SOME ASPECTS OF PHYTOPLANKTON BLOOMS IN RELATION TO PELAGIC FISHES

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By

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C E R T I F I C A T E

This is to certify that this thesis is a record of research work carried out by Smt. S. Ravi Kala under my supervision and guidance for the Ph.D. Degree of the University of Cochin and no part of it has previously formed the basis for the award of any degree in any other University.

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D E C L A R A T I O N

I hereby declare that the thesis "some aspects of phytoplankton blooms in relation to pelagic fishes" is a record of research work done by me and this has not previously formed the basis for the award of any degree, diploma or other similar title.

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I. INTRODUCTION

'Plankton' means that which is drifted, the word having been coined by Victor Hensen in 1887. It includes large section of plants and animals which drifts at the mercy of the water movements. The great majority of planktonic organisms are unicellular plants and related forms i.e. the phytoplankton. Phytoplankton are universally distributed in all adequately lighted bodies of water whether fresh or salt. The wide distribution of phytoplankters and their subsequent abundance accounts for the great importance of the phytoplankton as a major basic food material in the food cycle of aquatic situations. They are of very great importance in all sizeable bodies of water.

The phytoplankton is by no means uniformly distributed from place to place even within short distances. Certain areas may have a profuse phytoplankton production while other areas near by may have a scanty population. Such local variations may have a number of different causes which may be physical, chemical or biological. An originally uniformly distributed population of phytoplankters may lose its uniformity due to the grazing activities of zooplankters or other animal life. The phytoplankton proper is confined to the euphotic and disphotic zones. Phytoplankton production is greatest in the well lighted upper layers of the water in such a manner that their bulk is to be found below the most productive layers. The continued presence of phytoplankton in the surface layers is explained on the assumption that they constantly are restocked by the turbulence of the water. The total production of organic matter of phytoplankton in a year considerably exceeds that of the animals. These finely scattered and microscopic plants can really form a vegetation which can support all the teeming animal life of the sea. The most prominent members and commonly observed types of phytoplankton in both temperate and tropical seas are the diatoms, dinoflagellates and marine blue green algae. Marine planktonic blue green algae seems to be restricted to a relatively few species but they may be very important in the population where they occur.

Phytoplankton is of great economic importance not only in the biology of the pelagial but also of the benthal, particularly in areas distant from the coasts because it provides the principal source of primary nutrition. Copepods and other zooplankton groups such as euphausids, shelled pteropods and appendicularians as well as the larval forms of many different classes and orders of both bottom living and pelagic marine animals appear to be herbivorous on the phytoplankton. The presence of considerable populations of both pelagic and benthic animals in deep sea and oceanic areas gives ample evidence of offshore production, as these form the only oceanic plants together with a few others drifting from coastal waters, that constitute the actual source of food for the offshore animals. It seems that the coastal waters, on the whole are fifty times more productive than open ocean waters and in general, the abundant coastal fauna, both benthic and pelagic substantiate this. Sufficient appreciation of any problem in fishery research is only to be attained through awareness of the biological wealth, reached in the first instance by the study of the plankton. Food cycles in the sea are essentially based upon the type and amount of plant nutrients and light, both of which are required for assimilation and primary production. Some of the released substances have biotic effects eg. vitamins and certain assimilates, while others produce antibiotics and also certain toxins during mass outbursts of phytoplankton organisms. The biological history of a water may therefore be important to its fauna and flora. The food supply to certain fishes itself is fundamentally phytoplankton and hence this is of basic importance to the fisheries.

Since phytoplankton organisms are among the most rapidly growing elements of the ocean population, some of them divide several times a day under favourable condition. These populations are very responsive to changes in the environment. Better growing conditions cause a dramatic outburst of phytoplankton growth. Sometimes they become abundant enough to impart colour to the areas they occupy. This phenomenon of explosive growth is also termed 'red tide'. During a bloom, the quantity of phytoplankton may double daily producing great clouds of billions of cells, until impoverishment of plant nutrients and increased grazing by more slowly growing zooplankton slow down the rate of increase, bringing it into equilibrium or causing a sharp decline in total phytoplankton of the area and replacing it largely with zooplankton.

The blooms can be of practical importance in human affairs. Their effect may be beneficial in forming the basis for a rich food supply for animals higher in the food chain or directly for the fishes themselves or it may be catastrophic due to secondary conditions or the production of toxic metabolites leading to mass mortality of marine organisms with cumulative noxious side effects. Fisheries may be profoundly affected by the blooms, particularly in certain areas where they recur with some frequency. Extensive phytoplankton blooms are not always deleterious in their effects. The increased quantity of phytoplankters present may act as basic food for an increased quantity of animal life and ultimately may result in an increase of fish population or of the population of commercially important invertebrates, thus benefitting man.

II. REVIEW OF THE PREVIOUS WORKS

1. Occurrence of blooms along various coasts

There are large number of sighting and characterization of phytoplankton blooms from various regions. Characterization of the bloom off Nova Scotia in the Bedford basin revealed that *Ceratium longiceps* made upto 70% of the total particle volume (Taguchi 1981). *Ceratium tripos* dominated the spring bloom in the New York bight (Conway and Whiteledge 1979). Malone *et al.* (1976) studied an extensive bloom of *Ceratium tripos* in Middle Atlantic Bight. Swift (1982) noted that the bioluminescent waters of northern Europe were associated with a late summer bloom of *Ceratium* spp. LeFevre and Grall (1970) noted red tide due to *Noctiluca scintillans* off the western coast of Brittany. Fung and Trott (1973) noted *N. scintillans* red tide from Hong Kong and Pingree *et al.* (1977) observed *N. scintillans* red tide at the western entrance to the English Channel. In Argentine continental shelf *N. scintillans* blooms appeared in spring/summer 1980 and 1981 (Carreto *et al.*, 1981). Thomas (1979) analysed a bloom of *Noctiluca miliaris* which occurred at Lysekil, Sweden in July 1978. Red water phenomenon due to *N. miliaris* was reported from the Gulf of Trieste in June 1977 (Cassinari *et al.*, 1979). Parker *et al.* (1981) reported *Noctiluca* sp. bloom from Ireland.

Iliehev *et al.* (1983) observed a red tide of *Noctiluca miliaris* in Peter the Great Bay. A brown discolouration of the water occurred off west port (Karamea bight) in March 1976 and March 1978. This nontoxic bloom was cuased by *Prorocentrum micans* (Cassie 1981). *Mesodinium rubrum* and *Prorocentrum gracile* were found responsible for red tide in the Algarve coast, Portugal in July 1980 (Sampayo and Cabeccadas 1981). Tyler and Seliger (1981) made observation of blooms over the 10 years period from 1969 through 1978 and observed four major blooms of *Prorocentrum mariae lebouriae* in northern Chesapeake Bay (1970,1971,1973 and 1975). Grall (1976) and Pingree *et al.* (1977) reported from the English Channel during 1976 a bloom of *Gyrodinium aureolum*. In the Ireland a dense bloom of *G. aureolum* occurred during 1978 (Roden *et al.*,1980). An investigation of the southern Ireland coastal and offshore concentration of *G. aureolum* was initiated in August 1979 to provide a background against which to assess the effects of *G. aureolum* and other red tide organisms (Jenkinson and Connors 1980). Populations of *Gyrodinium uncatenum* form massive summer red tides in the Chesapeake Bay (Tyler *et al.*, 1982). Lembeye *et al.* (1975) observed the blooming of *Gonyaulax catenella* in the straits of Magellan. Cho (1978) reported a bloom of *Gonyaulax* spp. in Jinhae Bay. Blooms of *Gonyaulax monilata* were also observed off coastal waters of

Florida, Alabama, Mississippi and Louisiana (Perry *et al.*, 1979). De Freitas and Lunetta (1982) reported the occurrence of red tide in the littoral of Rio de Janiero, Brazil during a scientific excursion to Trindade Island. Dinoflagellates of the genus *Gonyaulax* spp. were abundant in the plankton samples. Kamykowski (1980) reported a sub thermocline, sub halocline bloom of two dinoflagellates *Gonyaulax polygramma* and *Gymnodinium simplex* off Panama city, Florida. Kofoid and Swezy (1921) have reported the occurrence of the phenomenon of yellow water near La Jolla, California. The causative organism of bloom was *Gymnodinium flavum*. However, *G. flavum* did not bloom in this area in the subsequent years till 1980 and during the latter half of July 1980, a bloom of *G. flavum* caused water discolouration in La Jolla Bay, California (Cullen *et al.*, 1982) and Huntley (1982) observed suppression of zooplankton grazing due to this bloom.

Holmes *et al.* (1967) noted in La Jolla Bay during 1964 to 1966 five red water dinoflagellate blooms. The organisms were *Gymnodinium* spp. and *Cochlodinium* spp., *Prorocentrum micans* and *Noctiluca* sp., *Polykrikos* sp., *Gonyaulax polyedra* and *Ceratium* spp. Murphy *et al.* (1975) observed a red tide of *Gymnodinium breve* in east coast of Florida during November 1972. The predominant organisms in a red water dinoflagellate bloom in Baja, California were

Gonyaulax polyedra, *Ceratium furca* and *Gymnodinium* spp. (Blasco 1977). Fudge (1977) made analysis of red tides off Malta during 1972 to 1975 and concluded that *Prorocentrum triestinum*, *Prorocentrum gibbosum*, *Peridinium formosum*, *Gonyaulax polyedra*, *Cochlodinium* sp. and *Ptychodiscus* sp. were observed. A red tide of *Peridinium* spp. occurred in Seto Inland Sea (Endo and Nagata 1984). In the north sea spring bloom of diatoms were succeeded by a considerable growth of dinoflagellates and *Dinophysis norvegica* was the most abundant (Dodge 1977). Large scale red tides of *Chattonella* sp. took place at the northern part of Kagoshima Bay in 1977 and at Suho Nada (Yoshida and Numata 1982).

Pratt (1965) noted spring diatom flowering in Narragansett Bay and the population was dominated by *Skeletonema costatum*. Bodungen *et al.* (1981) studied a *S. costatum* bloom in Baltic sea. Blooms of *S. costatum* was observed in south Norway (Kattner *et al.*, 1982). A *S. costatum* bloom appeared in the Bay of Santander (Reguera 1983). Dahril and Shoji (1981) observed dense discolouration in the Nagasaki Bay, Japan was caused by pre-dominance of *Skeletonema* sp. and *Olithodiscus* sp. Barlow (1982) analysed a bloom in the southern Benguela current dominated by *Skeletonema costatum* and *Chaetoceros compressus*. Sorokin and Konovalova (1973) studied under the lee of a bay in the Japan sea, the winter bloom of diatom consisted mainly of *Thalassiosira* spp. and *Chaetoceros* spp., Conover (1975) noted bloom of *Thalassiosira nordenskioldii* in Bedford basin, Nova Scotia, Canada. Fudge (1977) noted a monospecies bloom of *Chaetoceros* spp. in the Malta coast. Cho (1977) reported the occurrence of red water due to *Chaetoceros* spp. near Chungmu in the summer of 1974. A study of surf diatom populations at thirteen beaches along the Oregon and Washington during 1977 to 1978 showed the blooms of *Chaetoceros armatum* and *Asterionella socialis* between point greenville, Washington and Cape Blanco, Oregon (Garver and Lewin 1981). An exceptionally large and early bloom between Edinburg and Rotterdam was observed. During this period unusually high numbers of diatoms occurred in the central area of the southern bight. The diverse and abundant flora included both pelagic and benthic forms with a strong representation of species of *Biddulphia* spp. and was associated with high counts of Copepods and planktonic larvae (Reid *et al.*, 1982). Brongersma Sanders (1957) and Wood (1965) concluded that *Trichodesmium* spp. bloom is wide spread in tropical seas. The name red sea is due to the colour imparted by the *Trichodesmium* spp. bloom. Off the Tonga Island, Bowman and Lancaster (1965) observed *Trichodesmium erythraeum* bloom. Interestingly, only few harpacticoid and cyclopoid copepods dominated the zooplankton in bloom area while calanoid copepods and chaetognaths were dominant in water adjacent but outside of the bloom. Qasim (1979) observed *Trichodesmium* spp. bloom in the strait of Malaca. Eleuterius *et al.* (1981) made an analysis of the bloom of *Trichodesmium erythraeum* in coastal waters of Mississippi and adjacent waters of Gulf of Mexico and Tsunogoi *et al.* (1983) reported it from the Japan.

2. *Factors controlling the formation of blooms*

The primary productivity in land and sea is of great importance in the maintenance of the various life forms. The productivity is preserved because of the interaction of a number of environmental factors both physical, chemical and biological. The sequence of events linking the primary production and the organisms of importance to man are of special interest. Changes in production of species which are favourable to man can produce impact on human population.

The marine algae play a very important role in the cycles of matter on earth, since their total mass and consequently their gross photosynthetic activity is at least equal to that of all land plants combined and is probably mainly greater. The great bulk of the marine algae are unicellular floating (planktonic) organisms predominantly diatoms, dinoflagellates and blue-green algae. The enormous total volume of earth's oceans makes them the most abundant of all photosynthetic organisms (Stanier et al., 1974). Biological and chemical factors are most critical in determining the environmental responses of the causative organism while physical factors are the most important concentrating agents (Collier 1958).

The events relating to the formation of the red tide or phytoplankton blooms can essentially be classified into four categories. Initially the factors required for the initiation of the blooms or red water phenomenon should be present. Subsequently the maintenance of the organisms for a period of time, their transport and dissipation leads to the completion of blooming phenomenon (Steidinger 1975). Prakash (1975b) also observed that the development of the bloom comprised of two stages i.e. (1) Initiation of a bloom (2) Subsequent development and continuation of this bloom to the extend that it becomes visible. The number of organisms occurring per ml. of sea water during blooming vary significantly. The peak in growth is reached principally in two ways: (1) Accelerated biological growth which is dependent on specific environmental factors such as temperature, light and certain nutrients. (2) Physical mechanisms that concentrate the organisms. The mechanisms are triggered by metereological events such as wind and rain. Most situations are a combination of the two. The formation of the patches depends upon two factors i.e. when cell masses to be carried shorewards by breaking waves and turbulent mixing in the upper layers are in equilibrium patches forms (Mc Lachlan and Lewin 1981). Defant (1961) noted that convective circulation helps in concentrating the filaments into dense patch. Red tide occurring areas are located between the extremes of active upwelling and passive concentrating mechanism (Dale and Yentsch 1978, Blasco 1977). In the temperate oceans, the blooms of algae occur seasonally and the plankton ecosystem is regulated by their occurrence (Dale and Yentsch 1978).

Red tide caused by monospecific blooms follow a sequence of development governed by specific biologic and hydrographic events. Life cycles coupled with physical conditions are primary contribution to the initiation of blooms (Steidinger and Haddad 1981). Several physical and biological factors are implicated in the formation of the phytoplankton blooms. The dinoflagellate Prorocentrum mariae lebouriae has specific physiological characteristic that allow it to participate in a sub surface transport from the southern Chesapeake Bay to the northern bay where it upwells and forms red tides. A particular growth rate dependence both on temperature and salinity restricts its year round distribution to the high salinity southern bay. The winter spring phasing of the stream flows in both northern and southern bays may be used to predict the degree *Prorocentrum mariae-lebouriae* blooming in the northern bay in summer (Tyler and Seliger 1981). The *Prorocentrum mariae-lebouriae* accumulates in a sub surface concentration maximum below the pycnocline. Rapidly decreasing depths of the upper bay causes the Pycnocline to rise, mixing the previously light limited *Prorocentrum mariae-lebouriae* and its nutrient rich bottom waters to the surface where rapid growth ensures. Once the dinoflagellate is in surface waters positive phototaxis combined with both wind and tide driven surface convergence, produce dense surface patches or red tides (Tyler and Seliger 1978). Changes in iron concentrations have been suggested as a major cause for initiation of *Gonyaulax tamarensis* bloom (Dale and Yentsch 1978). Kim and Martin (1974) reported that maximum iron index preceded the bloom in Charlotte harbour, Florida. A positive correlation between high concentration of iron in run off water with the occurrence of major *Gymnodinium breve* bloom in coastal Florida waters was observed (Ingle and Martin 1971). Glover (1978) observed during the 1975 bloom on south Booth Bay harbour that soluble iron concentration in the first 20 m of water were three times greater while particulate iron concentration only increased transiently before the fall bloom. Nutrient enrichment experiment and chlorophyll a cytochrome f' ratios indicated that low iron concentrations limited phytoplankton populations. In the succeeding year off the coast of Monhegan Island, increased iron concentration from land run off preceded a dinoflagellate bloom (Glover 1978). Land run off of humic substances, chelate iron and other trace elements are suggested as responsible elements in the induction of the bloom. Growth promoting substances have been detected in stimulating red tide outbreaks. However, other factors such as temperature, salinity, basic nutrients, water stability, clarity and movement at optimum levels are necessary for the initiation of the bloom (Sasner 1973). Yentsch (1977) noted association of dinoflagellate blooms with river discharge high in organic matter and the absence of such blooms in areas suspected of receiving substantial trace metal input from land. Gunter (1979) and Gunter and Lyles (1979) recorded blooms following heavy rains. Besides land drainage which contains biologically active substance pollution also contributes to the formation of a bloom (Prakash 1975a). Chew (1955) reported from his hydrological studies off the west coast of Florida that progressive concentration of buoyant material initially distributed over a large area may produce a bloom. The red tide of Gymnodinium breve which frequently occurs off the west coast of Florida is attributed to this phenomenon of convergence of the organisms in a limited place from a large area. LeFevre and Grall (1970) suggested a similar mechanism of convergense for the formation of red tides of *Noctiluca scintillans*. An intense multiplication takes place in water masses situated along the convergence, these appearing as microplaces where optimal condition especially of nutrients are available. The convergence reduce diffusibility and have contributed to the maintenance of dense population. An alternative mechanism supposes that the convergence acts as a mechanical factor of concentrating the organism remaining passively or actively at the surface without following the downwelling water. The association of high nutrients (as nitrates) with diatoms and low with dinoflagellates appears in these data as a clear trend from diatom dominated to mixed to dinoflagellate dominated population as nutrient declines. Wave induced circular patterns may allow a certain degree of retention of nutrients in the surf thus allowing for bloom development and persistence (Mc Lachlan 1980). Tsunogai and Watanabe (1983) noted that diatoms are predominant when all the physical and chemical conditions are adequate for plankton growth and flagellates replace diatoms after dissolved silicate in the sea water has been almost completely consumed by diatoms. However, the dark uptake of nitrate apparently equally characteristic of starved diatoms and dinofalgellates and migratory capability of dinoflagellates explains persistence of dinoflagellate blooms after their development (Mac Isaac 1978). Studies on Gymnodinium breve blooms occurring along the west coast of Florida during 1976,1977 and 1978 showed that the dissolved oxygen levels were never below 83% saturation although the numbers of Gymnodinium breve organisms were above the ichthyotoxic threshold level (Heyl et al., 1978). Simultaneous presence of light and inorganic nitrogen especially nitrate appeared necessary to generate uptake rates sufficiently high to allow growth of these dinoflagellates to bloom proportions (Mac Isaac 1978). During some diatom and dinoflagellate blooms in Cochin backwater a negative correlation between cell concentration and salinity was observed. Also variation of phytoplankton was directly related to that of phosphate and nitrate (Devassy and Bhattathiri 1974). Vitamin B_{12} has been reported to be a critical factor in the initiation of several red tides. Off the coast of Banyuls the diatoms were observed in water rich in nutrients and Vitamin B_{12}. This enrichment was due to an exceptional upwelling of deep water to the thermocline level. Concommittantly with the occurrence of diatom blooms, high concentrations of Vitamin B_{12} were observed (Fiala 1982).

Concentration of diatoms in surface waters off Monhegan Island, Maine, USA bloomed in phase with a lunar cycle during the summer of 1978 (Balch 1981). Highest abundance of diatoms were associated with the major spring tide of each month. Dinoflagellates were more abundant during the intervening minor spring and neap tides. Vertical mixing during the spring to neap tidal cycle appeared to have influenced the vertical transport of chlorophyll upwards thus causing an increase in the surface cell counts of organisms. Succession within the major phytoplankton communities were also related to the lunar tidal cycle. The community assemblages were most pronounced immediately before or after the spring tide diatom bloom, but not during the transition from one community to another occurred during the more stable neap or minor spring tides. Epidemic blooms of toxic dinoflagellates occurred during major spring tides. A similar but combined effect of wind and tide is suggested as a mechanism of transport of Prorocentrum mariae lebouriae from the Chesapeake Bay to the bloom area (Tyler and Seliger 1978). Tidal effect on the occurrence of red tide was found to be great in Shonai estuary (Watanabe et al., 1980).

Of the several biological factors influencing the maintenance of the bloom, the most important is the limitation of the phytoplankton in the red tide by zooplankton. This is essentially brought about by grazing by the zooplankton on the species in the bloom. Grazing by microzooplankton has been implicated in the decline of some blooms (Blasco 1977) but most evidence has not confirmed that grazing losses became important before the loss of motility and sinking of dinoflagellate cells (Holmes *et al.*, 1967; Seliger *et al.*, 1971). However, Wyatt and Horwood (1973) feel that reduction of grazing mortality due to behavioural responses of macrozooplankton grazers could contribute to dinoflagellate blooms in coastal waters was showed in a mathematical model.

3. Effects of blooms

The relationship between blooms of plankton and shellfish was first noted by Lamouroux. In 1888, Lindner also suggested a food chain relationship for shellfish poisoning (Russel 1965). Sommer and Meyer (1937) investigated the paralytic shellfish poisoning (PSP) and demonstrated a direct relationship between the number of *Gonyaulax catenella* and the degree of toxicity in the mussel. Man has been poisoned by algal toxins through the food chain by eating shellfish at certain times and occasionally in local areas shellfish become extremely poisonous. Shellfish acquire this poison from certain dinoflagellates that grow in the water where the shellfish feed. *G. catenella* occurs along the pacific coast and has definitely been established as the cause of paralytic poison in California mussels and probably in Alaska butter clams (Schantz 1970). Needler (1949) and Prakash (1963) reported the red tide of *Gonyaulax tamarensis* and this was responsible for the poisoning of clams, scallops and mussels along the north Atlantic coast of America and throughout north sea. Wood (1968) and Robinson (1968) independently reported outbreak of shellfish poisoning caused by Gonyaulax tamarensis bloom along the north east coast of England. The toxic bloom of G. tamarensis and Prorocentrum micans was reported from the east coast (Adams et al., 1968). Gonyaulax acatenella is known to cause poisoning of clams in British Columbia (Prakash and Taylor 1966). Schradie and Bliss (1962) have reported that Gonyaulax polyedra which blooms along the coast of southern California and produces a poison that has some properties similar to that produced by G. catenella. However, the organism produces the poison only under a set of conditions. Gonyaulax monilata is known to bloom in the gulf of Mexico and produces a poison that is toxic to fish but not to chicken (Connell and Cross 1950, Gates and Wilson 1960 Ray and Aldrich 1967, Quayle 1969) and Prakash et al. (1971) noted annual blooms of toxic dinoflagellates which occurred along the Canadian, Atlantic and Pacific coasts contaminating shellfish with toxins and leading to paralytic shellfish poisoning. Studies by Burke et al. (1960) showed that the poison produced by Gonyaulax catenella is a product of the dinoflagellate and not a symbiotic effect of the bacteria that are normally associated with these dinoflagellates in their natural state. A bloom of Gonyaulax tamarensis off the north Umbrian coast of Britain appeared in May but the toxins accumulated by molluscs did not reach to safe levels until August (News and Views 1968). Guzman and Campodonico (1978) reported Gonyaulax catenella red tide in Chile which caused death of people. Shellfish toxin associated with PSP have been demonstrated annually since May 1968 when 78 people were affected after consuming mussels from the north east coast of England which was attributed to the bloom of Gonyaulax tamarensis (Ayres and Cullum 1978).

