the quantity of this diatom, and the oil sardine revealed that the bloom of this diatom could be used as an indicator of the abundance of the oil sardine. The oil sardine fishery commences with the commencement of the *Fragilaria*-bloom in the waters. It would appear that as more and more sardines invade the waters (as evidenced by increased landings) this plankter is grazed down and becomes apparently almost depleted. The grazing activity would seem to start at the periphery of the phytoplankton during the early part of the season and then gradually extend inward until finally the bloom is grazed down. After the main peak of the fishery has been attained and passed following the principal bloom of *Fragilaria*, it has been found, on some occasions, that if an increase of this diatom occurred in the waters, sardine also became available and once again the diatom is grazed down along with some other elements (Nair and Subrahmanyan, 1955). Even if the diatom is apparently absent in the usual plankton catches, gut contents of oil sardine have shown *Fragilaria* in not inconsiderable numbers; the scarcity of this diatom in the water may, perhaps, be due to the grazing effect on it by the fish. Therefore, it seems probable, that the relationship seen between this phytoplankter and the oil sardine is somewhat similar to that seen in the instance of phyto- zoo-plankton relationship, viz., a direct one to start with which becomes inverse owing to the grazing rate exceeding the multiplication rate of the diatom.

Obviously, this relationship leads to the querry whether one could expect increased oil sardine catches based on the intensity of the monsoon bloom of *Fragilaria*; in other words, could the intensity of the bloom of *Fragilaria* be an indication of the prospects of the oil sardine fishery of the following season? Records show (Subrahmanyan, MS) that between the years 1949 and 1954, *Fragilaria* had two outstanding peaks of production, in 1949 and 1953, and during the succeeding fishing seasons, heavy landings of oil sardine took place, those of 1953-54 season being a record for several years; the *Fragilaria* bloom in the year concerned, 1953, also being an outstanding one (*see* Subrahmanyan, 1959*a*). The next outstanding bloom of *Fragilaria* occurred in 1957 and this obviously had led to heavy landings of oil sardine in the 1957-58 season.

The relationship mentioned above between the oil sardine and *Fragilaria* naturally raises the question of the feeding habits of this fish. The observations (Nair, 1952) show that it is not exclusively dependent on *Fragilaria* but appears to show a preference for this diatom. Many other species of diatoms as well as other organisms have been reported from its gut. In the absence of a detailed quantitative study of the gut contents in comparison with the plankton content of the water, it is not possible to come to any conclusion on this subject. The presence in the gut of this fish of several other species from the plankton and the absence of *Fragilaria* on some occasions (when this diatom is not present in the water obviously) would indicate that the large quantities of *Fragilaria* when present are due to a particulate form of intake of food.

Studies on the feeding habits of the mackerel made so far show that the mackerel is an omnivore. Zooplankters, particularly, Copepods, constitute the bulk of its food. The accounts available would indicate that the mackerel is not quite discriminate in its mode of intake of food except to the extent of avoiding certain forms.

The fluctuation of the mackerel fishery shows that there is a direct relationship to start with between the phyto- and zoo-plankters on the one hand, and mackerel on the other which, later on, as the consumption of plankton increases, becomes inverse. It is seen that mackerel catches are of a high order when the standing crop of zoo-plankters is low; in other words, the latter never reaches a peak when mackerel is present.

As there is not much information available about the food of several of the other species of commercial importance, no further attempt at correlation is possible. However, it may be mentioned that large quantities of prawn are landed on the west coast which also form an important fishery during the months following the main outburst of phytoplankton. The food of prawn also consists of considerable quantities of phytoplankton elements, particularly *Fragilaria*, *Coscinodiscus*, *Pleurosigma*, *Navicula*, *Cyclotella*, etc. (Menon, 1951) on some of which the prawns feed when these sink to the bottom. The food of *Kowala coval* (Cuv.), the white sardine also consists of plenty of phytoplankton elements (Nair, 1951). It may be noted that the peak of the fishing season succeeds the main production of phytoplankton on this coast.

Similar observations on pelagic fisheries and plankton made elsewhere also lend support to those recorded here. As observed by Sette (1950) in the case of the Atlantic mackerel, *Scomber scombrus*, and Cushing (1955) in the case of the herring of the temperate waters, fish catches on the west coast of India also coincide with plankton concentration suggesting that fish tend to tarry in waters rich in plankton.