Maretic et al. (1978) reported that red tide provoked by dinoflagellates has appeared from 1968 in Pula. The species Prorocentrum micans, Gonyaulax polvedra and sometimes Noctiluca miliaris were detected; deaths of fishes and mussels were observed but it may be due to anoxia because toxicity of these dinoflagellates could not be proved. Blooming causing mass mortalities of both fish and invertebrates may be due to either anoxia or by the formation of toxic materials (Rounsefell 1975). Oshima et al. (1982) identified Protogonyaulax tamarensis as the causative organism of PSP in Japan. White (1977) reported herring kill in the Bay of Fundy due to toxic Gonyaulax excavata bloom. This was the first report implicating G. excavata in a fish kill in north America. In the south western Bay of Fundy White (1980) reported kills of adult herring which was linked to bloom of *Gonyaulax excavata*. Zooplankton have also showed the presence of the toxin during bloom (White 1979). Hayashi *et al.* (1982) reported the results of toxins profile of dinoflagellates and zooplankton collected during a *Gonyaulax excavata* bloom in the Bay of Fundy in 1980. In Winter, acquisition of *Gonyaulax excavata* toxins by offshore and inshore molluscan shellfish is caused by ingestion of cysts. Offshore seed bed serves as the prime source of motile cells which initiate the annual *Gonyaulax excavata* bloom in the Bay of Fundy. Molluscan shellfish can acquire *Gonyaulax* spp. toxin during non-bloom seasons through these cysts (White and Lewis 1982). Sweeney (1976) noted *Gonyaulax excavata* toxin causes death and irritation. Carreto *et al.* (1981) noted red tides associated with *G. excavata* and associated with toxicity in Argentine sea. Balch (1981) noted in the Maine coast epidemic blooms of *Gonyaulax excavata*. Hurst and Yentsch (1981) reported considerable variability of intoxification in *Mytilus edulis* leading to PSP along the Gulf of Maine coast. Mulligan (1973) studied during September 1972 a bloom of *Gonyaulax tamarensis* and the clams were found to be contaminated in Maine coast. White (1983) studied PSP during *Gonyaulax* spp. bloom and reported that during *Gonyaulax* spp. blooms zooplankton, molluscan shellfish and perhaps other components of the foodweb can become sufficiently toxic to present a danger to fish at several trophic levels.

Catastrophic mortality of fish and bottom living animals occurred off the west coast of Florida of 1946-'47 which was due to *Gymnodinium breve* bloom. The mortality of fish is not only the harmful effect of the *Peridinium* spp. as people living near the shore at the periods of these outbreaks suffered respiratory irritation (Wimpenny 1966). Martin and Martin (1976) noted that due to this bloom there arises fish kills and attendant clean-up problems. This red tide is also associated with health hazards such as *neurotoxic shellfish poisoning*, respiratory irritation and contact irritation. Red oysters followed by the bloom of *Gymnodinium splendens* and *Amphidinium fusiforme* in Delaware Bay was noticed (Pomeroy *et al.*, 1956).

A *Gymnodinium* spp. bloom from the South Africa was reported by Brown *et al.* (1979). Cho (1981) reported that the *Gymnodinium* spp. red tide occurred three times during 1981 in Jinhae Bay and it caused damage to the fisheries. Yasumoto *et al.* (1980) identified *Dinophysis fortii* as the causative organism of diarrhetic shellfish poisoning. Shimizu (1983) studied *Neurotoxic Shellfish Poisoning* (NSP) which has been known for many years in the Gulf of Mexico and causative organism *Gymnodinium breve* also causes massive fish kills during the bloom. But it is reported that *Gambierdiscus toxicus* a newly identified dinoflagellate is the causative organism. Red water phenomenon due to

Gyrodinium aureolum was observed by Leahy (1980) and calculated the percentage of living and dead animals. Falkowski et al. (1980) reported 60 million dollars loss of shellfish resulted from anoxia along New Jersey due to Ceratium tripos bloom. Malone (1978) also reported due to Ceratium tripos bloom in New York bight between January to July 1976 and extensive fish kill. Kat (1983) noted a diarrhetic shellfish poisoning in Netherlands due to Dinophysis acuminata. Gunter and Lyles (1979) reported oyster kill associated with Chaetoceros spp. bloom in the Gulf beach. Only an isolated report exists relating tamandare fever with Trichodesmium spp. bloom in recife north eastern Brazil (Sato et al., 1966). Fish mortality has also been reported to be due to the choking of gills by Trichodesmium spp. filaments (Desikachary 1959).

Maclean (1977) noted PSP due to Pyrodinium bahamense bloom in Papua New Guinea waters. Recently FNI (1983) reported poisoned seafood from Philippines, Thailand and Hong Kong. Later Rudi Hermes (1983) and Fishing Chimes (1984c) reported it as due to Pyrodinium bahamense red tide, and noted that the consumption of plankton feeding fishes like Rastrelliger spp., Sardinella spp. and mullet also in some cases caused the characteristic symptoms of PSP. Scheuer (1978) studied that the serious harm to human of dinoflagellates is poisoning through the food chain by consumption of toxic shellfish since in appearance both toxic and non-toxic shellfish appears alike.

4. Occurrence of blooms along Indian Coasts

There are sporadic reports in literature on the occurrence of red tides in the Indian Coastal waters. The Indian coastal belt bordering Bay of Bengal and Arabian sea roughly spans an area of 6000 km. The sighting of phytoplankton blooms were reported as far back as the year 1930.

On the eastern coastal line, observations on occurrence of blooms were made from the Bay of Bengal. Chidambaram and Unny (1944) observed swarming of *Trichodesmium erythraeum* in Pamban area. Chacko and Mahadevan (1956) noted the occurrence of red water due to *Trichodesmium erythraeum* and James (1972) studied *Trichodesmium thiebautii* bloom in the Gulf of Mannar. Ramamurthy (1970,1973 and 1975) made the analysis of the *Trichodesmium erythraeum* bloom in Porto Novo waters. Daniel *et al*. (1978) observed yellow water due to *Trichodesmium erythraeum* off Madras. Raghu Prasad (1953, 1956 and 1958) observed red water phenomenon caused by *Noctiluca miliaris* in the Palk Bay and off Mandapam. However, lethal actions of swarms of dinoflagellates on planktons were also observed (Raghu Prasad and Jayaraman 1954). Interestingly, varying intensities of populations of diatoms could be detected following *Noctiluca* bloom (Raghu Prasad and Jayaraman 1954). In the same region blooms of *Rhizosolenia alata* and *Rhizosolenia imbricata* occurred during March 1950 and February 1951 respectively (Raghu Prasad 1956). During the month of August 1966,1967 and May 1968 in Vellar estuary swarms of *Noctiluca miliaris* occurred and observed a red tide of *Trichodesmium* spp. (Santha Joseph, 1975,1982). Extensive discolouration of coastal waters of Waltair due to *Asterionella japonica* bloom was noted by Subba Rao (1969). Ganapati and Raman (1979) studied a *Skeletonema* sp. bloom in Visakhapatnam harbour. Madhupratap *et al.* (1980) noted in Nagapatnam a swarm of pelagic tunicates in association with a phytoplankton bloom consisting of *Chaetoceros* spp., *Nitzschia seriata*, *Rhizosolenia* spp., *Navicula* spp., *Thallassiothrix* spp. and *Trichodesmium erythraeum*. Rangarajan and Marichamy (1972) noted in Andamans blooms consisting of *Thalassiosira* spp. *Thallassiothrix* sp., *Biddulphia* spp., *Bacteriastrum* spp., *Ceratium* spp., *Chaetoceros* spp. and *Rhizosolenia* spp. Devasy *et al.* (1983) noted in the Bay of Bengal a mixed diatom bloom comprised mainly of *Thalassiosira subtilis* followed by *Skeletonema costatum*, *Thallassiothrix* spp., *Navicula* spp. and *Coscinodiscus* spp.

Along the western coast of India in the Arabian sea Bhimachar and George (1950) noted the formation of red tide phenomenon dominated by Noctiluca sp. and consisted of Gymnodinium spp., Coscinodiscus spp. and Dinophysis spp. George (1953) noted Noctiluca sp. bloom in Calicut. Subrahmanyan (1959) reported green discolouration due to green Noctiluca sp. and Panikkar (1967) observed mass mortality associated with Noctiluca sp. and Trichodesmium spp. blooms. Venugopal et al. (1979) studied the occurrence of discoloured water off Cochin and off Quilon associated with swarming of Noctiluca miliaris. Daniel et al. (1979) noted Noctiluca sp. swarms associated with the movement of extensive shoals of flying fish and dolphins in northern Arabian sea in 1974. Nair et al. (1984) noted Noctiluca miliaris bloom in Alleppey mud bank region in August 1971 and 1972. Prakash and Sarma (1964) recorded the presence of Gonyaulax polygramma off Cochin and there was virtual exclusion of zooplankton. George (1953) observed swarms of Ceratium spp. and Peridinium spp. along Calicut coast. Trichodesmium erythraeum and Trichodesmium hildebrandtii bloomed off Ullal near Mangalore imparting a greenish yellow colouration to the waters during the bloom (Prabhu et al., 1965). A bloom of Trichodesmium spp. was observed off Mangalore (Prabhu et al., 1971). Nagabhushanam (1967) reported the occurrence of Trichodesmium erythraeum bloom in Minicoy Island and Qasim (1970) noted the red tide of it near the Laccadive Island.

Red tide due to *Trichodesmium erythraeum* was studied in Goa coast (Ramamurthy *et al.*, 1972 and Devassy *et al.* 1978). Ramamurthy *et al.* (1972) studied that after the red tide of *Trichodesmium* spp. a mixed diatom bloom was observed in Goa waters. From the same region Devassy *et al.* (1979) noted that once the *Trichodesmium* spp. bloom was declined a mixed diatom bloom comprising largely of *Chaetoceros* spp. occurred. This was followed by swarms of cladocerans. The cladocerans are succeeded by *Noctiluca* sp. Devassy (1983) noted from the Mandovi and Zuari estuary, blooms of *Chaetoceros* spp., *Fragilaria oceanica* and *Leptocylindrus danicus*. Vijayalakshmi Nair *et al.* (1980) observed zooplankton in association with *Trichodesmium* spp. red tide in Goa waters. Verlancar (1978) noted the *Trichodesmium erythraeum* bloom at several places along the south west coast of India during March 1977. Sakthivel and Haridas (1974) observed synchronization of *Trichodesmium* spp. bloom and swarming of Pteropoda and Cladocera off Cochin. George (1953) noted swarming of *Pleurosigma* sp. and *Biddulphia* spp. and a bloom of *Fragilaria* sp. along the Calicut coast.

Subrahmanyan (1959) noted a relationship between bloom of *Fragilaria oceanica* and oil sardine fishery. Devassy (1974) noted *Fragilaria oceanica* bloom along Mangalore coast. Qasim *et al.* (1972) reported from the Cochin backwater blooms of *Coscinodiscus* spp., *Navicula* spp.

and *Skeletonema costatum*. Qasim *et al*. (1974) also noted the blooms of *Skeletonema costatum*, *Cerataulina* sp., *Merismopedia* sp. in Cochin backwater. Devassy and Bhattathiri (1974) observed from the same backwater blooms of *Ceratium* spp. *Peridinium* spp., *Nitzschia* spp. and *Skeletonema* sp. Joseph and Pillai (1975) studied the *Chaetoceros* spp. and *Skeletonema costatum* bloom in the Cochin backwater. The phytoplankton blooms reported from the Indian coast from 1971 to 1984 were represented in Fig.1.

5. Scope of the present study

Marine environment forms a model ecosystem wherein there exists dynamic equilibrium between the various organisms. The phytoplankton being the primary producers, their growth, maintenance and decay can shift the equilibrium significantly. In this context the blooming phenomenon has far reaching effects.

One impact of this unusual growth not only affects the biological processes of the phytoplankton dependent species including fish but alters the other environmental parameters of the area in question. The growth utilizes the existing nutrients which may be depleted in certain seasons. This in turn may adversely affect other forms which are dependent on a common nutrient pool for their maintenance. The phenomenal growth also would lead to a stage in which

Fig.1. The phytoplankton blooms in Indian coast from 1971 to 1984.

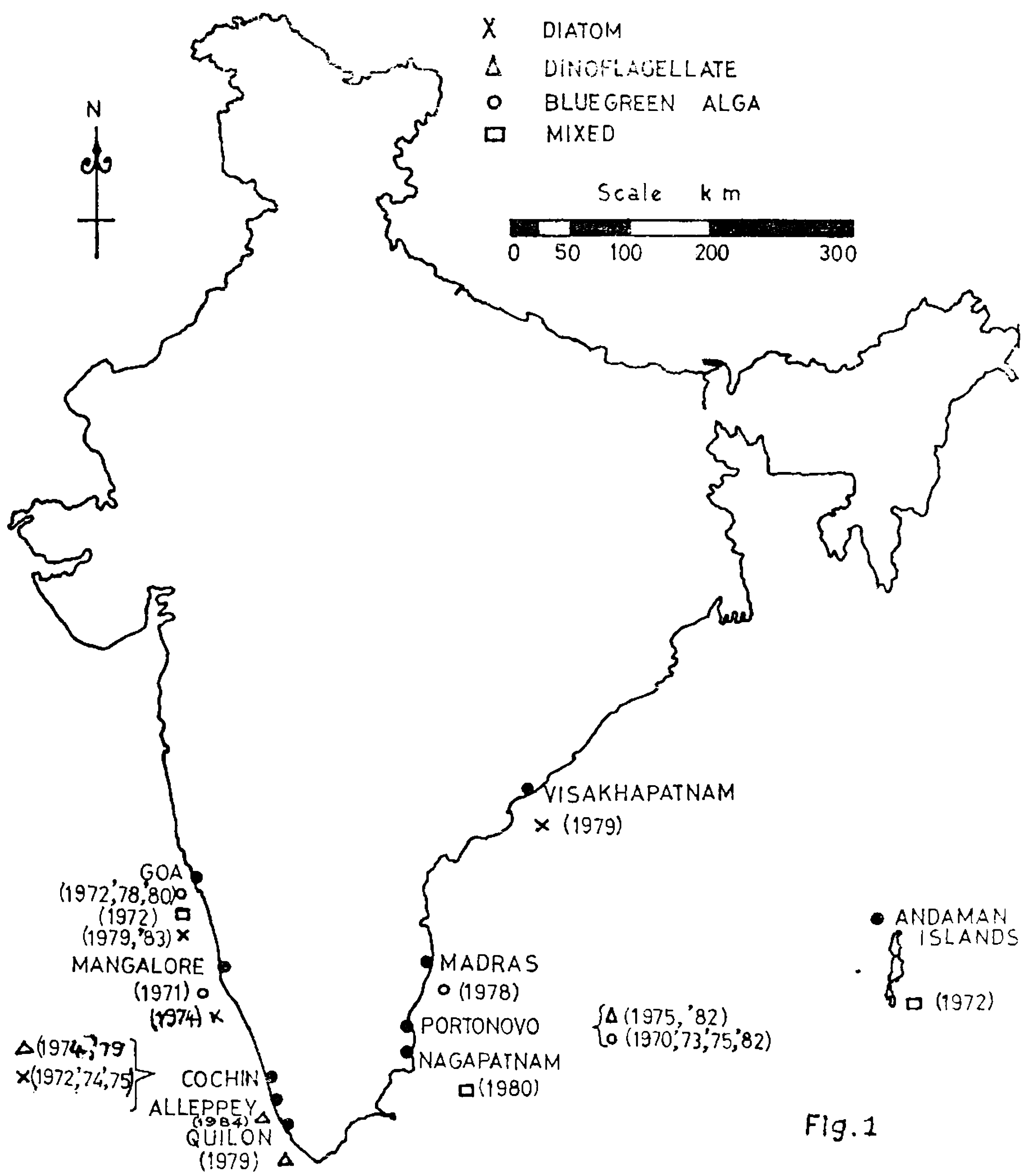

X DIATOM
Δ DINOFLAGELLATE
o BLUEGREEN ALGA
□ MIXED
N
Scale km
0 50 100 200 300
VISAKHAPATNAM
× (1979)
GOA
(1972,'78,'80) o
(1972) □
(1979,'83) ×
MANGALORE
(1971) o
(1974) ×
Δ(1974,'79
×(1972,'74,'75
COCHIN
ALLEPPEY
(1984) Δ
QUILON
(1979) Δ
MADRAS
o (1978)
PORTONOVO
NAGAPATNAM
□(1980)
Δ (1975,'82)
o (1970,'73,'75,'82)
ANDAMAN
ISLANDS
□ (1972)

Fig. 1

the available materials for growth are made extinct. This eventually would culminate in the decay of the blooming of phytoplankton, setting into operation those constituents in the food chain which are responsible for the release of nutrients that are locked in the decaying matter.

The south west coast of India with its unique tropical climate forms an important area for investigation relating to fishery. The pelagic fishery contributes very significantly not only to the fish landings in this area but also to the total country's fish landings. However, the data (MPEDA 1981 and 1982, CMFRI 1982 and 1983) showed that there has not been any considerable increase in the production of fish for the last few years (Fig.2).

Ramalingam (1984) also reported that along the south west coast the landings suffered a set back and declined in-spite of increasing the mechanised fishing along this coast. This is, all the more critical because of the increased rates in human consumption of fish (FAO 1983). Indian fishery contributes major part of total world fish landings. The unique position which contributed to the south west coast of India is due to the formation of mud banks (Virabhadra Rao 1973, CMFRI 1980, CMFRI 1984). According to Banerji (1973) and MPEDA (1977) nearly two third of the marine fish landing in India came from the pelagic fisheries

Fig.2. The pelagic fish landings of India and Kerala from 1970 to 1982.

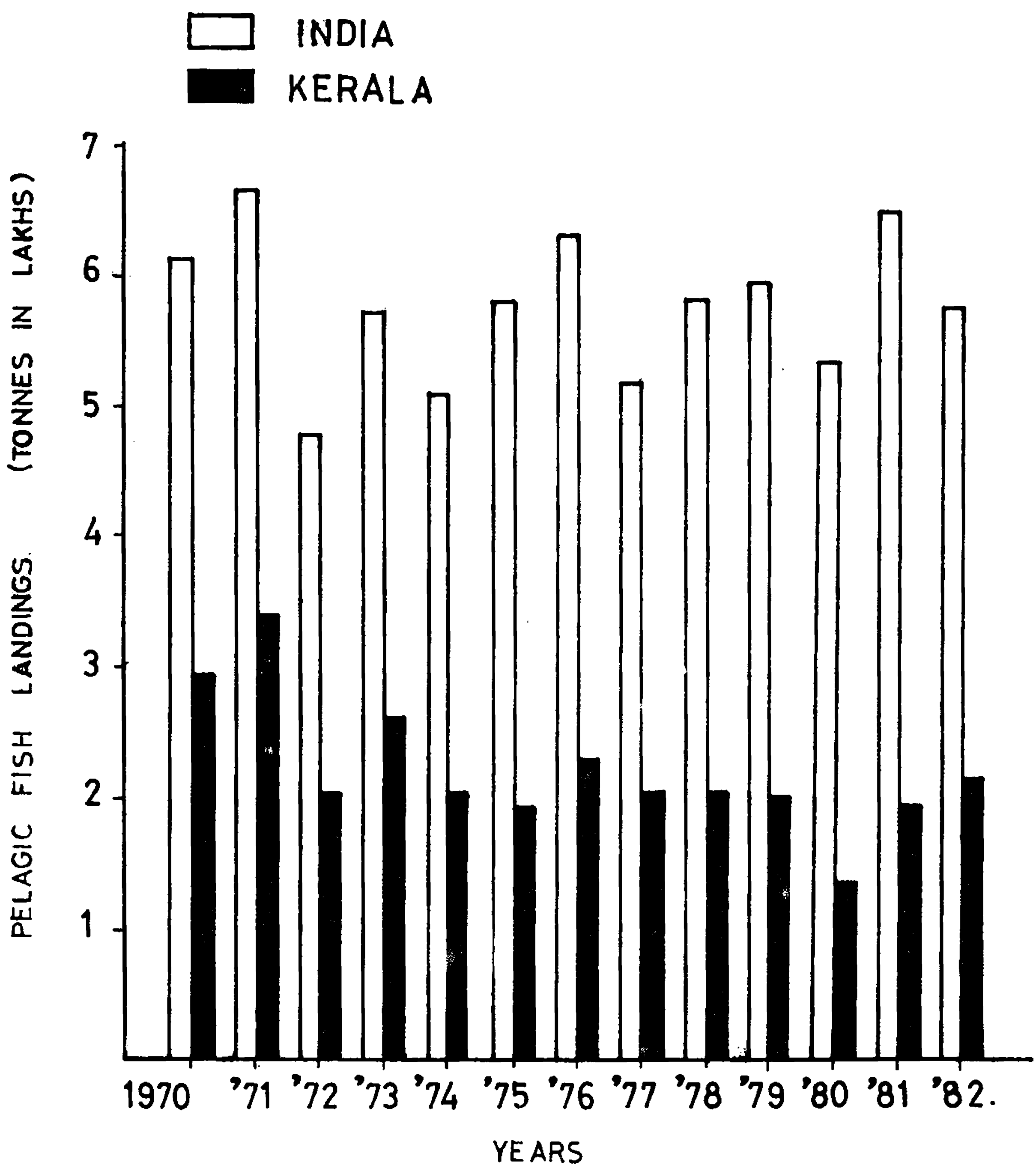

INDIA
KERALA
PELAGIC FISH LANDINGS (TONNES IN LAKHS)
7
6
5
4
3
2
1
1970
'71
'72
'73
'74
'75
'76
'77
'78
'79
'80
'81
'82.
YEARS

Fig.2.

and the major pelagic fishery like mackerel and oil sardine are from the south west coast of India. It may also be pointed out that Kerala has 600 kms long coastline which is about 9% of India's coastal length and it is the single largest fish landing state in the country. Considering the importance of this region the UNDP/FAO Project was established along this coast. Hence all attempts should be concentrated to increase the landings in this area to keep up with the increased fish consumption rate.

Of the various relationships involving the phytoplankton the one involving the pelagic fish is of direct consequence and significance to man. Of the various factors exerting their influence on the maintenance of fish shoals, the most significa is the presence of feed i.e. phytoplankton. The importance of the pelagic fishery, to the economy is evident. Since the pelagic fishes depend mainly on phytoplankton in their food chain, the presence and growth of the phytoplankton communities are vital for the production of fishes. It is known that the shoals of some of the pelagic fishes are present in surface waters of south west coast in most of the seasons. The bloom specifically could be of value to the fishes as the abundant growth could provide plenty of feed if they are favoured as food. On the contrary, if the blooming organism(s) generate materials which are toxic directly to fish or to some other marine forms, they can produce adverse effects to pelagic fishes and even to man. However, increased number of fishes occur during certain blooms of plankton (FAO 1976). This presents the possibility of increasing the catch by the expansion of the phytoplankton populations. Eventhough upwelling could bring additional nutrients, food supply to the surface waters, this by itself has been ruled out as cause of the occurrence of more fish in a particular area (FAO 1976). The phenomenon of blooming hence has significance in this context.

Knowledge about the interrelationship of favourable phytoplankton blooms and fish shoals would indicate methods to increase fish production. One possible approach would be to induce the blooming of phytoplankton by means of natural induced favourable phytoplankton blooms thereby increasing the feed in an area several fold within a very short time so that large numbers of fish can prey on them. The previous reports from the Indian coasts regarding blooms tried to relate the organism constituting the bloom and its parameters (Raghu Prasad 1953 and 1956, Subba Rao 1969, Devassy 1974, Devassy and Bhattathiri 1974, Devassy et al. 1978, Devassy et al. 1979, Verlancar 1978, Venugopal et al. 1979, Madhupratap et al. 1980, Ramamurthy 1975, Ramamurthy et al. 1972 and Daniel et al. 1978). But there are no systematic attempts to investigate the biological parameters such as blooming phenomena governing the maintenance of fish shoals in the area so that maximum exploitation of these resources can be made.

Studies were taken up to monitor the development of blooms of diatoms, dinoflagellates and blue green algae along the south west coast of India. Characterization of the blooms includes the identity of the organisms constituting the blooms, its colour, structure and pattern, its periodicity and duration and their impact on pelagic fishes were carried out. The detailed study also conducted with regard to cell counts of the bloomed organisms from the day of its appearance till its disappearance from the 3 observation centres. The fishes those found in the bloomed region were also collected and the guts were analyzed. An year round study is necessary to investigate the gut contents of the pelagic fishes during various seasons to see whether the bloomed organisms are included or not in the general feed. From the foregoing observation the present study tried to find out the blooms which are favourable to the pelagic fishes. These blooms could be used to exploit the usefulness of these organisms to fishery as an increased food supply.

III. MATERIALS AND METHODS

The study of the phytoplankton blooms along the south west coast of India were carried out during February 1982 to August 1984. Observations and collections of samples were made from off Quilon, off Alleppey and off Calicut i.e. 8°54'N - 76°36'E, 9°24'N - 76°18'E and 11°6'N - 75°48'E respectively (Fig.3) and between 5 to 8 fathoms. For field collection smaller fishing boats as well as exploratory trawlers were used. The crew of the local fishing vessels have been requested to collect water samples and other necessary informations and the messages were passed on to the author. On receipt of such messages the author along with the supervising guide made simultaneous observations on board. Samples were collected in the bloom patches. Daily collections of samples were made from the day of the appearance till its disappearance. Two litres of surface water were collected from the bloom areas. The phytoplankton nets could not be used for these blooms as the nets were clogged during towing operations. This result clutches of the bloomed organisms escaped from the net gave erroneous results in relation to water filtered through the net. Samples thus collected were preserved in 2% to 3% formali for further studies. The mortality of fishes, if any, was estimated on the basis of visual observations. The appearance, duration and locality of the blooms were also noted.

For laboratory analysis of the formalin fixed sample, the sample was allowed to sediment for 24 hours. Then the samples were decanted and the sedimented phytoplankton were analysed using an inverted microscope (Hasle 1978). The combined plate chamber of the inverted microscope consists of a top cylinder (sedimentation cylinder) and a plate chamber. Depending upon the quantity of phytoplankton, sediment chamber of 5 ml, 10 ml, 25 ml, 50 ml or 100 ml capacity were used. The cylinder of the desired capacity was placed on top of the plate chamber. The well shaken preserved water sample has been poured into the combined chamber to overflow, a top plate is placed in position to eliminate dust and evaporation. Care should be taken to remove all water outside the chamber to keep in particular the thin glass bottom clear. After sedimentation the top cylinder was slowly pushed away from the plate chamber by using the square top plate of the plate chamber. Pushing stops when the cylinder reached the small opening near the end of the perspex plate of the plate chamber. As soon as the circular top plate of the sedimentation cylinder was removed, water was drained out of the cylinder through the small hole below. Care was taken to limit the use of tall cylinders because of attachment of organisms to the chamber wall especially for chain-forming and Setae-bearing species of diatoms and some dinoflagellates.

The following precautions as suggested by Hasle (1978) were observed. The sample was shaken gently several times (100 or 200) before it was poured into the sedimentation chamber. This helped to loosen organisms attached to the storage bottle. The sample was brought to room temperature, before filling the chamber, to prevent formation of air bubbles on the chamber walls. The cell counts per day were noted from the samples. An average of 5 estimations were made in each sample of the bloom patch. Mean average of cell counts/ml was taken as standard unit throughout the study.

To observe the gut contents of the pelagic fishes, samples were collected from the trawl nets and purse seine nets used by 32', 46' and 37' boats in a specific locality in the bloom area. An year round study of the gut content analysis were done from September 1983 to August 1984 in order to see whether the bloomed organisms are included in the general feed or not. For this purpose an average of 4 to 5 samples of fishes of each genera were collected monthly from fish landing places of the coasts of Quilon, Alleppey and Calicut. The geographic location of the landing centres where sample collections were made is shown in Fig.3. Fishes were collected immediately after the catches. These samples were fixed by injecting formalin (5 ml/fish). The fixed fish samples were kept submerged in 5% formalin. The samples of fishes collected during bloom period were also preserved in the above mentioned method. Identification of fishes were done according to the FAO species identification sheets (FAO 1974,1984b). The samples were dissected and the guts were carefully removed and preserved in 2% formalin for the analysis of gut contents. The preserved guts were transferred to a clear glass slide. The gut contents were released from the cavity by mechanical manipulations with a needle. The contents thus exuded were observed in a binocular microscope. The points (numerical) method suggested by Pillay (1952) was followed. The organisms observed i.e. diatoms, dinoflagellates and blue green algae were identified. The food items are classified as very common (75-100%), common (50-74%), frequent (25-49%), Rare (1-24%) etc. based on

counts and judgement by the eye and the contents of the stomachs are then tabulated. For identification of diatoms, dinoflagellates and blue green algae the following keys (Subrahmanyan 1946, Newell and Newell 1963 and Umezaki 1961) were used respectively.

Criteria for selecting the observation centres

Out of all the ten major fish landing places visited along the south west coast of India from Cape Comorin to Cannanore, the reasons for selecting the above mentioned

Fig.3. Map of south west coast of India showing sampling stations.

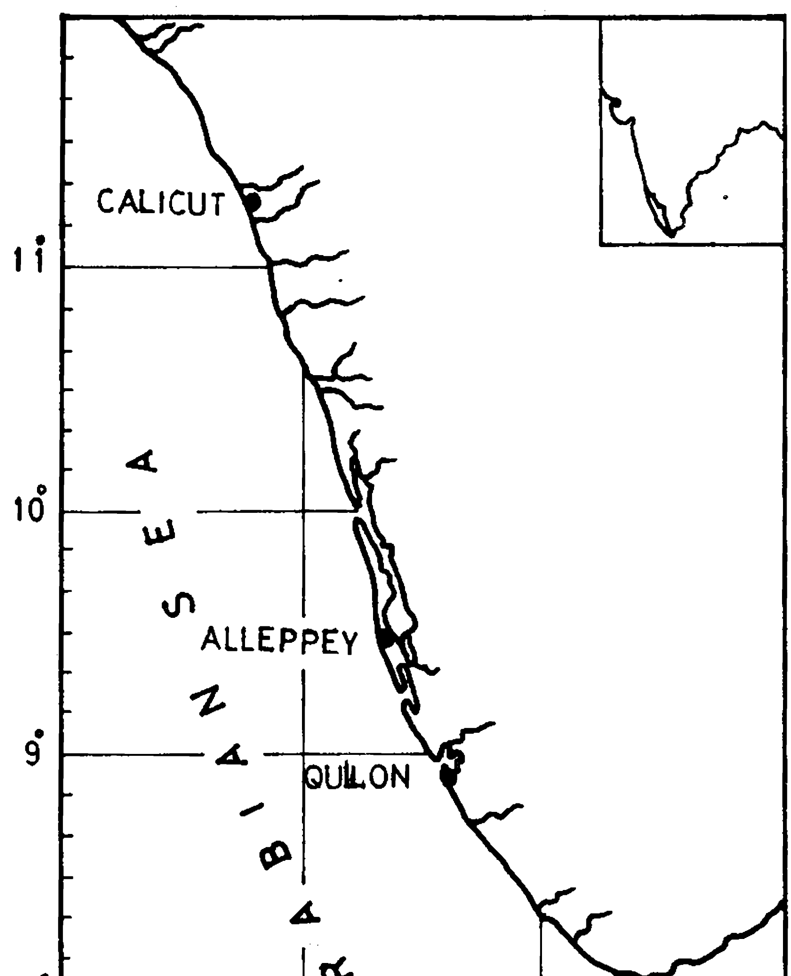


Fig. 3.

3 centres were as follows:- (1) Easy accessability by road to landing centres. (2) Easy accessability to nearshore areas by boat for observing the blooms in respect of above three stations. (3) Operation of fishing vessels throughout the year. (4) Other infrastructural facilities like landing platforms and fishing jetties are operative throughout the year including monsoon periods.

IV. OBSERVATION

1. Characterization of the phytoplankton blooms

The planktonic organisms being interlinked to various other organisms of the food chain, their multiplication and maintenance can produce changes in the marine ecosystem. Recently Revikala and Ramamurthy (1984) reviewed the occurrence of phytoplankton blooms from the east and west coast of India during the last two decades.

Observations on red tides of phytoplankton blooms along the south west coast of India were made from the beginning of the year 1982.

BLOOMS OF 1982

Ceratium spp.

Bloom of *Ceratium* spp. occurred from 3rd February to 12th February 1982 (Fig.4). It was first observed off Quilon on 3rd February and it lasted upto 10th February (8 days), the cell counts ranged from 65 cells/ml to 712 cells/ml. A day later i.e. on 4th February it was observed off Alleppey and was seen upto 12th February (9 days), the cell counts were between 46 cells/ml to

596 cells/ml. On 5th February it was detected off Calicut. The 8 days bloom showed the cell counts from 41 cells/ml to 685 cells/ml (Table I). The bloom was observed at 5 fathoms and had a patchy appearance. Shoals of pelagic fishes were absent in the bloom patches. However, fishes were caught in the nearby vicinity of the bloom. No off odour or irritation were observed.

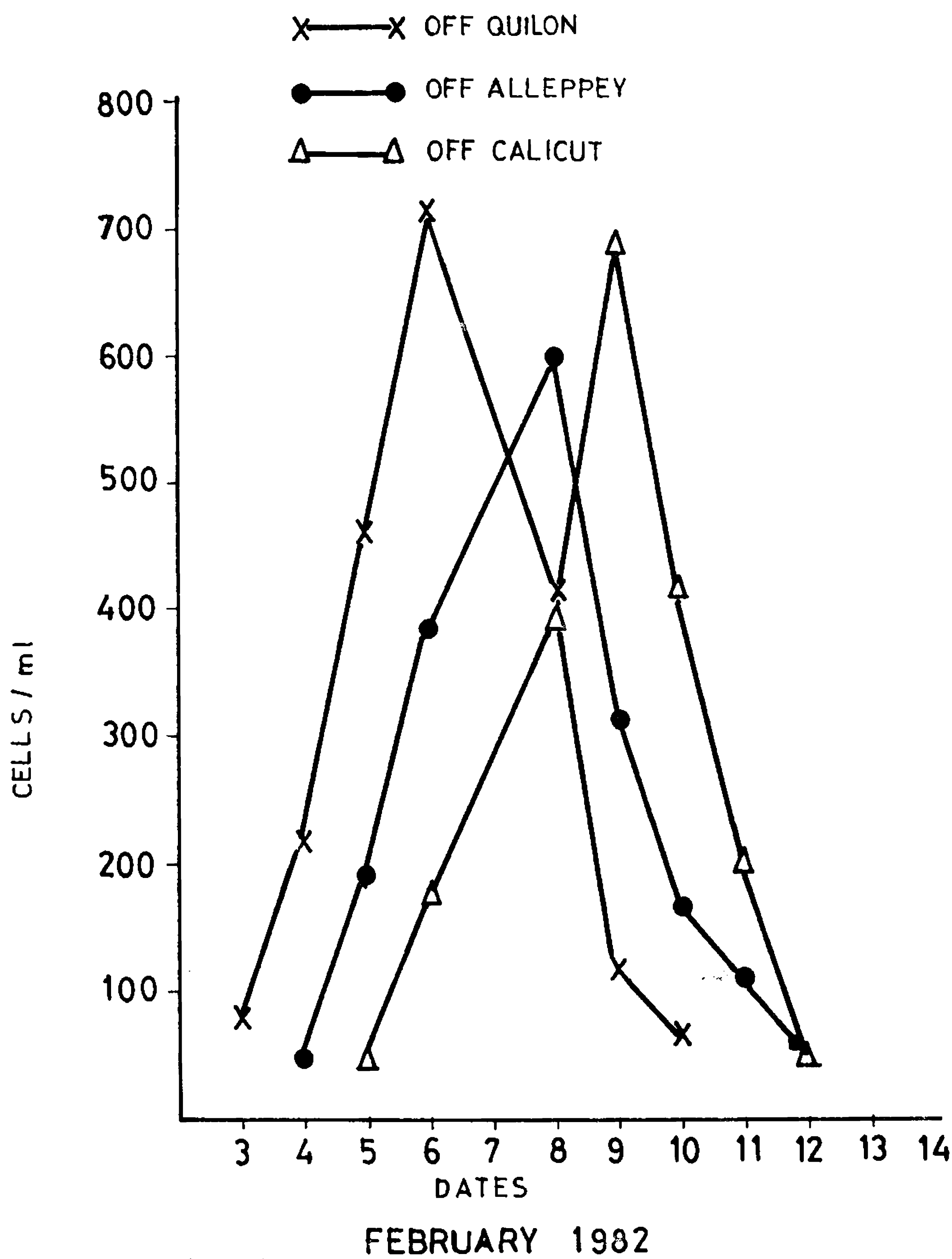
Trichodesmium spp.

The blue green alga red tide of *Trichodesmium* spp. was observed between 5 to 7 fathoms from 20th March to 8th April 1982 (Fig.5). On 20th March it made its appearance off Calicut and lasted upto 2nd April (14 days) and the cell counts varied from 40 cells/ml to 1360 cells/ml. On 24th March it again appeared off Alleppey and it was observed upto 6th April (14 days) and the cell counts ranged from 40 cells/ml to 978 cells/ml. Simultaneously it occurred off Quilon from 27th March to 8th April (13 days). The cells counts increased from 40 cells/ml to 1200 cells/ml (Table II). No off odour was observed to the bloom which was in the form of streaks and patches. Fishes were caught in the bloomed area and it was noticed that pelagic fish shoals freely swim through the bloom.

Peridinium spp.

In the month of May a bloom of *Peridinium* spp. appeared from 17th May to 22nd May 1982 (Fig.6). First it made its appearance off Quilon and off Alleppey on 17th May. Off Quilon it lasted upto 21st May (5 days);

Fig.4. Blooming pattern of *Ceratium* spp. during February 1982.



OFF QUILON
OFF ALLEPPEY
OFF CALICUT
800
700
600
500
400
300
200
100
CELLS / ml
3 4 5 6 7 8 9 10 11 12 13 14
DATES
FEBRUARY 1982

Fig. 4.

Table I. Cell counts of *Ceratium* spp. during the bloom period in 1982.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1982 February	3	75	-	-
	4	218	46	-
	5	456	192	41
	6	712	382	172
	7	-	-	-
	8	412	596	385
	9	115	312	685
	10	65	166	412
	11	-	112	198
	12	-	52	44

Fig.5. Blooming pattern of *Trichodesmium* spp. during March to April 1982.

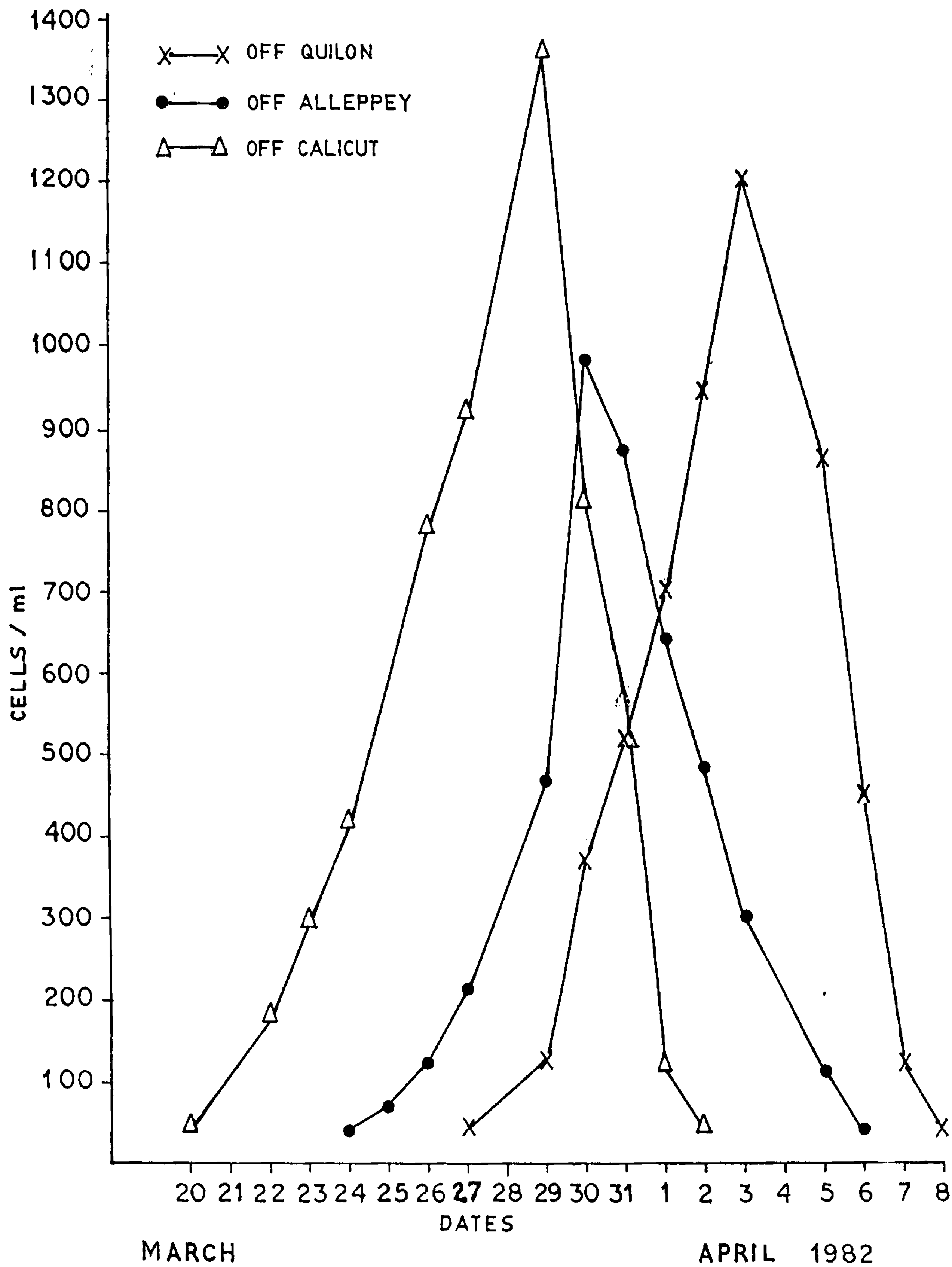

OFF QUILON
OFF ALLEPPEY
OFF CALICUT
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
CELLS / ml
20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8
DATES
MARCH
APRIL 1982

Fig. 5.

Table II. Cell counts of *Trichodesmium* spp. during the bloom period in 1982.

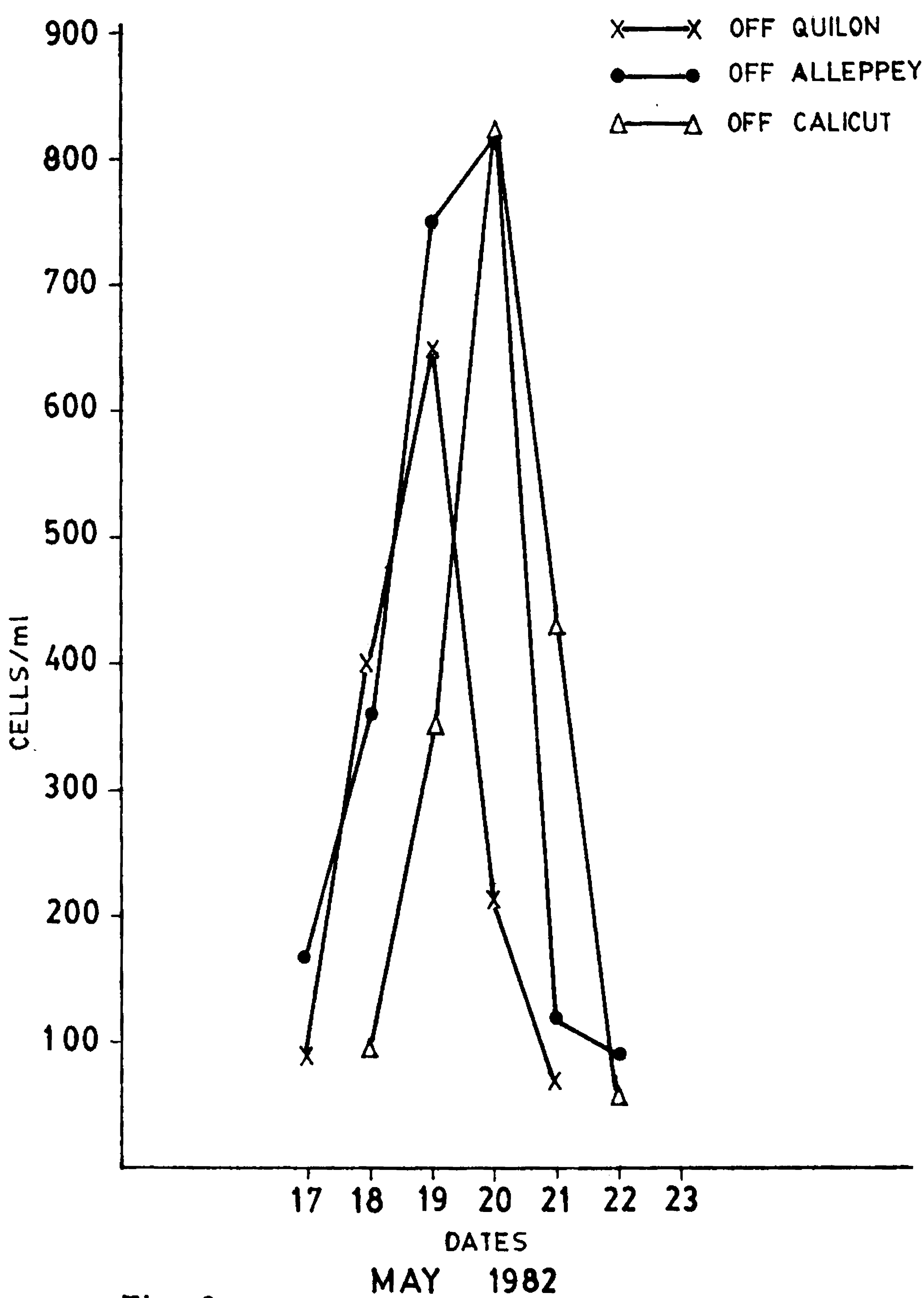
Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1982 March	20	-	-	40
	21	-	-	-
	22	-	-	175
	23	-	-	292
	24	-	40	412
	25	-	66	-
	26	-	122	776
	27	40	212	914
	28	-	-	-
	29	120	465	1360
	30	366	978	806
	31	512	872	512
April	1	695	640	116
	2	936	482	40
	3	1200	300	-
	4	-	-	-
	5	860	114	-
	6	450	40	-
	7	120	-	-
	8	40	-	-

the cell counts ranged from 64 cells/ml to 646 cells/ml. Off Alleppey it was seen upto 22nd May (6 days); the cell counts were between 90 cells/ml to 820 cells/ml. Off Calicut it appeared on 18th May and was observed upto 22nd May (5 days); the cell counts were between 52 cells/ml to 824 cells/ml (Table III). The observation was made between 5 to 6 fathoms and the bloom was in the form of patches. Though no fishes were found in the blooms, shoals were caught outside the vicinity but no irritation and no off odour has been noticed.