It is interesting to note that both oil sardine and mackerel appear earlier in the south and slowly extend northwards and their disappearance follows a reverse pattern (Panikkar, 1952). The SW monsoon breaks earlier in the south and the bloom of phytoplankton and zooplankton also begins earlier there and spreads north and the current circulation at this time is from north to south; it is possible that the migration of the fishes at this time is due to the increasing bloom of plankton, its food, earlier in the south and its spreading north and also their tendency to swim against the flow of current. In the latter period, the current becomes reversed and flows from south to north and the bloom of plankton during this period depends more or less on the influx of the Bay of Bengal water into the Arabian Sea and, probably, the intensity of the bloom is greater as one proceeds south; and, the movement of the fishes and their disappearance starting from the north to the south would appear to be correlated with the bloom of plankton and their tendency to swim against the current. Thus, the sequence of appearance and disappearance of these fishes may be related to water movements and plankton bloom; and it is possible, as observed by Sette (1950) that these fishes reach various areas along their route of migration at times when on the average, feeding conditions are favourable.

Another interesting point that emerged from the studies on the west coast may also be mentioned here. It is well known that phytoplankton production depends also on phosphate content of the water. Though such sharp inverse ratio between the two is not obvious here owing to several factors (*see* Subrahmanyan, 1959*b*) it was, nevertheless, seen that higher values portend higher production of phytoplankton and the latter rich fish landings; thus, a direct relationship between the integral mean phosphate content of the years and also the phosphate maximum during the years on the one hand, and that of fish landed on the other exists. The time lag is practically nothing here, perhaps, because of the tropical environment, unlike in the temperate regions where there is a time lag of a few years which helps prediction of the herring fishery very much in advance. Further, it was also seen that a parallel relationship exists between the integral mean phosphate content and the total amount of rainfall; which again, indicates a relationship between fish landings and total precipitation, similar to the relationship found by Kalle (1949) between herring catches and precipitation in the northern waters.

MAGNITUDE OF PRODUCTION

Before concluding this review, it may be worthwhile to examine the magnitude of production of phytoplankton and its relationship to commercial fish landings. This should throw some light on the intensity of exploitation going on at present and also show whether there is scope for increased exploitation or whether we are already depleting the stock. Such aspects have been discussed for the temperate waters by some authors.

It has generally been found that the magnitude of phytoplankton production is several times that of commercial landings of fish; e.g., Riley (1950) states that this could be even 1000 times the commercial catch of fish. Several methods have been adopted to arrive at the estimation of production of phytoplankton and organic matter in the hydrosphere. These have been reviewed by the writer elsewhere (Subrahmanyan, 1959*a*). A general review of the rates of production in various areas and the magnitude of the standing crop indicates that the west coast of India is a very highly fertile region and the writer has estimated the production there on an average to be at least six times that found in the English Channel, based on the magnitude of the standing crop, which of course, is a reflection of the magnitude of production.

For the English Channel, Cooper (1933) has calculated the intensity of phytoplankton production; the minimum production calculated by him for an area of 82,100 sq. kilometers and of 72 metres depth on an average, was found to be 115 million metric tons annually. The total landings of commercial fish in the English Channel ports in U.K. and French coast amount to 71,000 metric tons a year; the fraction of fish landed to total production of phytoplankton worked out to 0·0006 or 0·06 per cent only in an area very intensely exploited by modern methods.

In a similar manner the phytoplankton production calculated for the west coast for an area of 155,400 sq. kilometres of 100 metres depth, a potential fishing area, works out to 1,813 million metric tons; and according to the rate found by the *John Murray Expedition* for the Arabian Sea, at a period after the main peak of production had passed the production amounts to 820 million metric tons.

The quantity of commercial fish landed on the west coast, according to the Central Marine Fisheries Research Station Annual Report for 1955, totals 455,900 i.e. about 80 per cent of the total marine fish landed in India.

Therefore, the ratio of phytoplankton production to fish landed works out to 1:0·00002515 and 1: 0·00005558; or in other terms, 0·0025 per cent and 0·0056 per cent respectively, according to the rates worked out by the writer and John Murray Expedition. In both instances, the quantity of fish landed is of a lower magnitude when compared with an intensely exploited area like the Channel, where it may be seen, the proportion is ten times or more. It may, therefore, be suggested that on the west coast of India, a more intensive exploitation of the sea over wider area within the continental shelf alone is likely to increase the harvest from the sea considerably. As Steemann Nielsen (1952) has observed, investigation of the production of matter can give valuable information on local possibilities of large scale fishing.