Asterionella japonica Cleve

In the year 1982 July a bloom of *Asterionella japonica* Cleve which has got a dark and dirty yellow colour made its appearance from 5th July to 15th July (Fig.7). Off Calicut it appeared from 5th July to 14th July (10 days) and the cell counts determined were from 40 cells/ml to 1680 cells/ml. On 7th July it was seen off Alleppey and was observed upto 14th July (8 days); the cell counts varied from 58 cells/ml to 1480 cells/ml. Off Quilon it made its appearance from 9th July to 15th July (7 days) and cell counts ranged from 78 cells/ml to 1285 cells/ml (Table IV). No off odour was observed in the streaks and patches of bloom and lot of pelagic fishes were found swimming in that area.

Fig.6. Blooming pattern of *Peridinium* spp. during May 1982.



X—X OFF QUILON
●—● OFF ALLEPPEY
△—△ OFF CALICUT
900
800
700
600
500
400
300
200
100
CELLS/ml
17 18 19 20 21 22 23
DATES
MAY 1982

Fig. 6.

Table III. Cell counts of *Peridinium* spp. during the bloom period in 1982.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1982 May	17	86	166	-
	18	395	360	92
	19	646	750	345
	20	212	820	824
	21	64	120	426
	22	-	90	52

Fig.7. Blooming pattern of *Asterionella japonica* Cleve during July 1982.

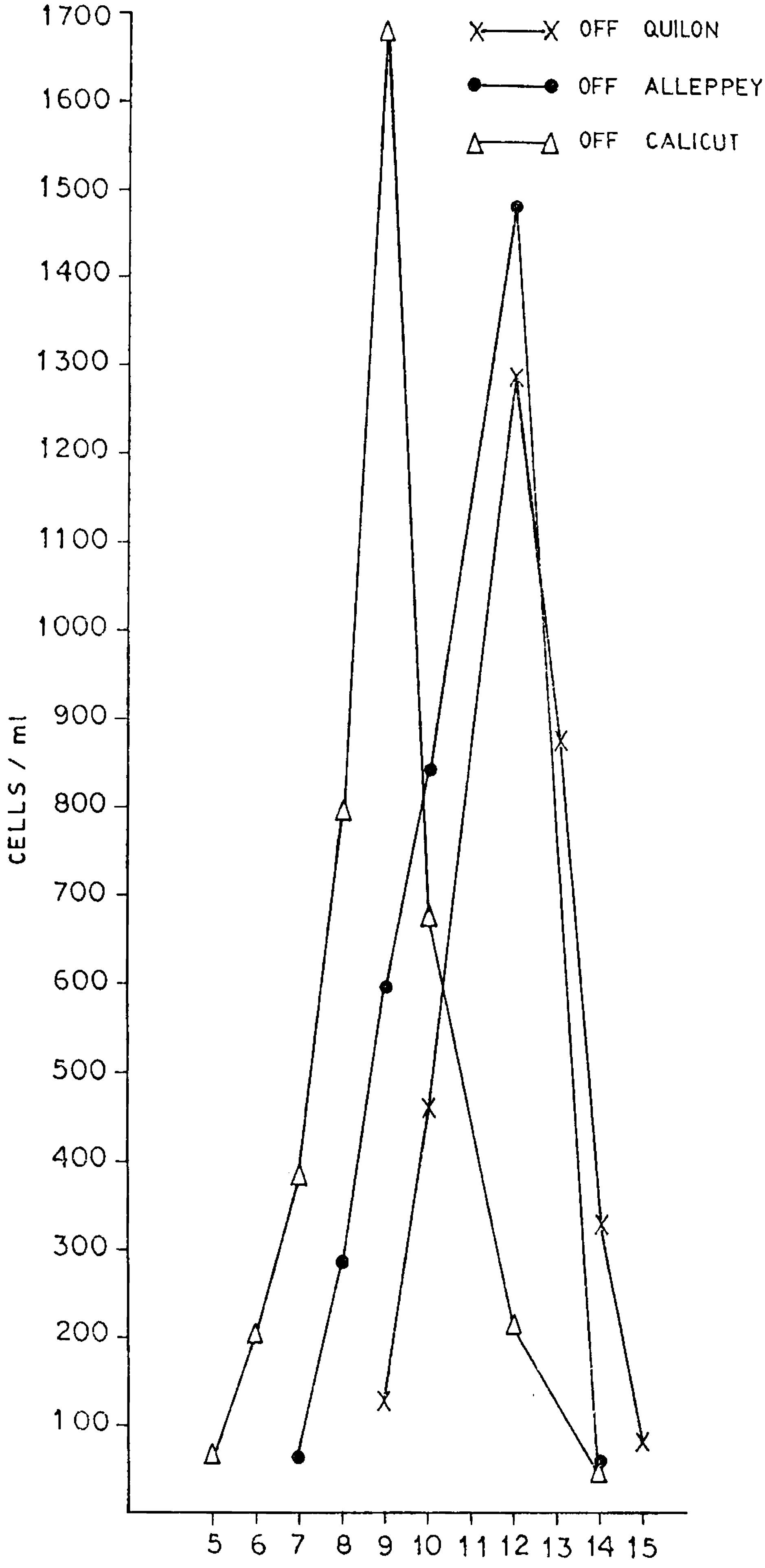


Fig. 7. JULY 1982

Table IV. Cell counts of *Asterionella japonica* Cleve during the bloom period in 1982.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1982 July	5	-	-	56
	6	-	-	197
	7	-	62	378
	8	-	285	794
	9	120	596	1680
	10	456	842	672
	11	-	-	-
	12	1285	1480	214
	13	873	-	-
	14	327	58	40
	15	78	-	-

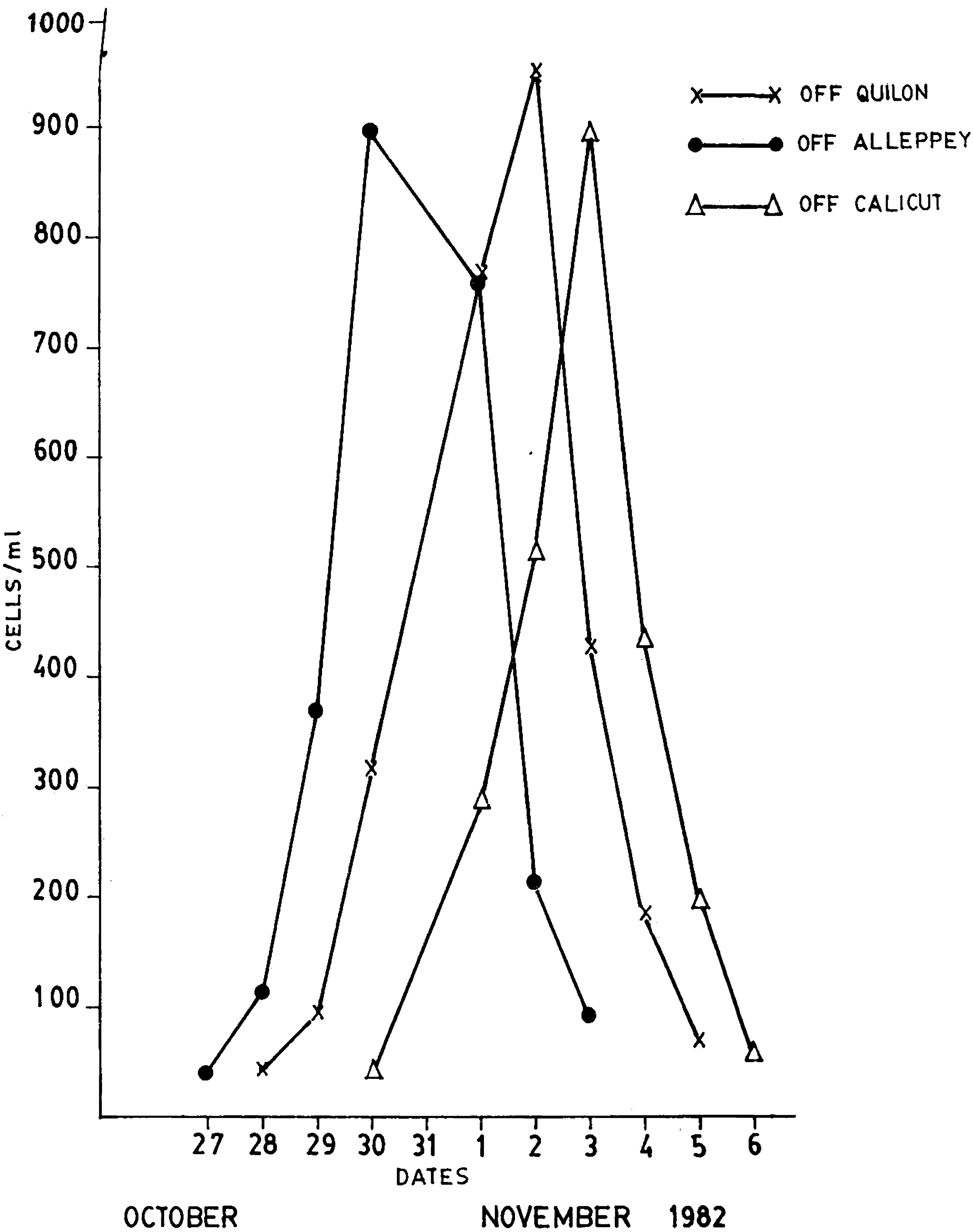
Skeletonema costatum (Greville) Cleve

The yellow coloured *Skeletonema costatum* (Greville) Cleve bloom which started appearing from 27th October and lasted upto 6th November 1982 (Fig.8). First it appeared off Alleppey on 27th October and noticed upto 3rd November (8 days) and the cell counts were between 40 cells/ml to 898 cells/ml. Off Quilon it appeared on 28th October and was observed upto 5th November (9 days); the cell counts varied from 40 cells/ml to 950 cells/ml. Off Calicut the bloom appeared on 30th October and noticed upto 6th November (8 days). The cell counts increased from 40 cells/ml to 896 cells/ml (Table V). The bloom was seen between 5 to 6 fathoms and lot of pelagic fishes were seen in that region.

Asterionella japonica Cleve and *Thallassiothrix* spp.

A bloom of *Asterionella japonica* Cleve and *Thallassiothrix* spp. was also studied during December 1982. The bloom appeared between 5 to 6 fathoms, the colour being muddy yellow. The bloom appeared from 10th December to 18th December (Fig.9). Off Calicut it was observed from 10th December to 16th December (7 days) and the cell counts ranged from 64 cells/ml to 712 cells/ml. On 11th December it was seen off Alleppey and noticed upto 17th December (7 days); the cell counts varied from 40 cells/ml to 644 cells/ml. Off Quilon it appeared from 13th December to

Fig.8. Blooming pattern of _Skeletonema costatum_ (Greville) Cleve during October to November 1982.



OFF QUILON
OFF ALLEPPEY
OFF CALICUT
CELLS/ml
1000
900
800
700
600
500
400
300
200
100
27
28
29
30
31
1
2
3
4
5
6
DATES
OCTOBER
NOVEMBER 1982

Fig. 8.

Table V. Cell counts of *Skeletonema costatum* (Greville) Cleve during the bloom period in 1982.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1982 October	27	-	40	-
	28	40	112	-
	29	92	368	-
	30	314	898	40
	31	-	-	-
November	1	765	756	286
	2	950	212	512
	3	426	94	896
	4	184	-	436
	5	68	-	196
	6	-	-	58

18th December (6 days) and the cell counts ranged from 66 cells/ml to 698 cells/ml (Table VI). The bloom appeared as streaks and patches. Fishes were found swimming in the bloom.

In general during 12 months period of 1982 six phytoplankton blooms were studied. Out of the six blooms two blooms were dinoflagellates, one blue green alga and three diatoms. In order to make a critical evaluation, the observation has been further extended in 1983.

BLOOMS OF 1983

Trichodesmium spp.

In 1983 February the explosive growth of the blue green alga has taken place. The yellowish brown colour was observed between 5 to 6 fathoms. It appeared from 18th February to 28th February (Fig.10). First it appeared off Alleppey on 18th February to 25th February (8 days), the cell counts increased from 54 cells/ml to 968 cells/ml. On 21st February it appeared off Quilon and lasted upto 28th February (8 days), the cell counts increased from 40 cells/ml to 982 cells/ml. It bloomed from 22nd February to 28th February (7 days) off Calicut; the cell counts were between 40 cells/ml and 945 cells/ml (Table VII). Fishes were found swimming freely in the bloomed area which was found as streaks and patches. No ill effects and no off odour were particularly noticeable.

Fig.9. Blooming pattern of *Asterionella japonica* Cleve and *Thalassiothrix* spp. during December 1982.

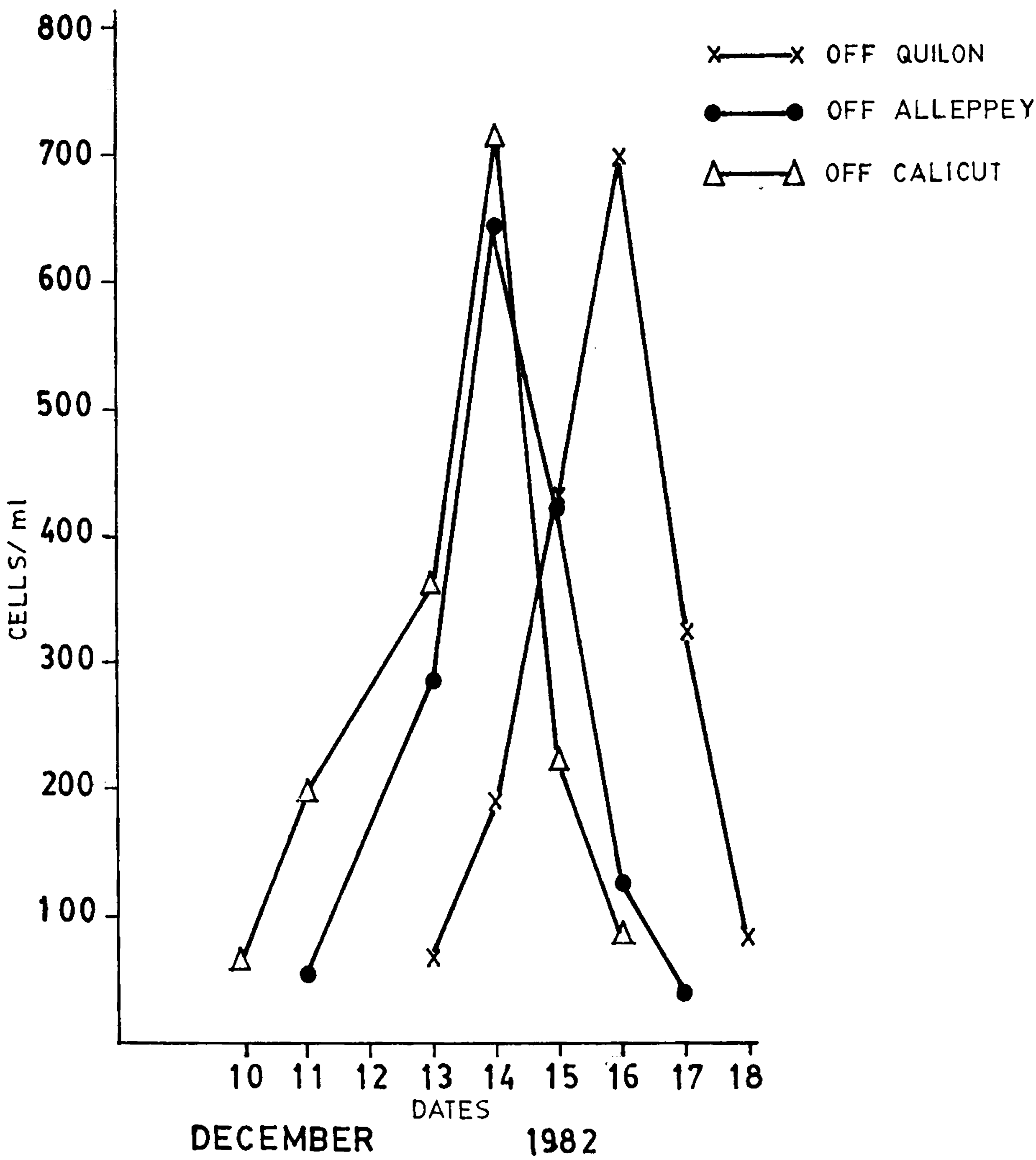
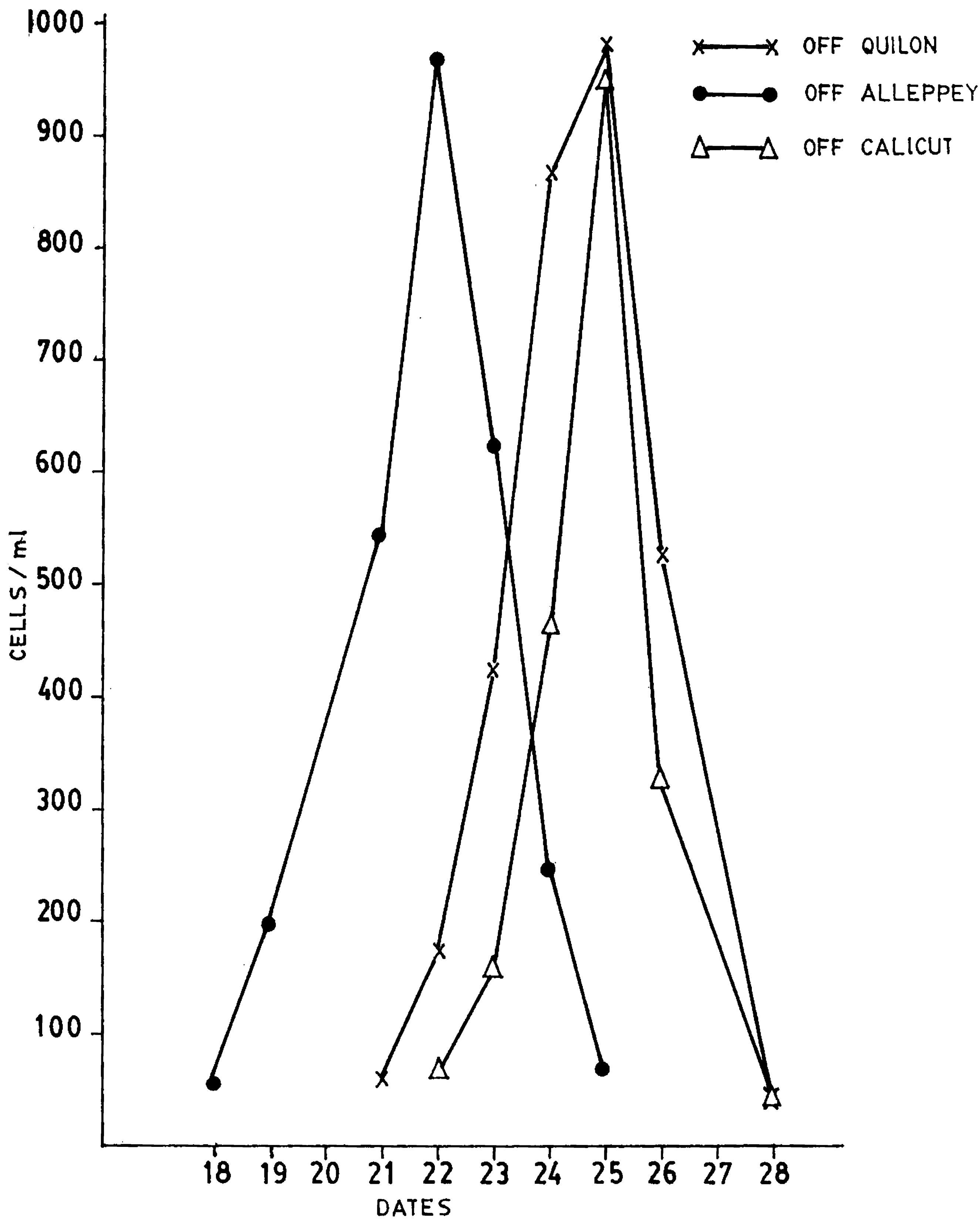

800
700
600
500
400
300
200
100
CELLS/ ml
OFF QUILON
OFF ALLEPPEY
OFF CALICUT
10 11 12 13 14 15 16 17 18
DATES
DECEMBER 1982

Fig. 9.

Table VI. Cell counts of *Asterionella japonica* Cleve and *Thalassiothrix* spp. during the bloom period in 1982.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1982 December	10	-	-	64
	11	-	52	194
	12	-	-	-
	13	66	282	356
	14	186	644	712
	15	426	420	220
	16	698	125	84
	17	324	40	-
	18	82	-	-

Fig.10. Blooming pattern of *Trichodesmium* spp. during February 1983.



FEBRUARY 1983

Fig. 10.

Table VII. Cell counts of *Trichodesmium* spp. during the bloom period in 1983.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1983 February	18	-	54	-
	19	-	196	-
	20	-	-	-
	21	58	544	-
	22	174	968	66
	23	422	622	158
	24	865	246	464
	25	982	68	945
	26	525	-	326
	27	-	-	-
	28	40	-	40

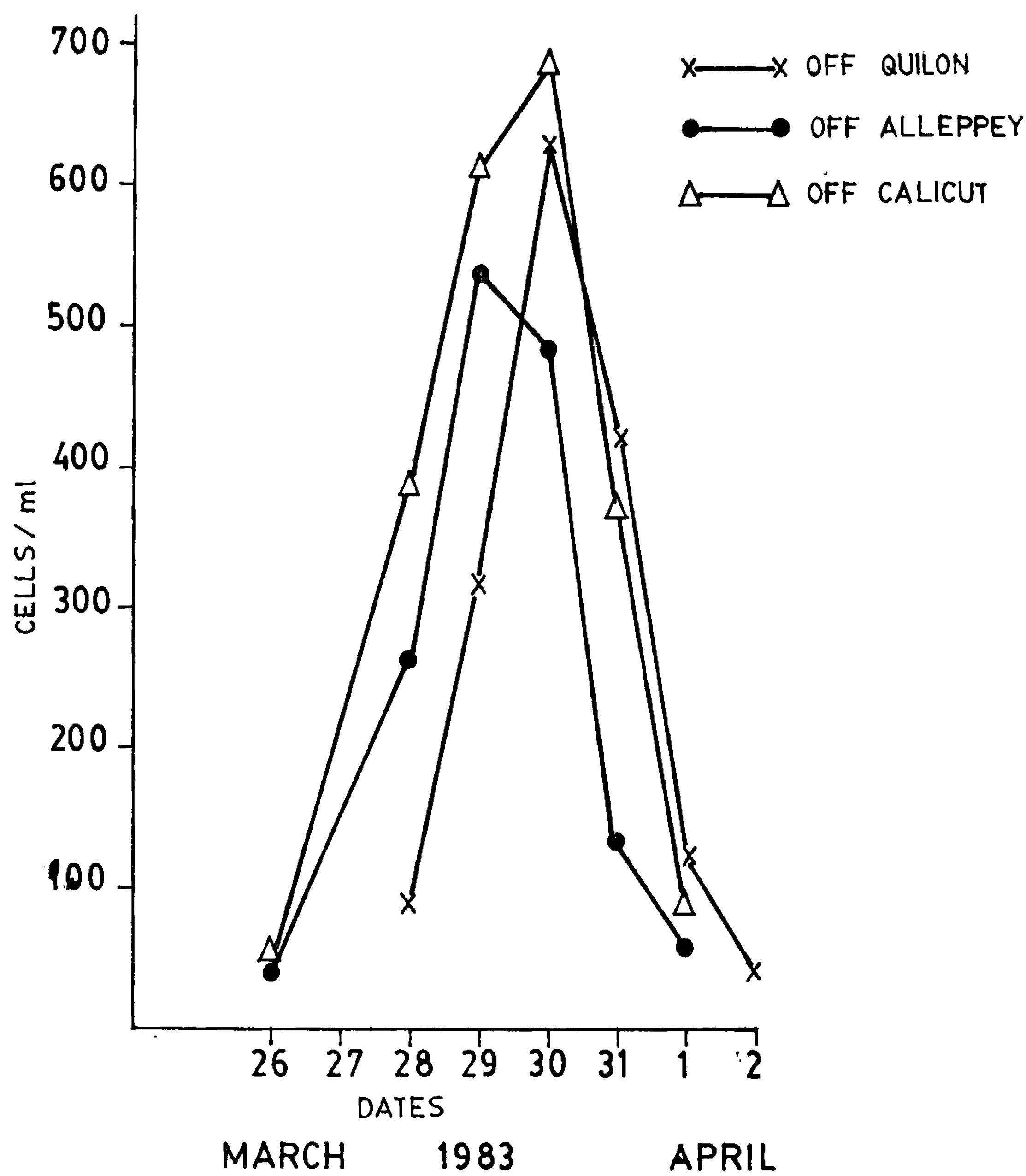
Ceratium spp.

A red tide of *Ceratium* spp. which was greenish was studied between 5 to 6 fathoms.from 26th March to 2nd April 1983 (Fig 11). Off Alleppey and off Calicut it appeared from 26th March to 1st April (7 days). Off Alleppey the cell counts varied from 40 cells/ml to 536 cells/ml. Off Calicut the cell counts increased from 50 cells/ml to 684 cells/ml. Off Quilon it appeared from 28th March to 2nd April (6 days), the cell counts varied from 40 cells/ml to 626 cells/ml (Table VIII). The bloom was in the form of patches and no fish seemed to be found or caught in that region.

Noctiluca miliaris Suriray

The red tide of *Noctiluca miliaris* Suriray which has got a greenish colour was observed at 6 fathoms between 14th June to 7th July 1983 (Fig.12). On 14th June it started appearing off Calicut and was seen upto 23rd June (10 days) and the cell counts increased from 40 cells/ml to 984 cells/ml. Off Quilon it started appearing on 24th June and lasted upto 2nd July (9 days). The cell counts increased from 58 cells/ml to 842 cells/ml. Off Alleppey the cell counts were between 56 cells/ml to 786 cells/ml (Table IX) and appeared from 29th June to 7th July (9 days). No fish seem to be found or caught in the blooms which appeared as streaks and patches.

Fig.11. Blooming pattern of *Ceratium* spp.
during March to April 1983.



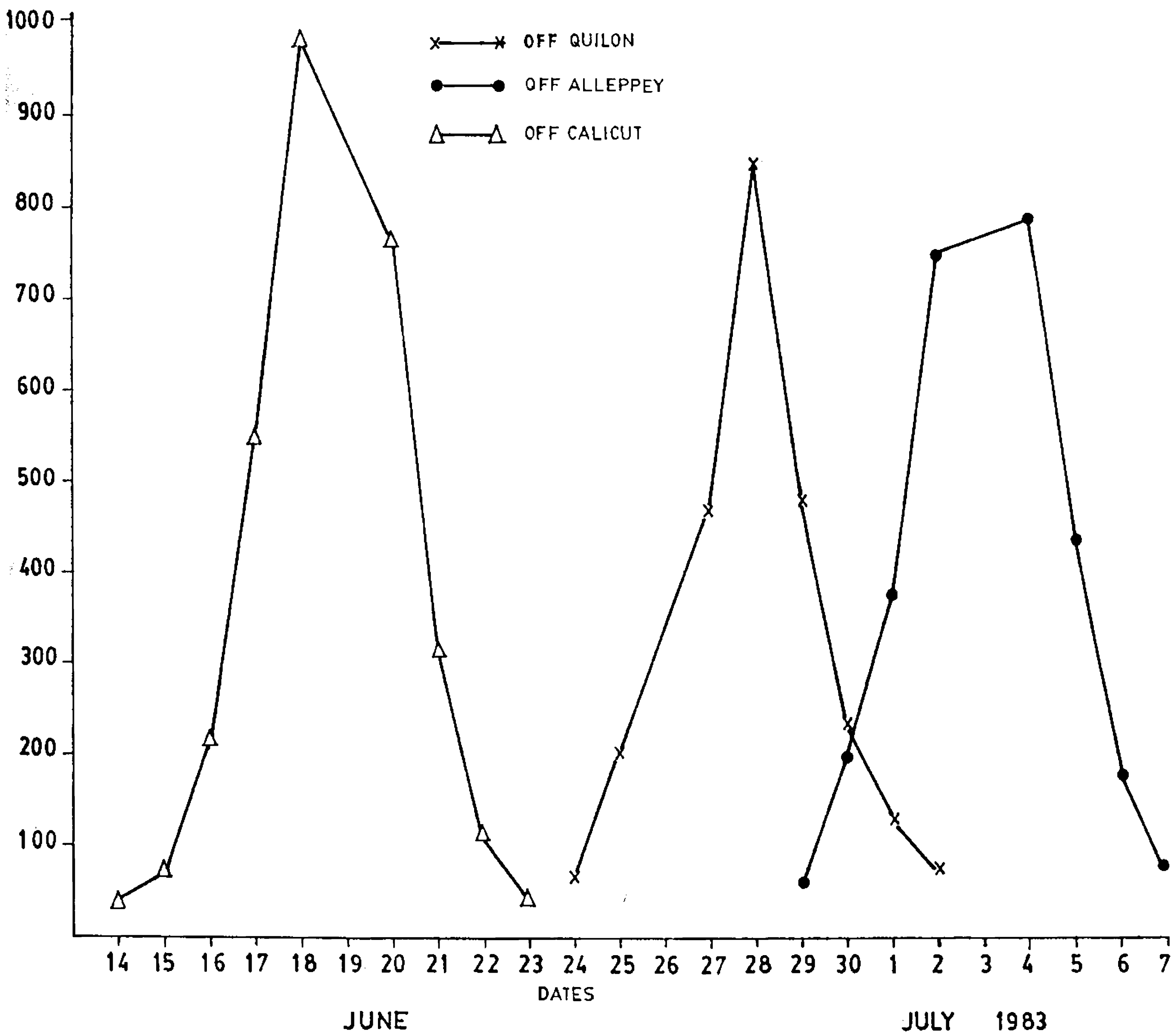
700
600
500
400
300
200
100
CELLS / ml
OFF QUILON
OFF ALLEPPEY
OFF CALICUT
26
27
28
29
30
31
1
2
DATES
MARCH
1983
APRIL

Fig. 11.

Table VIII. Cell counts of *Ceratium* spp. during the bloom period in 1983.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1983 March	26	-	40	50
	27	-	-	-
	28	86	264	336
	29	314	536	612
	30	626	482	684
	31	418	134	368
April	1	120	58	88
	2	40	-	-

Fig.12. Blooming pattern of Noctiluca miliaris Surirey during June to July 1983.



1000
900
800
700
600
500
400
300
200
100
OFF QUILON
OFF ALLEPPEY
OFF CALICUT
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7
DATES
JUNE
JULY 1983

Fig. 12.

Table IX. Cell counts of *Noctiluca miliaris* Suriray during the bloom period in 1983.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1983 June	14	-	-	40
	15	-	-	69
	16	-	-	212
	17	-	-	546
	18	-	-	984
	19	-	-	-
	20	-	-	765
	21	-	-	312
	22	-	-	108
	23	-	-	40
	24	58	-	-
	25	196	-	-
	26	-	-	-
	27	464	-	-
	28	842	-	-
	29	476	56	-
	30	228	198	-
July	1	128	372	-
	2	72	748	-
	3	-	-	-
	4	-	786	-
	5	-	432	-
	6	-	176	-
	7	-	78	-

<u>*Skeletonema costatum*</u> (Greville) Cleve

Between 5 to 6 fathoms from the same region a dark yellow to dirty yellow coloured diatom bloom of <u>*Skeletonema costatum*</u> (Greville) Cleve was studied between 26th August to 5th September 1983 (Fig.13). First it was seen off Calicut on 26th August to 2nd September. The cell counts increased from 40 cells/ml to 892 cells/ml. The following day i.e. on 27th August it appeared off Alleppey and was seen upto 3rd September, the cell counts ranged from 40 cells/ml to 860 cells/ml and off Quilon it was noted on 29th August and lasted upto 5th September. The cell counts varied from 40 cells/ml to 940 cells/ml (Table X). The 8 days bloom has got the appearance of streaks and patches and fishes were found swimming in that region.

<u>*Asterionella japonica*</u> Cleve and <u>*Thalassiothrix*</u> spp.

A muddy yellow colour was seen which was due to <u>*Asterionella japonica*</u> Cleve and <u>*Thalassiothrix*</u> spp. bloom from 17th October to 28th October 1983 (Fig.14). On 17th October it discoloured the off Quilon region and was studied upto 25th October and cell counts varied from 40 cells/ml to 842 cells/ml. On 18th October it was observed off Calicut and lasted upto 26th October and the cell counts ranged from

Fig.13. Blooming pattern of *Sceletonema costatum* (Greville) Cleve during August to September 1983.

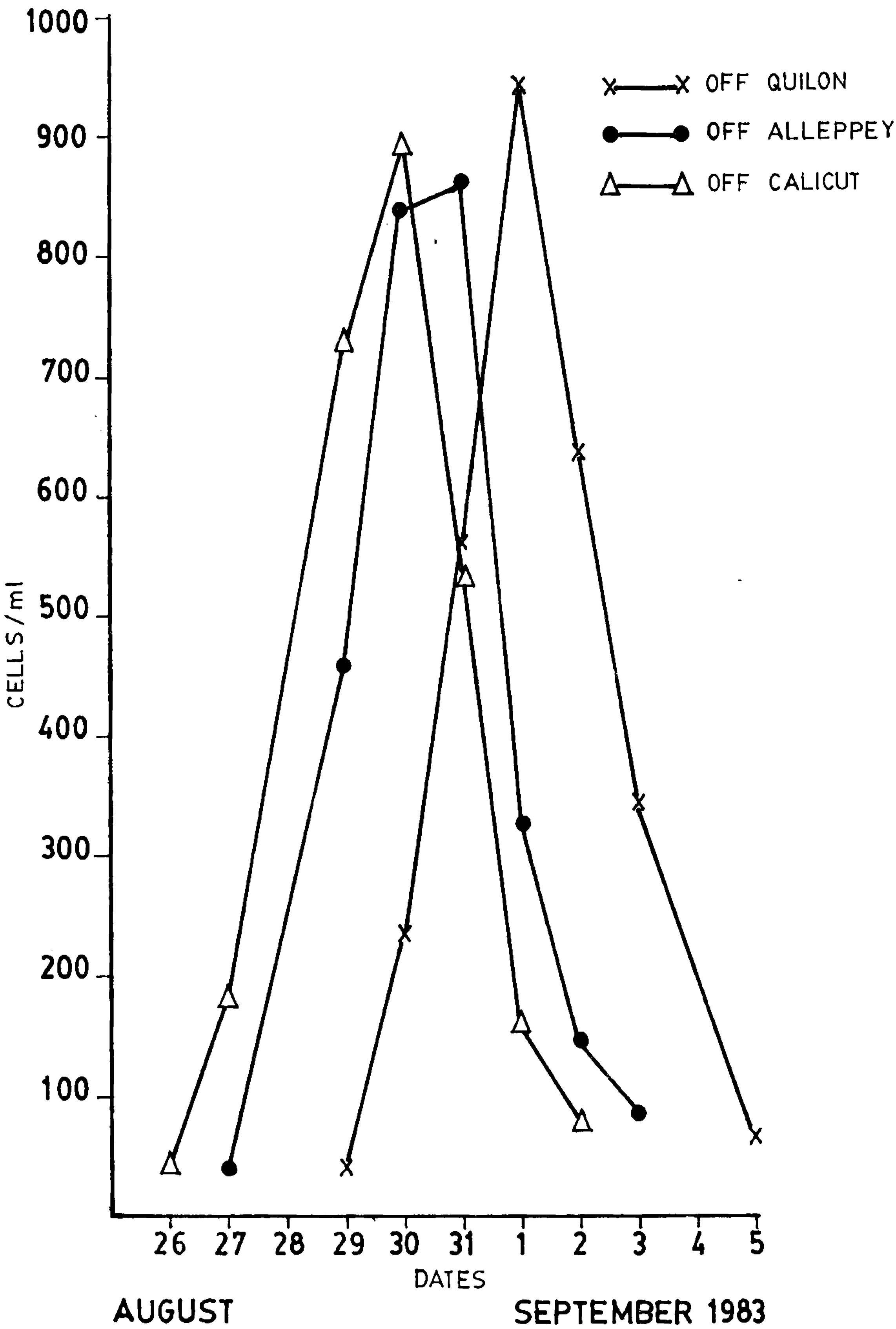

1000
900
800
700
600
500
400
300
200
100
CELLS/ml
OFF QUILON
OFF ALLEPPEY
OFF CALICUT
26
27
28
29
30
31
1
2
3
4
5
DATES
AUGUST
SEPTEMBER 1983

Fig. 13.

Table X. Cell counts of *Skeletonema costatum* (Greville) Cleve during the bloom period in 1983.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1983 August	26	-	-	40
	27	-	40	184
	28	-	-	-
	29	40	460	728
	30	234	840	892
	31	560	860	530
September	1	940	326	165
	2	638	146	78
	3	342	88	-
	4	-	-	-
	5	64	-	-

40 cells/ml to 754 cells/ml. From 20th October to 28th October it was seen off Alleppey; the cell counts increased from 40 cells/ml to 796 cells/ml (Table XI). The 9 days bloom appeared as streaks and patches and the fishes were found swimming freely in the bloom.

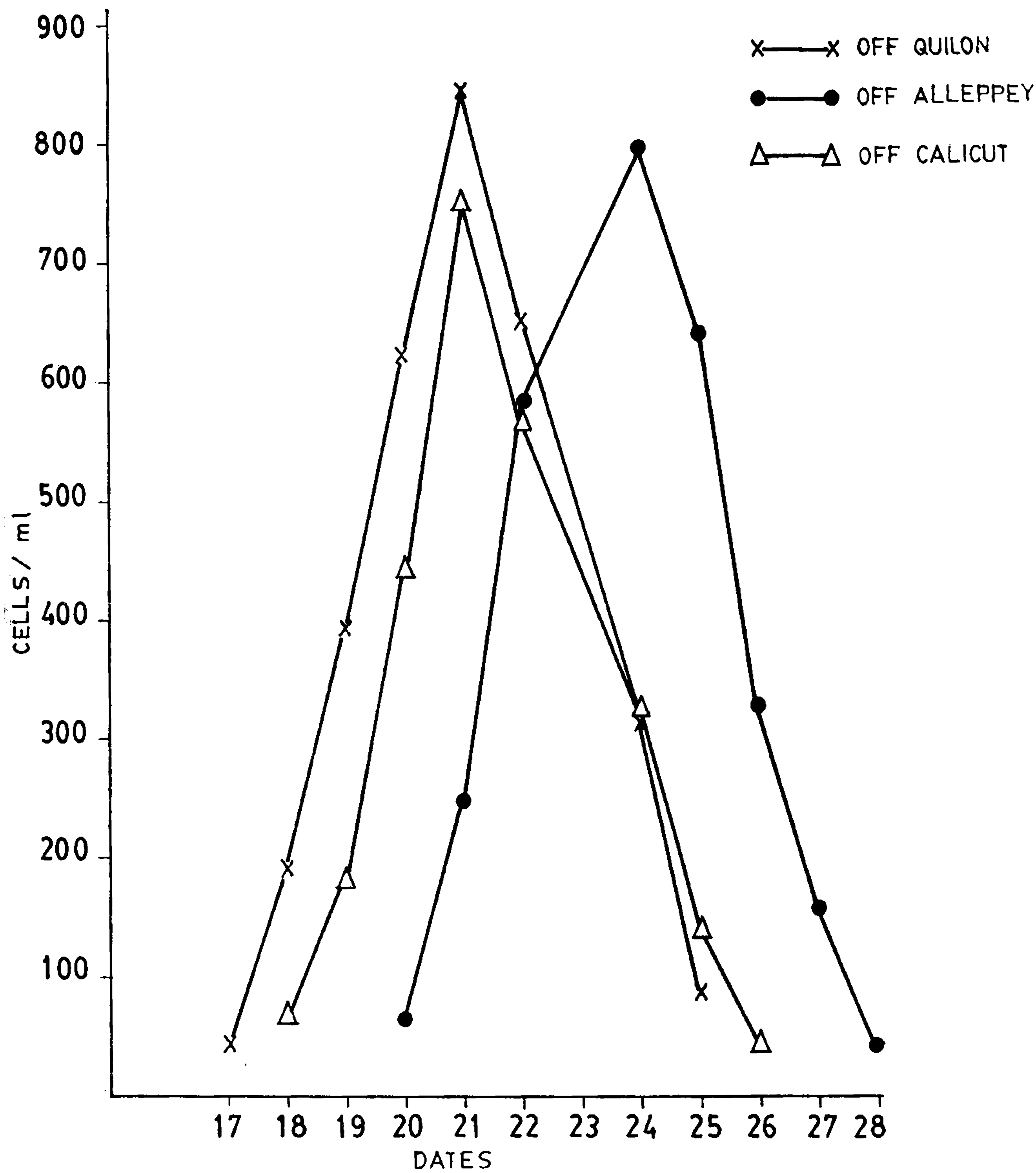
Coscinodiscus spp.

The organisms which imparted green colour between 5 to 6 fathoms was *Coscinodiscus* spp. which appeared from 14th November to 19th November 1983 (Fig.15). On 14th November to 18th November it was noted off Quilon. The cell counts increased from 58 cells/ml to 468 cells/ml. Simultaneously the same bloom was observed from 15th November to 19th November off Alleppey and off Calicut. Off Alleppey the cell counts ranged from 66 cells/ml to 464 cells/ml, off Calicut it was ranged from 68 cells/ml to 480 cells/ml (Table XII). The bloom was of shorter duration i.e. 5 days but like other blooms it was in the form of streaks and patches. Pelagic fishes were found swimming freely in the bloom.

Chaetoceros spp.

In December 1983 the organism constituting the formation of the bloom was *Chaetoceros* spp. It appeared from 12th December to 17th December (Fig.16). On 12th December it started appearing off Quilon and noted upto

Fig.14. Blooming pattern of _Asterionella japonica_ Cleve and _Thallassiothrix_ spp. during October 1983.



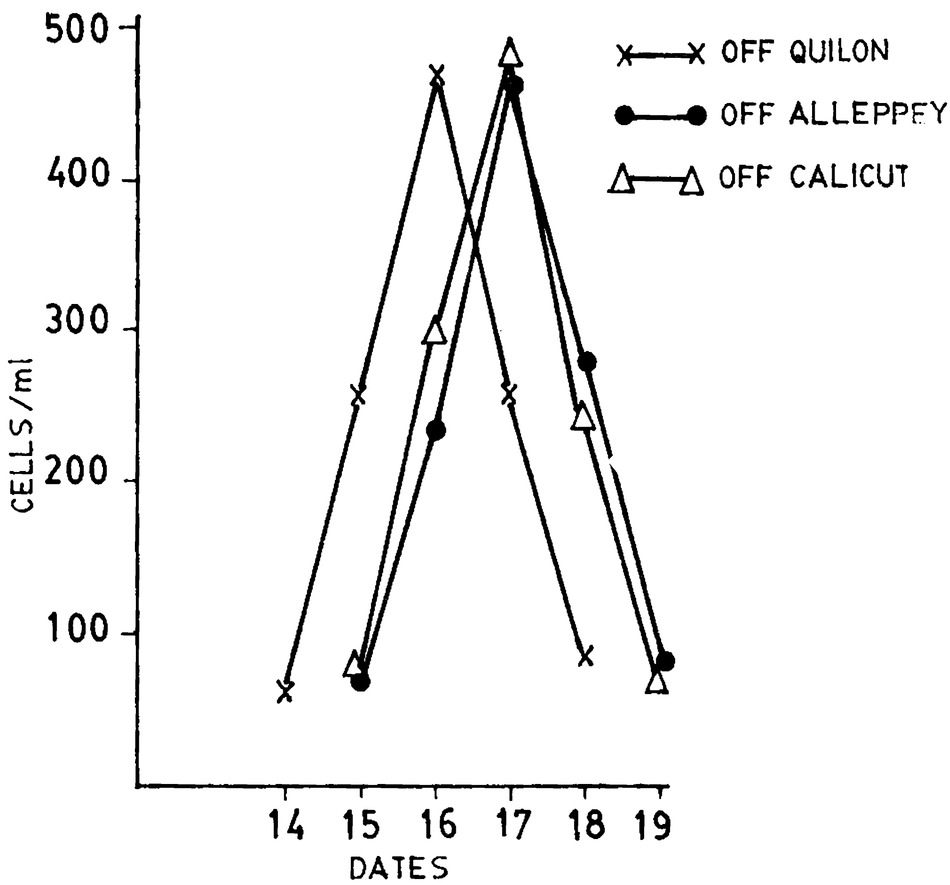
OCTOBER 1983

Fig.14.