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Discussion

M. R. Suxena: It is usually observed that in summer when the temperature goes high and there is more organic matter in the medium, blue-green algae give the maxima but afterwards the diatoms shoot up giving another maxima. Can this be correlated with the assumption that the diatoms require more oxygen and in such cases the blue-greens are oxygen consumers and afterwards act as oxygen donors ?

R. Subrahmanyan: But, on the West Coast, I may tell you that we did not have the blue-green algae constituting a considerable part of the flora. During the warm months we do come across *Trichodesmium erythracium* and others but they are not in such large quantities. During the main bloom, about 99·9 per cent of the total number of phytoplankton is constituted by diatoms to start with and gradually it comes down to 98 per cent and only two per cent being contributed by the Dinophyceae and others and the blue-green algae do not come into the picture. We do come across blue-greens like *Anabaena* and others. They are only few.

N. K. Pannikkar: I think this is a very broad question and it is rather presumptuous for me to comment except that I might draw a parallel from the marine conditions. In fact, there is a very large body of evidence to show that when there are intense concentrations of certain organisms they do produce external metabolites. Dr. C. E. Lucas has reviewed this with reference to a series of planktonic combinations or organisms in biological reviews, and it is now accepted as a general concept and the factors are extremely complex and it is to be admitted that toxic substances are secreted by many of these forms. In fact this has been known in Herring fisheries for ages that when there are certain combinations there is a certain amount of avoidance on the part of Herrings under such areas.

M. O. P. Iyengar: Apart from various aspects of applications of phytoplankton growth, there is one thing which has been felt in the country, namely the occurrence of water blooms mainly by *Microcystis aeruginosa*. In temple tanks this is really a pest. The exact reasons for the continued occurrence of *Microcystis* as a permanent bloom in all the temple tanks has not yet been tackled properly nor the reasons for their permanent occurrence are known. Various explanations have been given for the occurrence of phytoplanktons either temporarily or permanently in all waters. This question is not only felt in our country but the question of permanent water blooms by the blue-green alga *Microcystis* is felt even in other countries. Various explanations have been attempted for the occurrence of water blooms of a temporary or a permanent nature. In fact the temporary water blooms may be in a way compared to the domination of one species and later replaced by another alga and so on. You find various stages of dominations throughout the year. The explanation for this is given as the presence of certain salts in the water or the complete consumption of a particular salt in the water and these are cited as limiting factors. But one single point does not seem to have been very seriously considered. Certain algae are known to secrete into the medium some substances which might check other algae, either temporarily or permanently. These substances which are secreted by the algae into the surrounding medium may be of the nature of antibiotic substance which probably keeps out all the other algae in the water, especially in the case of permanent water blooms as that of *Microcystis*. An anti-body from *Chlorella* has been found out, this is called chlorellin. It was accepted in the beginning but now the efficacy of chlorellin as an antibiotic substance has not been so very much accepted. They think its effect may be little but not to that extent of penicillin. Whether there is a production of an antibiotic substance or not by the permanent water bloom alga should be tested. Of all the methods it seems to me worth taking a large quantity of the tank water with *Microcystis* and then filtering it completely by bacterial filters and taking only the water and then try to grow various algae to see whether this water is inimical to other algae. If this is so then we can understand the reason for the dominance of *Microcystis* or other water bloom algae. The next question is whether the *Microcystis* simply chokes out the other algae physically by its very heavy growth. These two points, I deem, are worthwhile investigating. I just suggest this to the water biologists who deal with phytoplankton, apart from their uses in fisheries and so many other aspects, from purely an aesthetic stand point.

R. P. Verma: The data regarding the correlation between *Fragillaria oceanica* and Oil Sardine, appears to be inadequate for arriving at any positive conclusion.

R. Subrahmanyan: It was occurring along with *Fragellaria* bloom. Actually in 1951-52 there was a bloom of *Fragillaria* which was followed by the oil sardine. Actually in 1949 the data on landings was not available for correlation and for the 1951 revival, data are based on Mr. Nair's observations, but during the 1953-54 and 1957-58 season my own observations have confirmed what I have just given out to you.