Table XI. Cell counts of *Asterionella japonica* Cleve and *Thalassiothrix* spp. during the bloom period in 1983.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1983 October	17	40	-	-
	18	186	-	65
	19	394	-	180
	20	620	64	440
	21	842	246	754
	22	650	582	568
	23	-	-	-
	24	312	796	322
	25	84	640	140
	26	-	328	40
	27	-	158	-
	28	-	40	-

Fig.15. Blooming pattern of *Coscinodiscus* spp. during November 1983.



NOVEMBER 1983

Fig. 15.

Table XII. Cell counts of *Coscinodiscus* spp. during the bloom period in 1983.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1983 November	14	58	-	-
	15	254	66	72
	16	468	232	298
	17	252	464	480
	18	84	276	244
	19	-	80	68

16th December. The cell counts increased from 60 cells/ml to 464 cells/ml. On the same day it was observed off Alleppey also and was seen upto 16th December. The cell counts varied from 64 cells/ml to 480 cells/ml. But it was noted off Calicut only on 13th December to 17th December. The cell counts ranged between 72 cells/ml to 520 cells/ml (Table XIII). The streaks and patches were seem for 5 days and fishes were caught from that region.

Thus in 1983 seven phytoplankton blooms were studied. Out of these seven blooms only one blue green alga, two dinoflegellates and the remaining ones were diatom blooms. The studies relating to the observation of blooms was further carried out in 1984 also.

BLOOMS OF 1984

Biddulphia spp.

In January 1984 a diatom bloom of *Biddulphia* spp. appeared from 16th January to 23rd January (Fig.17). On 16th January it appeared off Alleppey and noted upto 21st January (6 days); the cell counts increased from 52 cells/ml to 486 cells/ml. Off Quilon it was seen on 17th January to 21st January (5 days); the cell counts increased from 56 cells/ml to 428 cells/ml. On 18th January to 23 January it was seen off Calicut (6 days), the cell counts ranged

Fig.16. Blooming pattern of *Chaetoceros* spp. during December 1983.

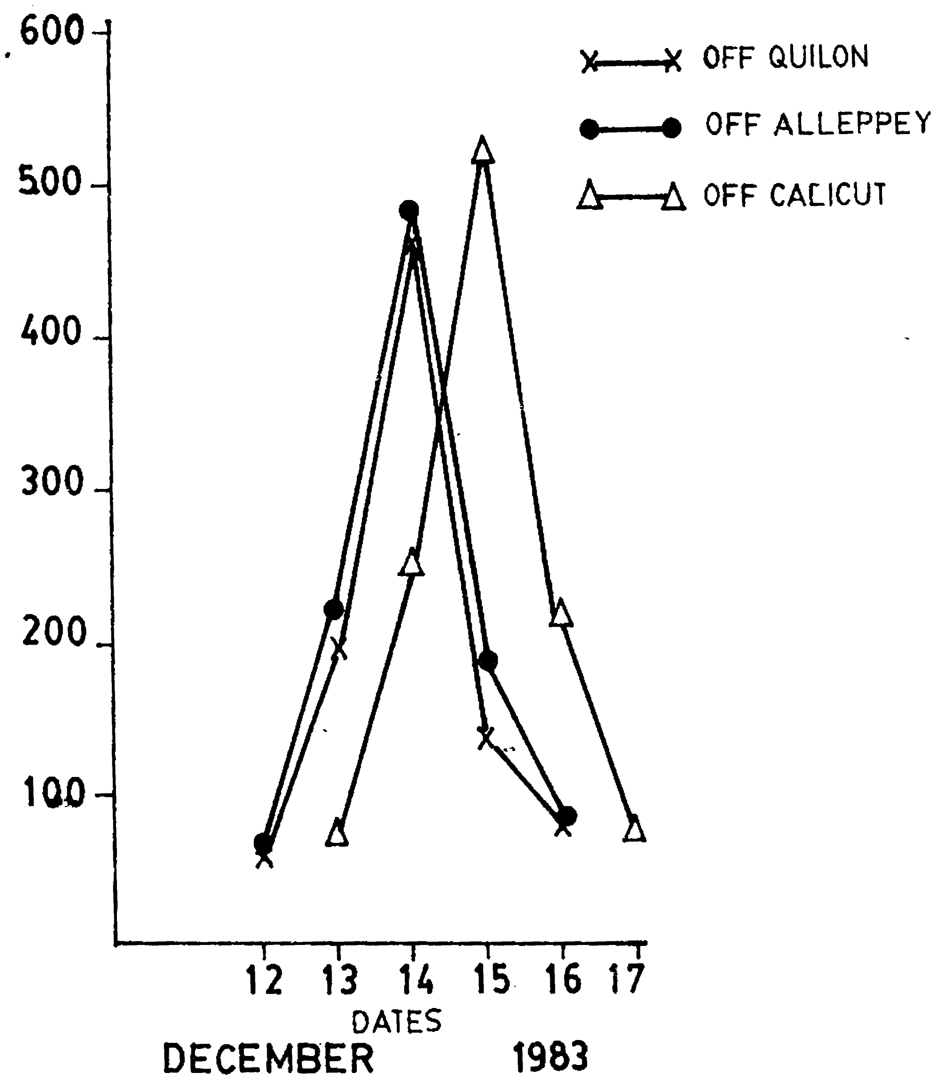

600
500
400
300
200
100
OFF QUILON
OFF ALLEPPEY
OFF CALICUT
12 13 14 15 16 17
DATES
DECEMBER 1983
Fig. 16.

Table XIII. Cell counts of *Chaetoceros* spp. during the bloom period in 1983.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1983 December	12	60	64	-
	13	196	220	72
	14	464	480	248
	15	132	186	520
	16	76	84	216
	17	-	-	72

from 58 cells/ml to 528 cells/ml (Table XIV). The bloom was noticed between 5 to 6 fathoms and lot of pelagic fishes were found swimming in that region.

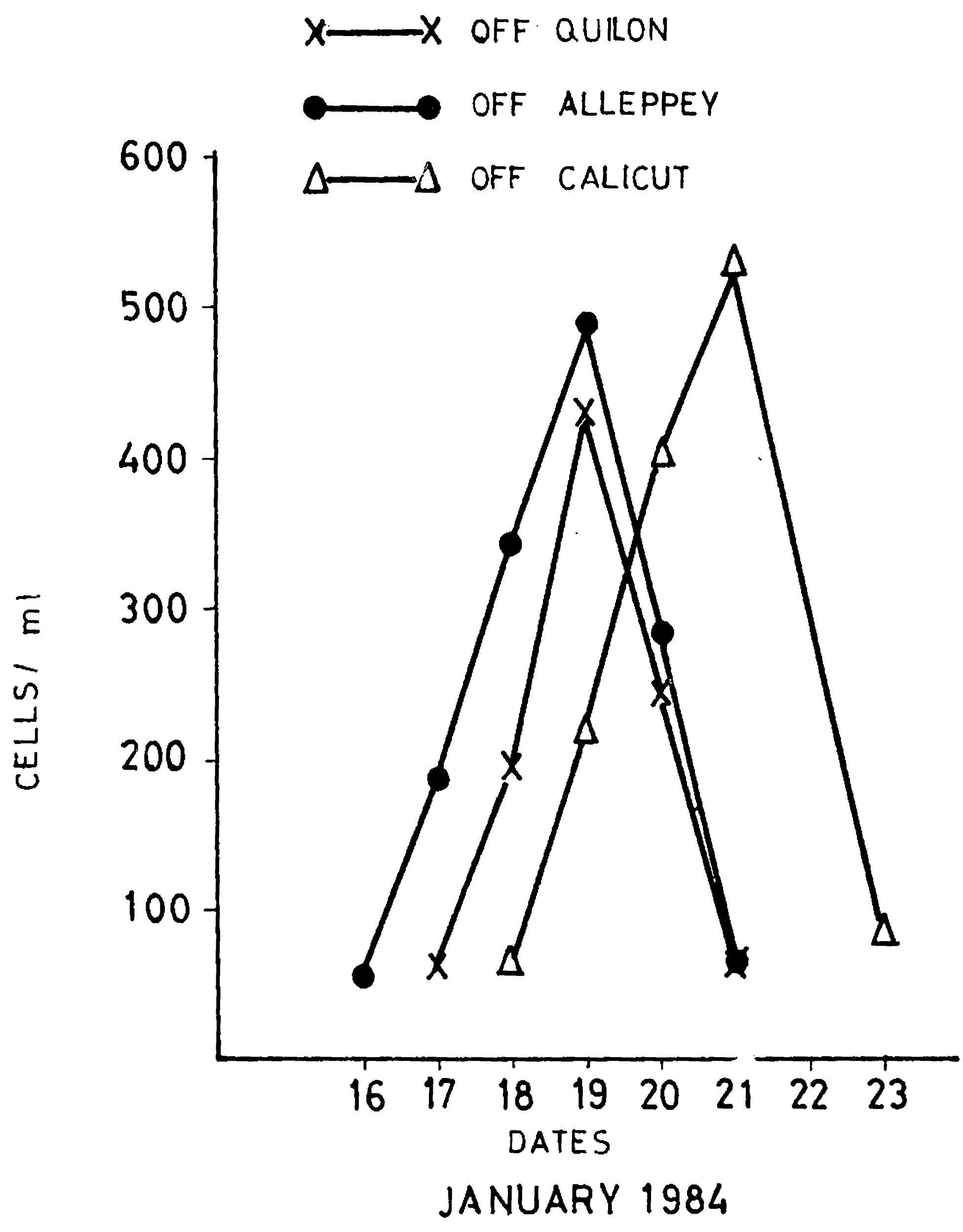
Cyclotella spp.

The light greenish coloured bloom of *Cyclotella* spp. appeared during 2nd February to 10th February 1984 (Fig.18). On 2nd February it was observed off Alleppey and studied upto 8th February. The cell counts ranged from 40 cells/ml to 452 cells/ml. The following day i.e. on 3rd February it was seen off Quilon and noted upto 9th February; the cell counts increased from 40 cells/ml to 682 cells/ml. On 4th February to 10th February it was noted off Calicut. The cell counts were between 40 cells/ml to 632 cell/ml (Table XV). The 7 days bloom was observed between 6 to 7 fathoms. Lot of pelagic fishes were found swimming in the bloom region.

Coscinodiscus spp.

A bloom of diatom *Coscinodiscus* spp. was observed from 13th February to 22nd February 1984 (Fig.19). On 13th February it was seen off Alleppey and lasted upto 20th February. The cell counts were between 40 cells/ml to 638 cells/ml. On 14th February to 21st February it was studied off Quilon; the cell counts increased from 52 cells/ml to

Fig.17. Blooming pattern of *Biddulphia* spp. during January 1984.



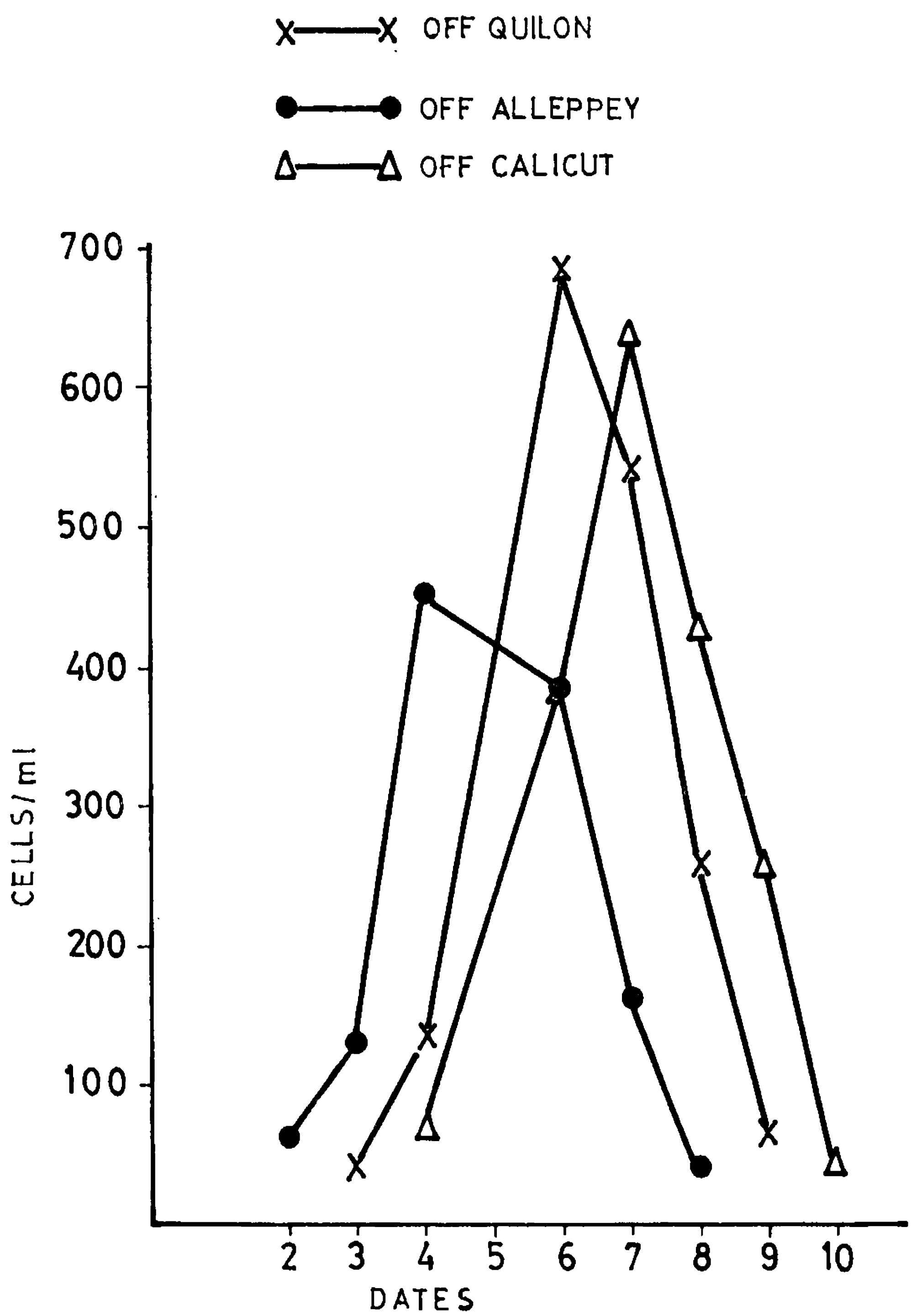
X——X OFF QUILON
●——● OFF ALLEPPEY
Δ——Δ OFF CALICUT
600
500
400
300
200
100
CELLS/ ml
16
17
18
19
20
21
22
23
DATES
JANUARY 1984

Fig. 17.

Table XIV. Cell counts of *Biddulphia* spp. during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 January	16	-	52	-
	17	58	186	-
	18	192	344	58
	19	428	486	214
	20	242	281	396
	21	56	64	528
	22	-	-	-
	23	-	-	78

Fig.18. Blooming pattern of Cyclotella spp. during February 1984.



FEBRUARY 1984

Fig. 18.

Table XV. Cell counts of *Cyclotella* spp. during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 February	2	-	64	-
	3	40	128	-
	4	134	452	62
	5	-	-	-
	6	682	386	384
	7	540	160	632
	8	258	40	420
	9	62	-	254
	10	-	-	40

662 cells/ml. On 15th February to 22nd February it was noted off Calicut. The cell counts varied from 40 cells/ml to 586 cells/ml (Table XVI). The 8 days bloom was observed in the 8 fathoms. The bloom was favourable to the pelagic fishes.

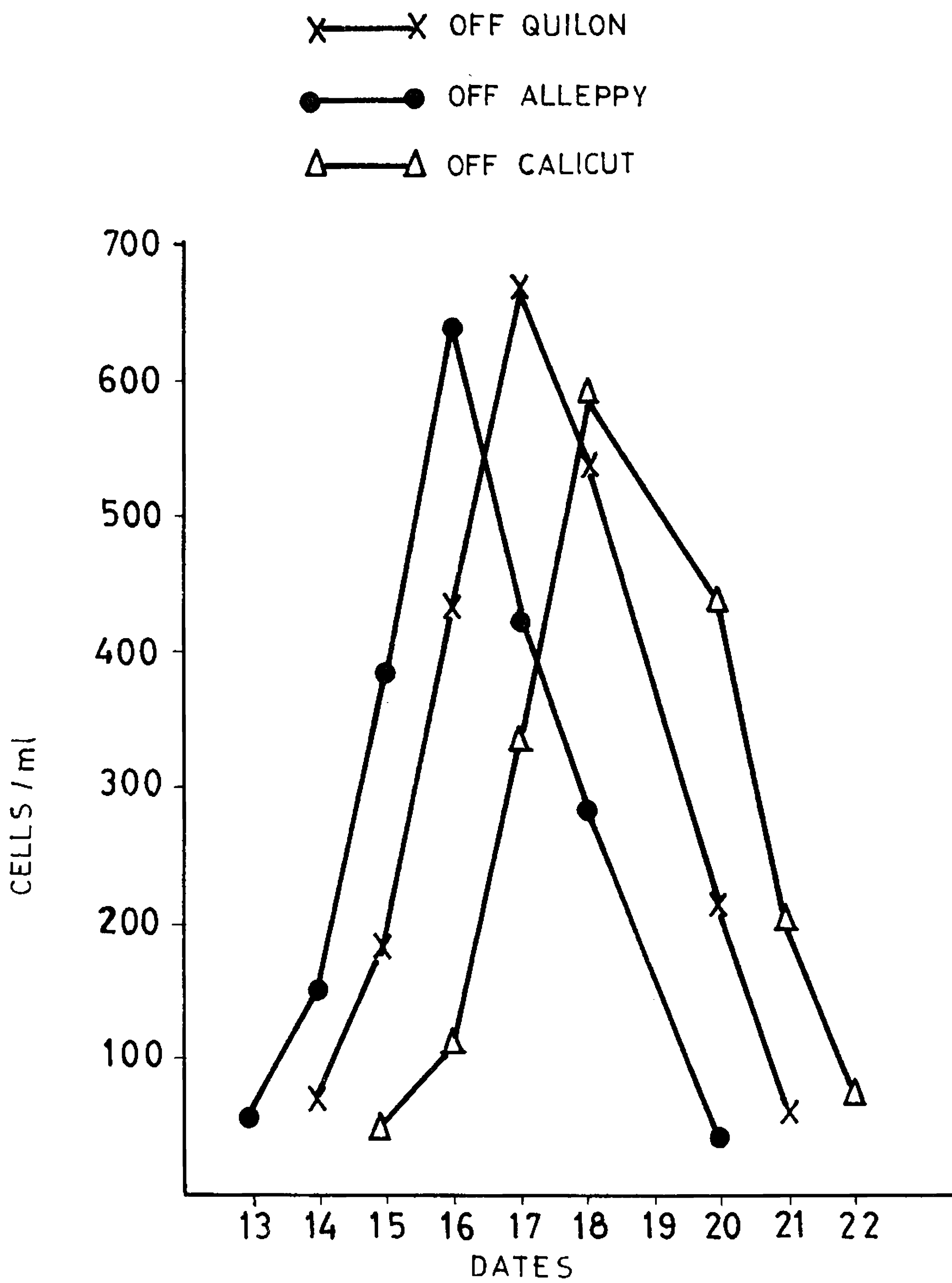
Biddulphia spp.

A bloom of Biddulphia spp. was noticed in the same region from 6th March to 14th March 1984 (Fig.20). On 6th March it was observed off Alleppey and noted upto 12th March. The cell counts were between 55 cells/ml to 712 cells/ml. On 7th March to 13th March it was seen off Quilon; the cell counts increased from 40 cells/ml to 756 cells/ml. On 8th March to 14th March it was studied off Calicut and the cell counts varied from 40 cells/ml to 540 cells/ml (Table XVII). The 7 days bloom was noticed between 5 to 6 fathoms and lot of pelagic fishes were found swimming in that region.

Trichodesmium spp.

During March 1984 a red tide appeared from 22nd March to 27th March (Fig.21). On 22nd March it appeared off Alleppey and off Calicut. Off Alleppey it was seen upto 26th March. The 5 days bloom showed the cell counts between 62 cells/ml to 714 cells/ml. Off Calicut it was observed upto 27th March (6 days) and the cell counts ranged

Fig.19. Blooming pattern of *Coscinodiscus* spp. during February 1984.



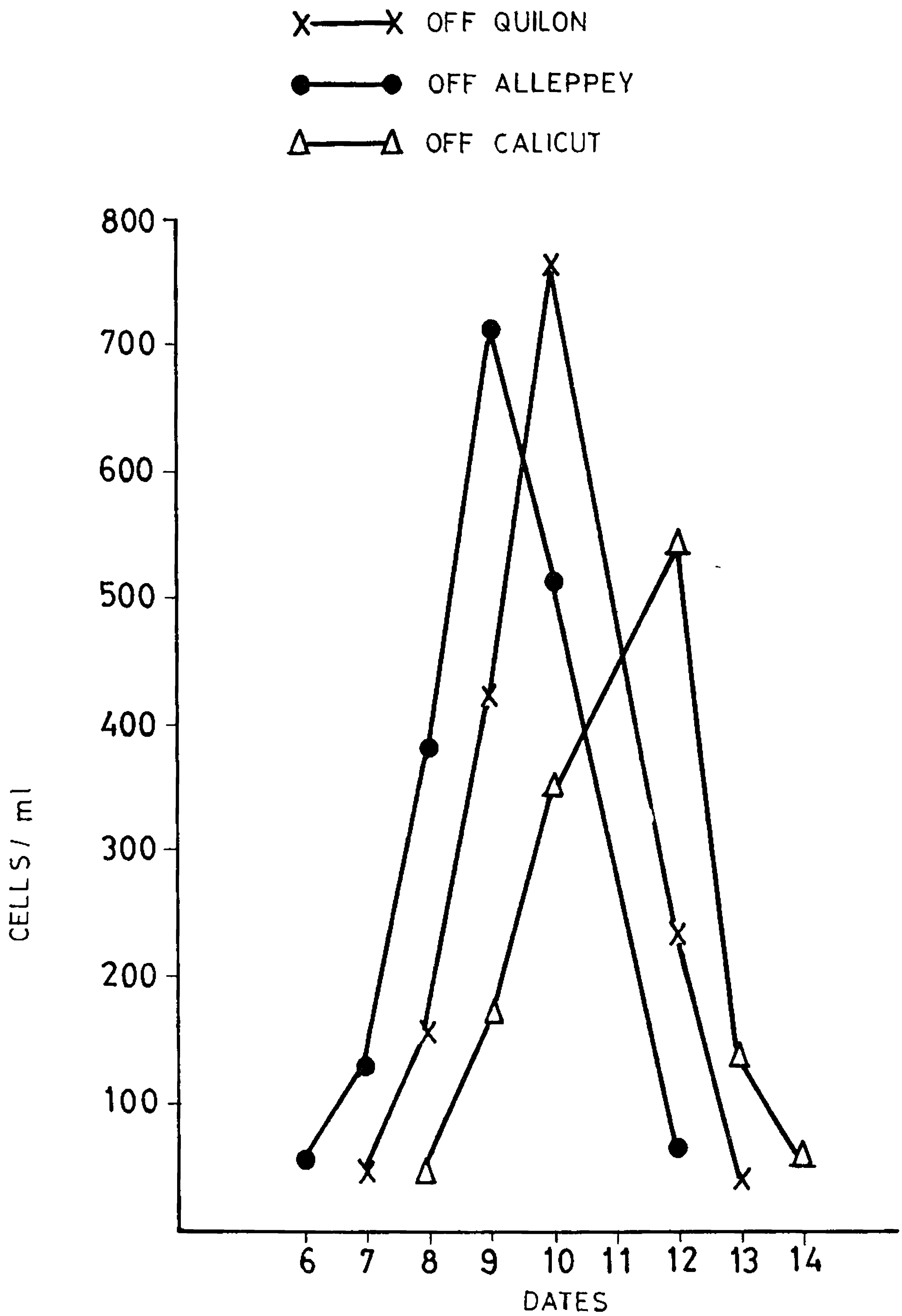
FEBRUARY 1984

Fig. 19.

Table XVI. Cell counts of *Coscinodiscus* spp. during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 February	13	-	52	-
	14	64	146	-
	15	180	382	40
	16	428	638	104
	17	662	424	328
	18	535	282	586
	19	-	-	-
	20	210	40	430
	21	52	-	198
	22	-	-	68

Fig.20. Blooming pattern of *Biddulphia* spp.
during March 1984.



MARCH 1984

Fig. 20.

Table XVII. Cell counts of *Biddulphia* spp. during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 March	6	-	55	-
	7	40	128	-
	8	154	384	40
	9	420	712	164
	10	756	510	348
	11	-	-	-
	12	230	68	540
	13	40	-	130
	14	-	-	54

from 40 cells/ml to 788 cells/ml. Off Quilon the 5 days bloom appeared from 23rd March to 27th March and the cell counts increased from 40 cells/ml to 620 cells/ml (Table XVIII). The light pinkish patches was observed between 6 to 7 fathoms and pelagic fishes were found swimming freely in the bloomed region.

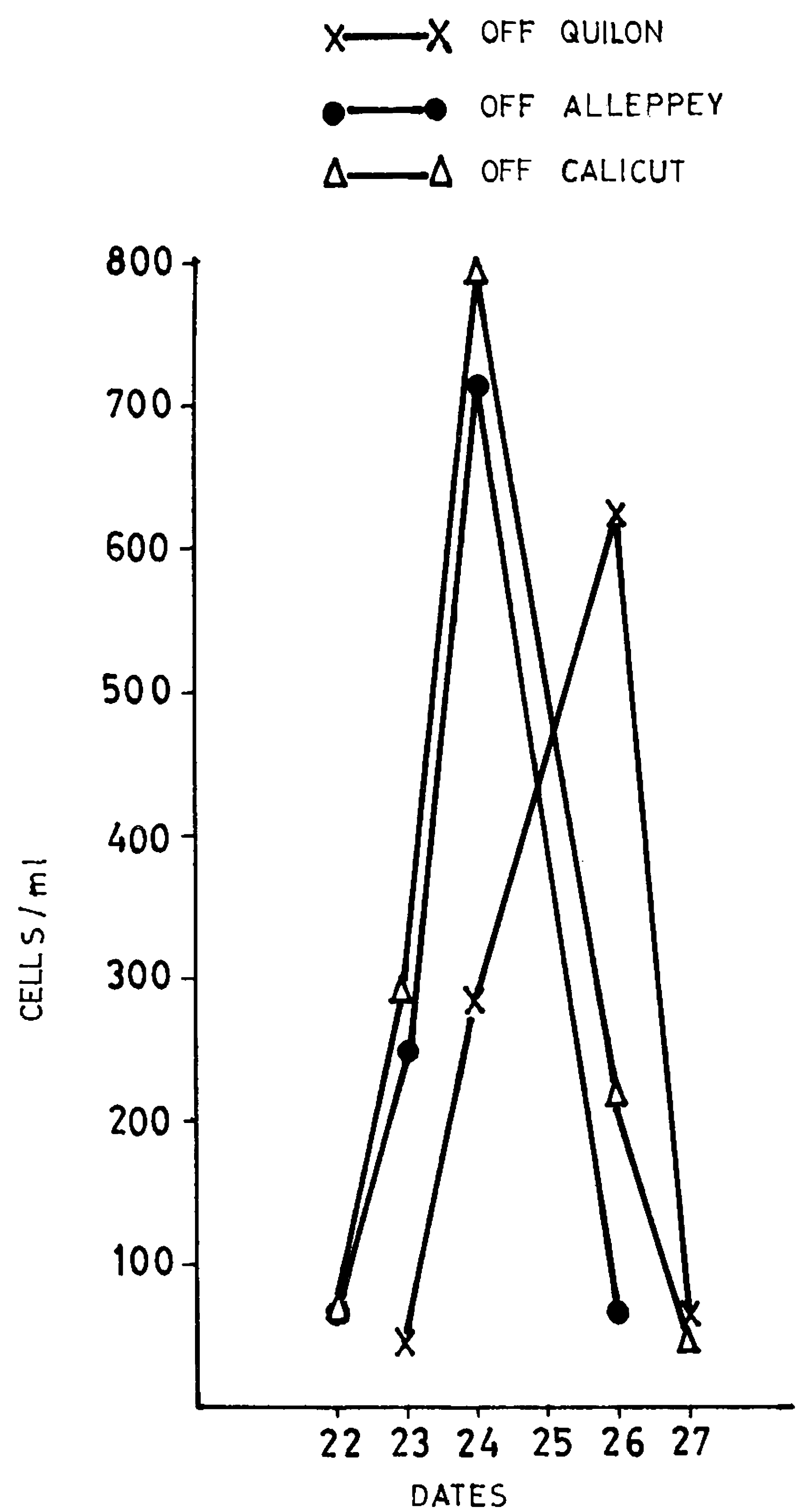
Peridinium spp.

The red tide of *Peridinium* spp. appeared from 14th April to 23rd April 1984 (Fig.22). First it appeared off Quilon on 14th April to 20th April (7 days). The cell counts were between 56 cells/ml to 540 cells/ml. On 16th April to 21st April (6 days) it was observed off Alleppey; the cell counts increased from 40 cells/ml to 582 cells/ml. Off Calicut it was seen from 17th April to 23rd April (7 days). The cell counts were between 40 cells/ml to 560 cells/ml (Table XIX). Dark brownish colour was observed between 6 to 7 fathoms and like the earlier observation fishes avoided the bloom area.

Fragilaria oceanica Cleve

A diatom bloom of *Fragilaria oceanica* Cleve was studied on 27th April to 3rd May 1984 (Fig.23). On 27th April to 2nd May it was seen off Quilon and off Alleppey. Off Quilon the cell counts increased from 54 cells/ml to

Fig.21. Blooming pattern of *Trichodesmium* spp. during March 1984.



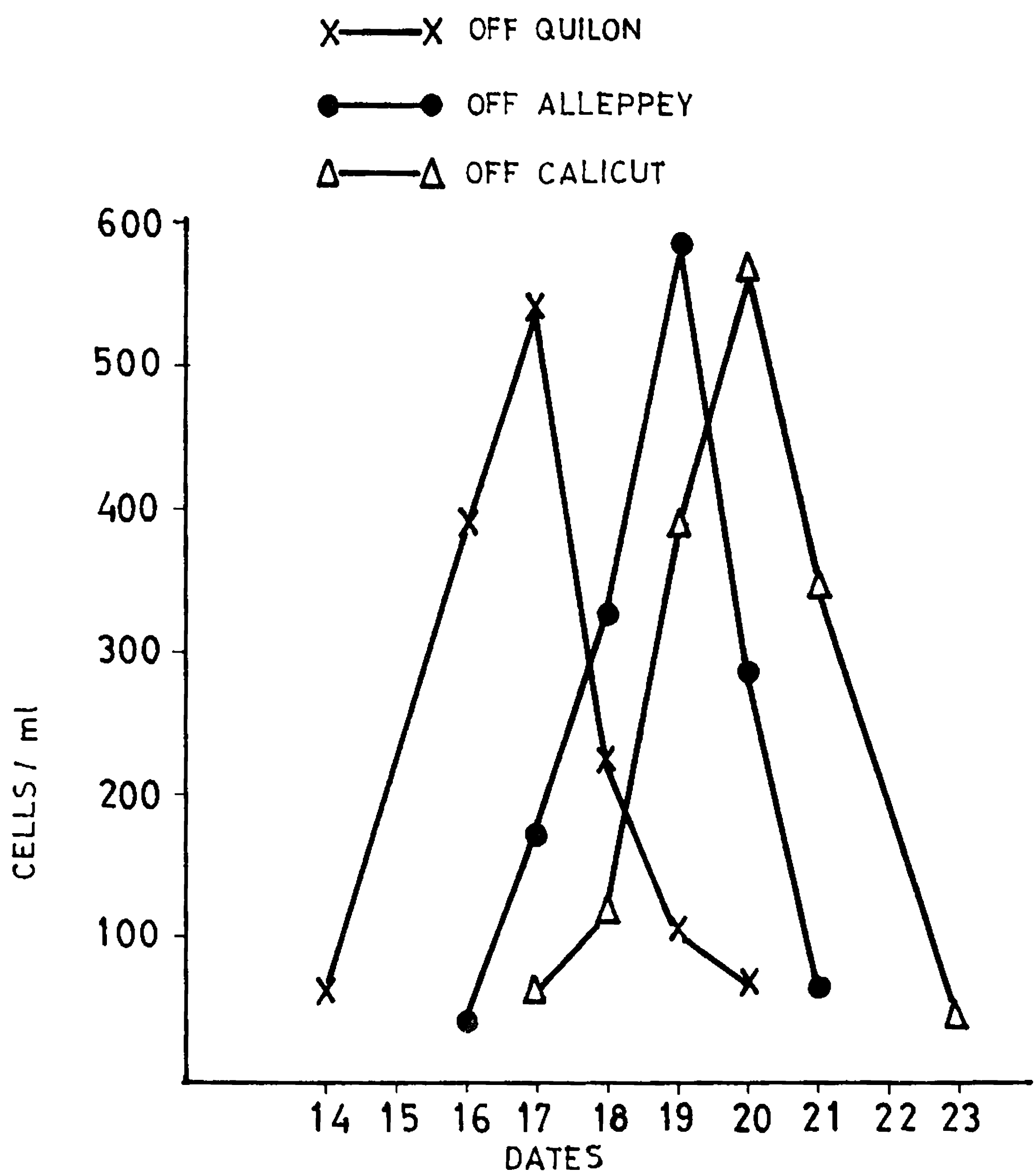
MARCH 1984

Fig. 21.

Table XVIII. Cell counts of *Trichodesmium* spp. during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 March	22	-	62	64
	23	40	248	280
	24	280	714	788
	25	-	-	-
	26	620	66	210
	27	70	-	40

Fig.22. Blooming pattern of *Peridinium* spp. during April 1984.



APRIL 1984

Fig. 22.

Table XIX. Cell counts of *Peridinium* spp. during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 April	14	56	-	-
	15	-	-	-
	16	388	40	-
	17	540	174	58
	18	224	326	162
	19	102	582	384
	20	68	288	560
	21	-	64	340
	22	-	-	-
	23	-	-	40

628 cells/ml. Off Alleppey the cell counts ranged from 40 cells/ml to 568 cells/ml. Off Calicut the bloom appeared from 28th April to 3rd May. The cell counts were between 52 cells/ml to 628 cells/ml (Table XX). The 6 days bloom was seen between 6 to 7 fathoms and appeared as light greenish patch. Lot of pelagic fishes were seen in the bloomed region.

Rhizosolenia spp.

The Rhizosolenia spp. bloom was observed during 22nd May to 30th May 1984 (Fig.24). On 22nd May to 28th May it was seen off Quilon and the cell counts ranged between 40 cells/ml to 768 cells/ml. On 23rd May to 29th May it was observed off Alleppey and the cell counts were between 40 cells/ml to 834 cells/ml. Off Calicut it appeared from 24th May to 30th May. The cell counts increased from 40 cells/ml to 520 cells/ml (Table XXI). The 7 days dirty yellow coloured bloom appeared between 5 to 6 fathoms. Fishes were found swimming freely in that region.

Pyxidicula minuta Grunow

The Pyxidicula minuta Grunow bloom was noted on 7th June to 14th June 1984 (Fig.25). On 7th June to 12th June it was noted off Calicut and the cell counts were between 55 cells/ml to 440 cells/ml. On 8th June to 13th June it was studied off Alleppey and the cell counts x

Fig.23. Blooming pattern of *Fragilaria oceanica* Cleve during April to May 1984.

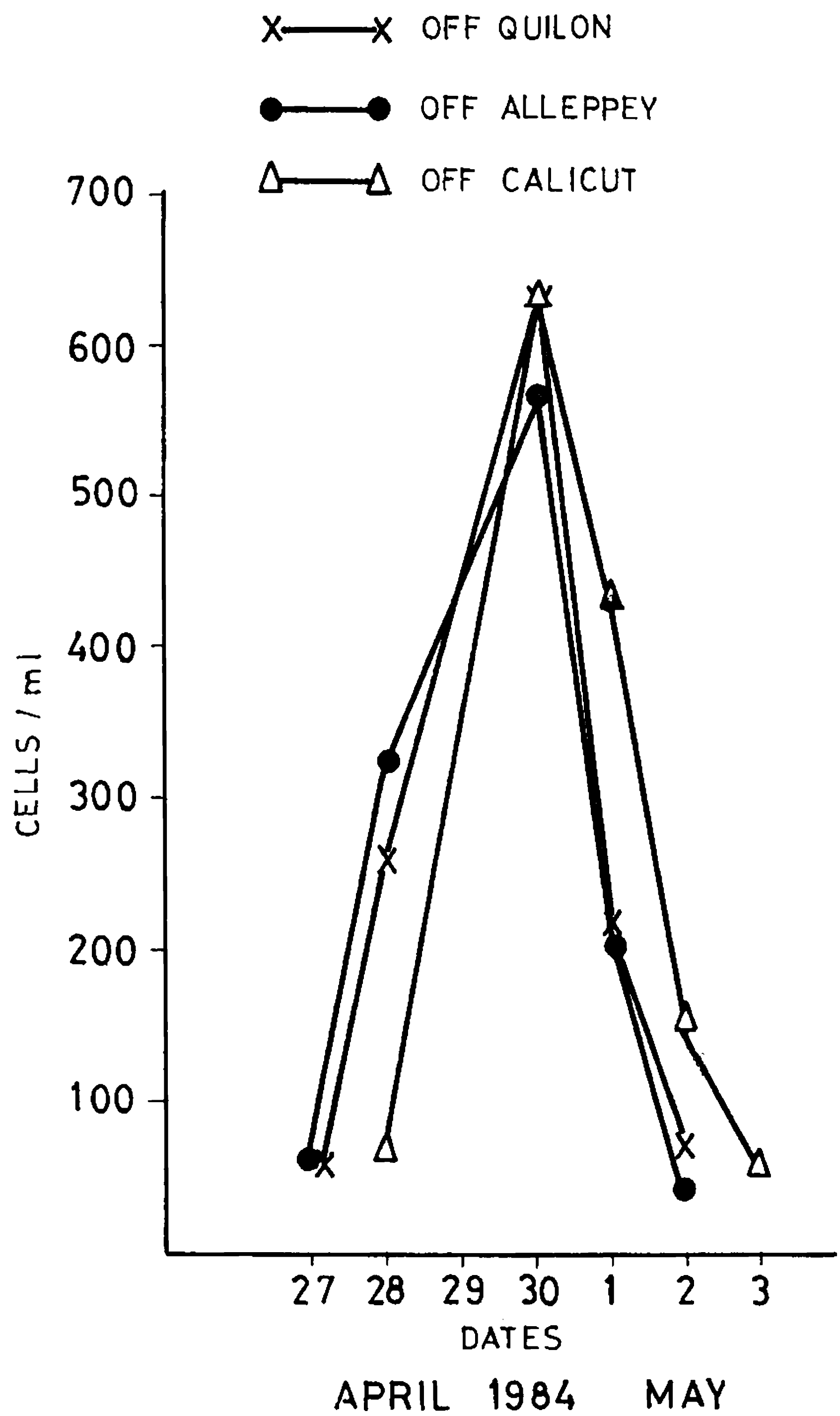
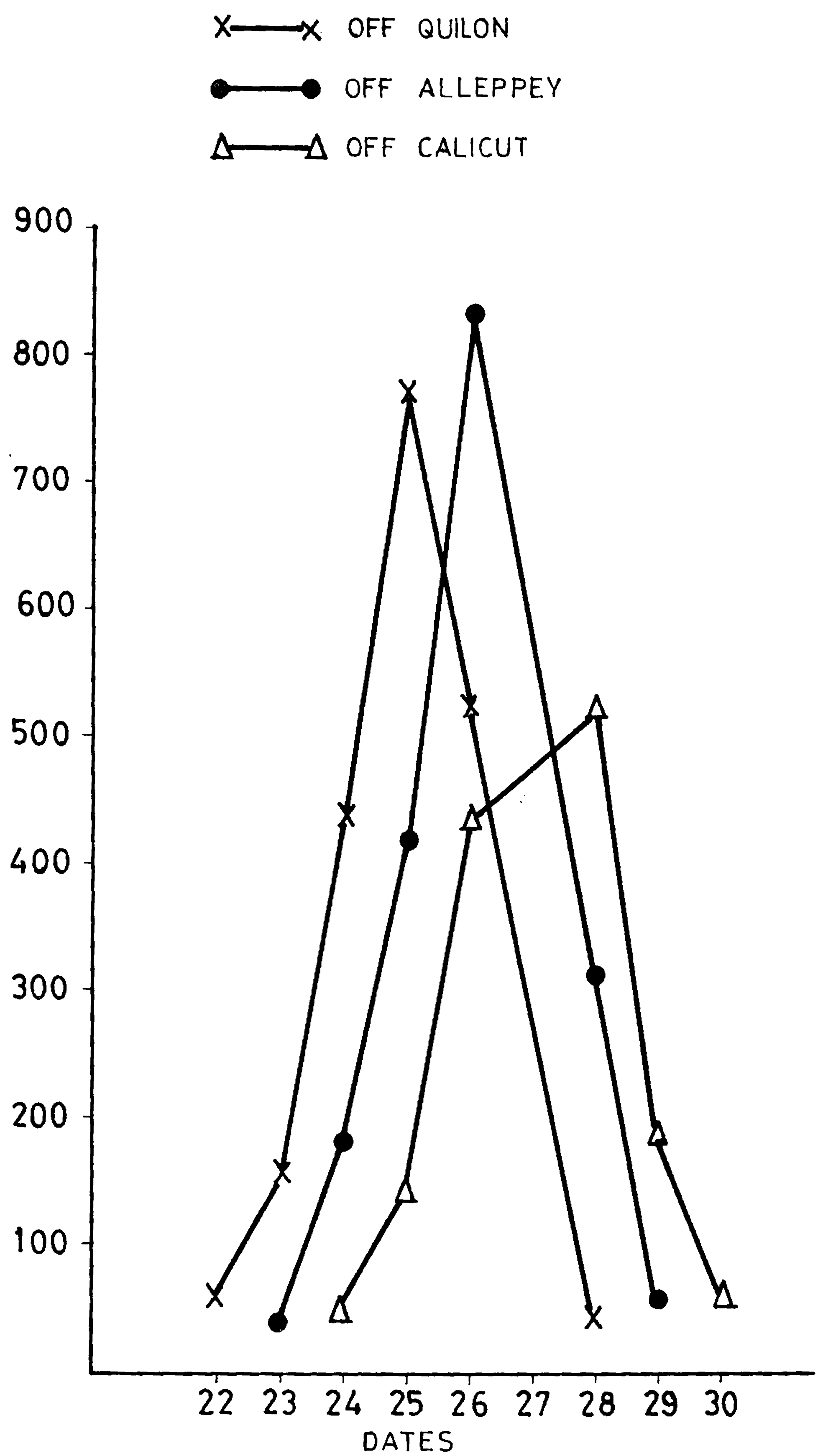

OFF QUILON
OFF ALLEPPEY
OFF CALICUT
700
600
500
400
300
200
100
CELLS / ml
27 28 29 30 1 2 3
DATES
APRIL 1984 MAY

Fig. 23.

Table XX. Cell counts of *Fragilaria oceanica* Cleve during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 April	27	54	58	-
	28	256	324	60
	29	-	-	-
	30	628	568	628
May	1	212	204	430
	2	68	40	150
	3	-	-	52

Fig.24. Blooming pattern of _Rhizosolenia_ spp. during May 1984.



MAY 1984

Fig. 24.

Table XXI. Cell counts of *Rhizosolenia* spp. during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 May	22	58	-	-
	23	154	40	-
	24	432	180	40
	25	768	420	138
	26	524	834	430
	27	-	-	-
	28	40	312	520
	29	-	56	184
	30	-	-	55

from 54 cells/ml to 638 cells/ml. On 9th June to 14th June it was observed off Quilon and the cell counts varied from 58 cells/ml to 676 cells/ml (Table XXII). The 6 days bloom appeared between 5 to 6 fathoms and the colour being greenish. Pelagic fishes were seen in the bloomed region.

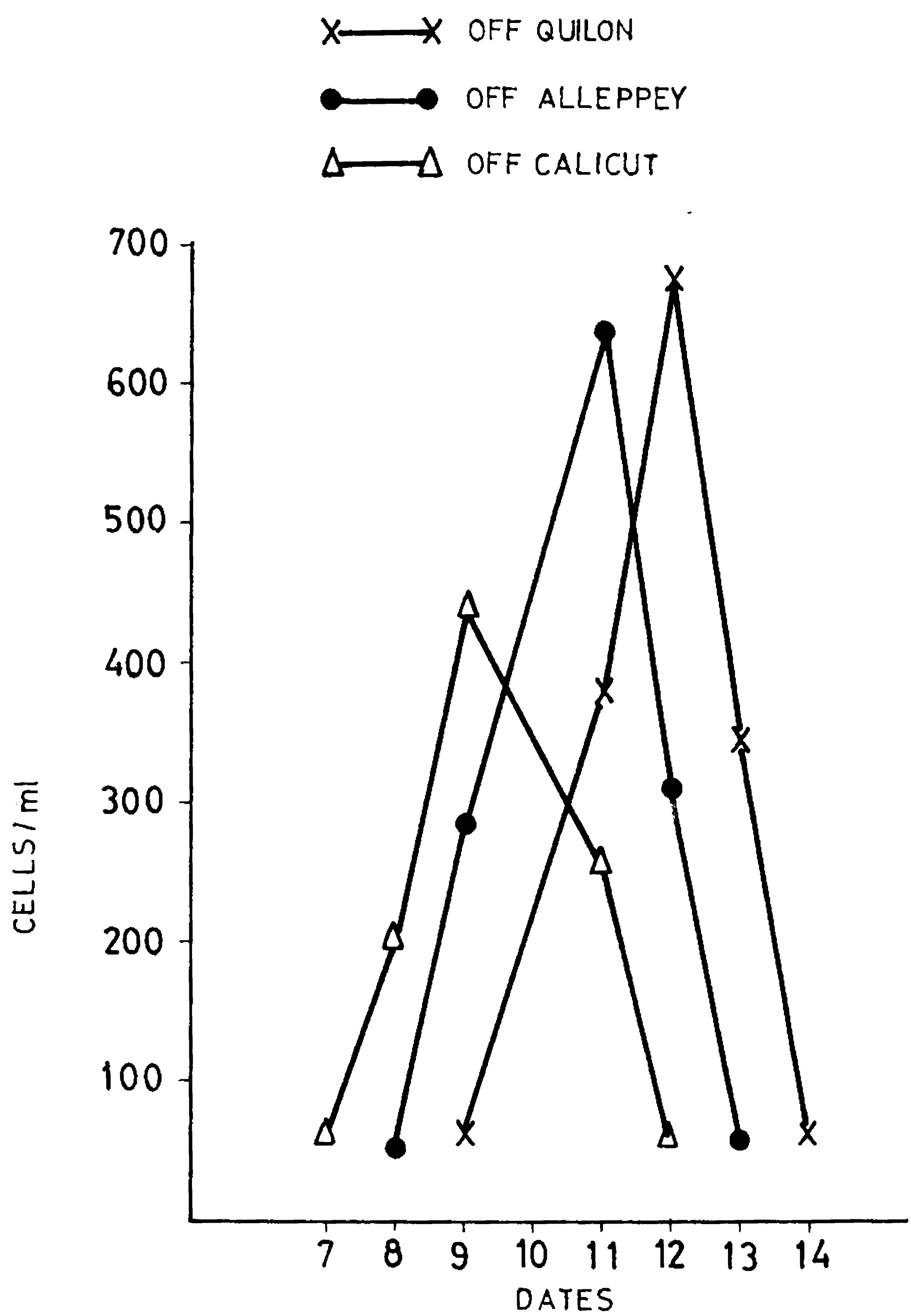
Asterionella japonica Cleve

The yellowish coloured bloom of *Asterionella japonica* Cleve occurred on 27th June to 4th July 1984 (Fig.26). First it appeared off Quilon on 27th June to 3rd July. The cell counts increased from 40 cells/ml to 580 cells/ml. On 28th June it was seen off Alleppey and lasted upto 4th July; the cell counts were between 40 cells/ml to 564 cells/ml. Off Calicut also it was noted from 28th June to 4th July and the cell counts ranged from 55 cells/ml to 512 cells/ml (Table XXIII). The 7 days bloom appeared between 5 to 6 fathoms. Pelagic fishes were found swimming in the bloomed region.

Triceratium spp.

A bloom of diatom *Triceratium* spp. appeared during 19th July to 26th July 1984 (Fig.27). First it appeared off Calicut on 19th July to 25th July. The cell counts increased from 40 cells/ml to 426 cells/ml. On 20th July to 26th July it was studied off Quilon and off Alleppey.

Fig.25. Blooming pattern of *Pyxidicula minuta* Grunow during June 1984.



JUNE 1984

Fig. 25.

Table XXII. Cell counts of *Pyxidicula minuta* Grunow during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 June	7	-	-	56
	8	-	54	198
	9	58	286	440
	10	-	-	-
	11	380	638	250
	12	676	312	55
	13	348	58	-
	14	60	-	-

Fig.26. Blooming pattern of *Asterionella japonica* Cleve during June to July 1984.

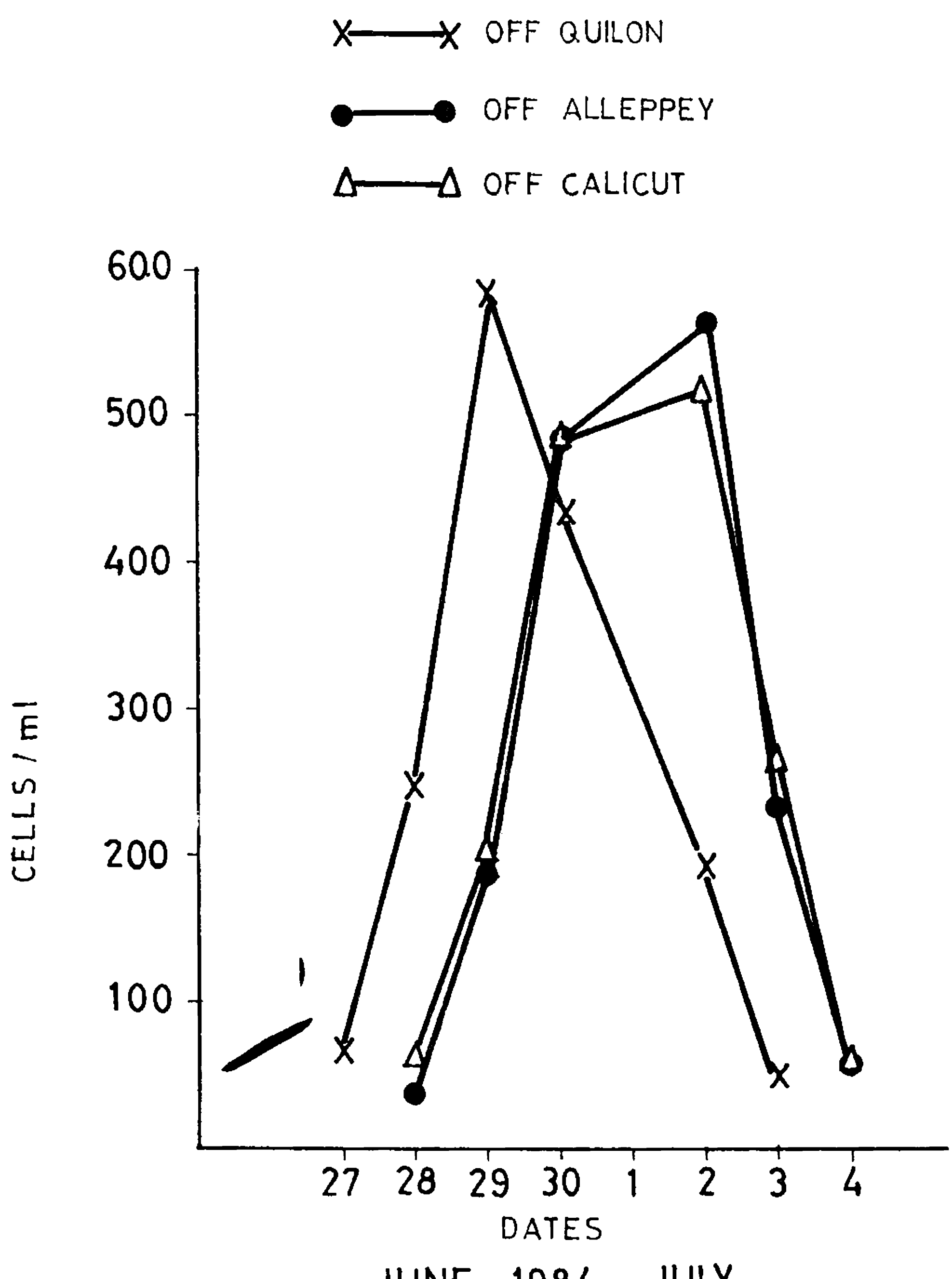

OFF QUILON
OFF ALLEPPEY
OFF CALICUT
600
500
400
300
200
100
CELLS / ml
27
28
29
30
1
2
3
4
DATES
JUNE 1984 JULY

Fig. 26.

Table XXIII. Cell counts of *Asterionella japonica* Cleve during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 June	27	60	-	-
	28	248	40	55
	29	580	190	196
	30	432	486	482
July	1	-	-	-
	2	186	564	512
	3	40	232	260
	4	-	58	58

off Quilon the cell counts varied from 56 cells/ml to 682 cells/ml; off Alleppey the cell counts ranged from 40 cells/ml to 632 cells/ml (Table XXIV). The 7 days bloom appeared as greenish yellow and it was seen between 6 to 7 fathoms. Lot of pelagic fishes were found swimming in that region.

Pyxidicula minuta Grunow and *Coscinodiscus spp.*

During the month of August 1984 a mixed diatom bloom of *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. appeared from 8th August to 16th August (Fig.28). First it was noted off Calicut on 8th August to 14th August. The cell counts ranged from 40 cells/ml to 580 cells/ml. The following day i.e. on 9th August to 15th August it was noted off Alleppey and the cell counts varied from 40 cells/ml to 470 cells/ml. On 10th August to 16th August it was noted off Quilon and the cell counts increased from 40 cells/ml to 522 cells/ml (Table XXV). The 7 days bloom appeared as greenish yellow and it was seen between 6 to 7 fathoms. *Pyxidicula minuta* Grunow is generally dominated when compared to *Coscinodiscus* spp. in all the three centres. Pelagic fishes were found swimming freely in the streaks and patches of the bloom.

It can be concluded that;

Fig.27. Blooming pattern of *Triceratium* spp. during July 1984.

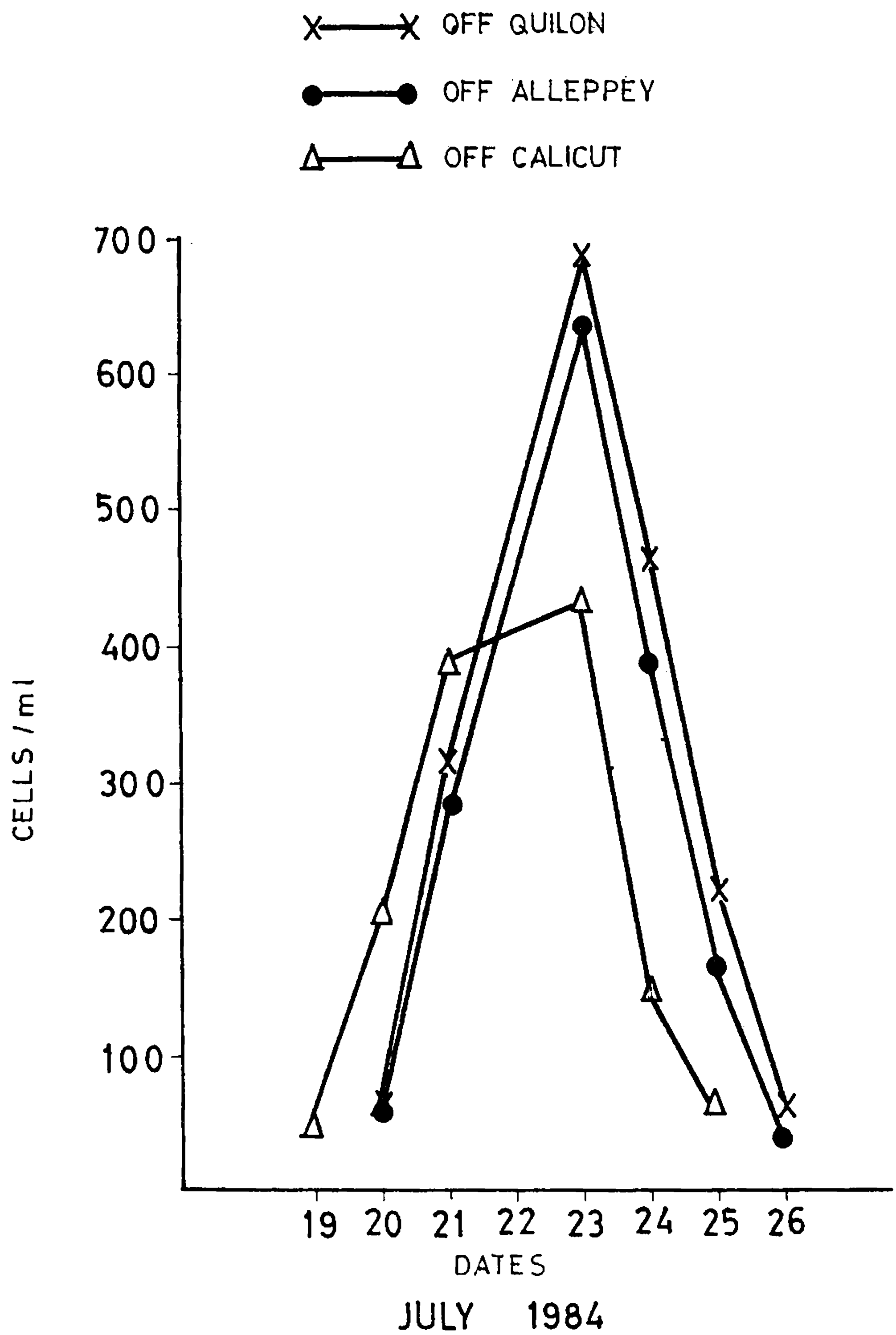
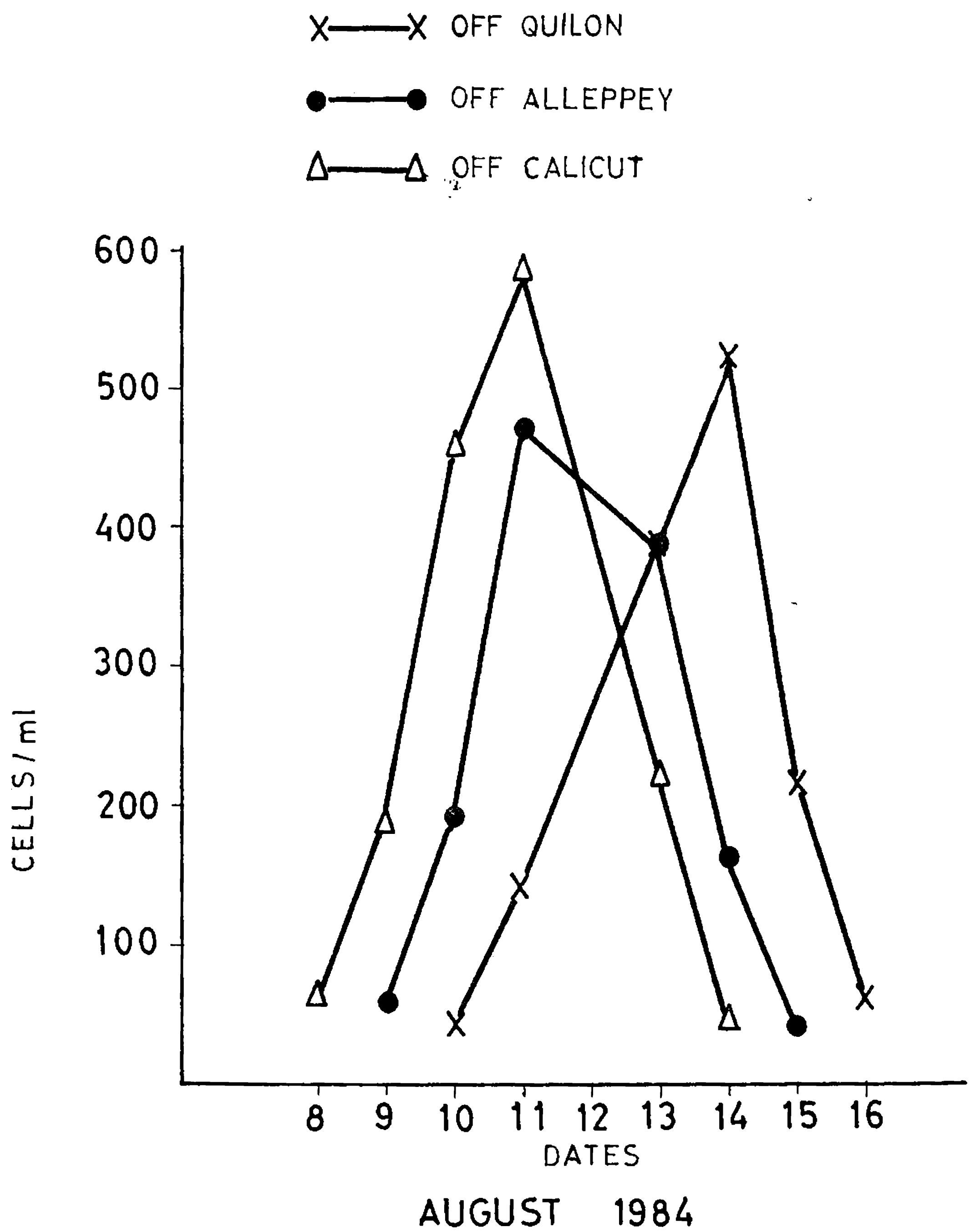

OFF QUILON
OFF ALLEPPEY
OFF CALICUT
700
600
500
400
300
200
100
CELLS / ml
19
20
21
22
23
24
25
26
DATES
JULY 1984

Fig. 27.

Table XXIV. Cell counts of _Triceratium_ spp. during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 July	19	-	-	40
	20	58	52	198
	21	310	284	380
	22	-	-	-
	23	682	632	426
	24	464	388	140
	25	216	164	58
	26	56	40	-

Fig.28. Blooming pattern of _Pyxidicula minuta_ Grunow and _Coscinodiscus_ spp. during August 1984.



OFF QUILON
OFF ALLEPPEY
OFF CALICUT
600
500
400
300
200
100
CELLS/ml
8
9
10
11
12
13
14
15
16
DATES
AUGUST 1984

Fig. 28.

Table XXV. Cell counts of *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. during the bloom period in 1984.

Bloom period (Year and month)	Dates of sampling	Cell counts (cells/ml)		
		off Quilon	off Alleppey	off Calicut
1984 August	8	-	-	56
	9	-	58	182
	10	40	190	454
	11	144	470	580
	12	-	-	-
	13	386	384	216
	14	522	162	40
	15	216	40	-
	16	56	-	-

Ceratium spp.

Ceratium spp. red tide occurred during February 1982 and March to April 1983. The 1982 red tide showed the cell counts between 41 cells/ml to 712 cells/ml and lasted for 8 to 9 days. The 1983 red tide lasted for 6 to 7 days and the cell counts ranged from 40 cells/ml to 684 cells/ml.

Trichodesmium spp.

Trichodesmium spp. red tide appeared during March to April 1982, February 1983 and March 1984. In 1982 the cell counts increased from 40 cells/ml to 1360 cells/ml and lasted for 13 to 14 days. The 1983 bloom lasted only for 7 to 8 days and the cell counts were between 40 cells/ml to 982 cells/ml. The red tide of 1984 was observed to 5 to 6 days and the cell counts varied from 40 cells/ml to 798 cells/ml.

Peridinium spp.

The *Peridinium* spp. red tide made its appearance during May 1982 and April 1984. In 1982 the bloom lasted for 5 to 6 days and the cell counts increased from 52 cells/ml to 824 cells/ml. In 1984 the cell counts were between 40 cells/ml to 582 cells/ml and lasted for 6 to 7 days.

Asterionella japonica Cleve

The bloom of this diatom was observed during July 1982 and June to July 1984. In 1982 it lasted for 7 to 10 days and showed the cell counts between 40 cells/ml to 1680 cells/ml. The 1984 bloom appeared for 7 days and showed the cell counts from 40 cells/ml to 586 cells/ml.

Skeletonema costatum (Greville) Cleve

The bloom was seen in October to November 1982 and August to September 1983. The 1982 bloom appeared for 8 to 9 days and the cell counts were between 40 cells/ml to 950 cells/ml. The 1983 lasted for 8 days and the cell counts ranged from 40 cells/ml to 940 cells/ml.

Asterionella japonica Cleve and *Thallassiothrix spp.*

This mixed bloom appeared during December 1982 and October 1983. In 1982 the bloom lasted for 6 to 7 days and the cell counts were between 40 cells/ml to 712 cells/ml. In 1983 the 9 days bloom showed the cell counts from 40 cells ml to 842 cells/ml.

Coscinodiscus spp.

The bloom of *Coscinodiscus* spp. made its appearance in November 1983 and February 1984. In 1983 the blooms lasted for 5 days and the cell counts ranged from 58 cells/ml to 480 cells/ml. In 1984 the cell counts increased from 40 cells/ml to 662 cells/ml and lasted for 8 days.

<u>*Biddulphia*</u> spp.

The <u>*Biddulphia*</u> spp. bloom appeared twice in 1984 i.e. January and March. In January the 5 to 6 days bloom showed the cell counts between 52 cells/ml to 528 cells/ml. The March bloom lasted for 7 days and the cell counts were between 40 cells/ml to 736 cells/ml.

Certain blooms appeared only once during the period of study.

<u>*Noctiluca miliaris*</u>

The red tide appeared only during June to July 1983. The bloom which lasted for 9 to 10 days and the increase of cell counts has taken place from 40 cells/ml to 984 cells/ml.

<u>*Chaetoceros*</u> spp.

The bloom of the <u>*Chaetoceros*</u> spp. appeared only in December 1983. The 5 days bloom showed the cell counts between 60 cells/ml to 520 cells/ml.

<u>*Cyclotella*</u> spp.

The bloom of <u>*Cyclotella*</u> spp. appeared only in February 1984. The cell counts ranged between 40 cells/ml to 682 cells/ml and lasted for 7 days.

Fragilaria oceanica Cleve

The bloom of *Fragilaria oceanica* Cleve made its appearance April to May 1984. The cell counts increased from 40 cells/ml to 628 cells/ml and lasted for 6 days.

Rhizosolenia spp.

The *Rhizosolenia* spp. bloom was studied during May 1984, which lasted for 7 days and the cell counts increased from 40 cells/ml to 834 cells/ml.

Pyxidicula minuta Grunow

The bloom of this diatom was observed during June 1984. The 6 days bloom showed the cell counts between 54 cells/ml to 676 cells/ml.

Triceratium spp.

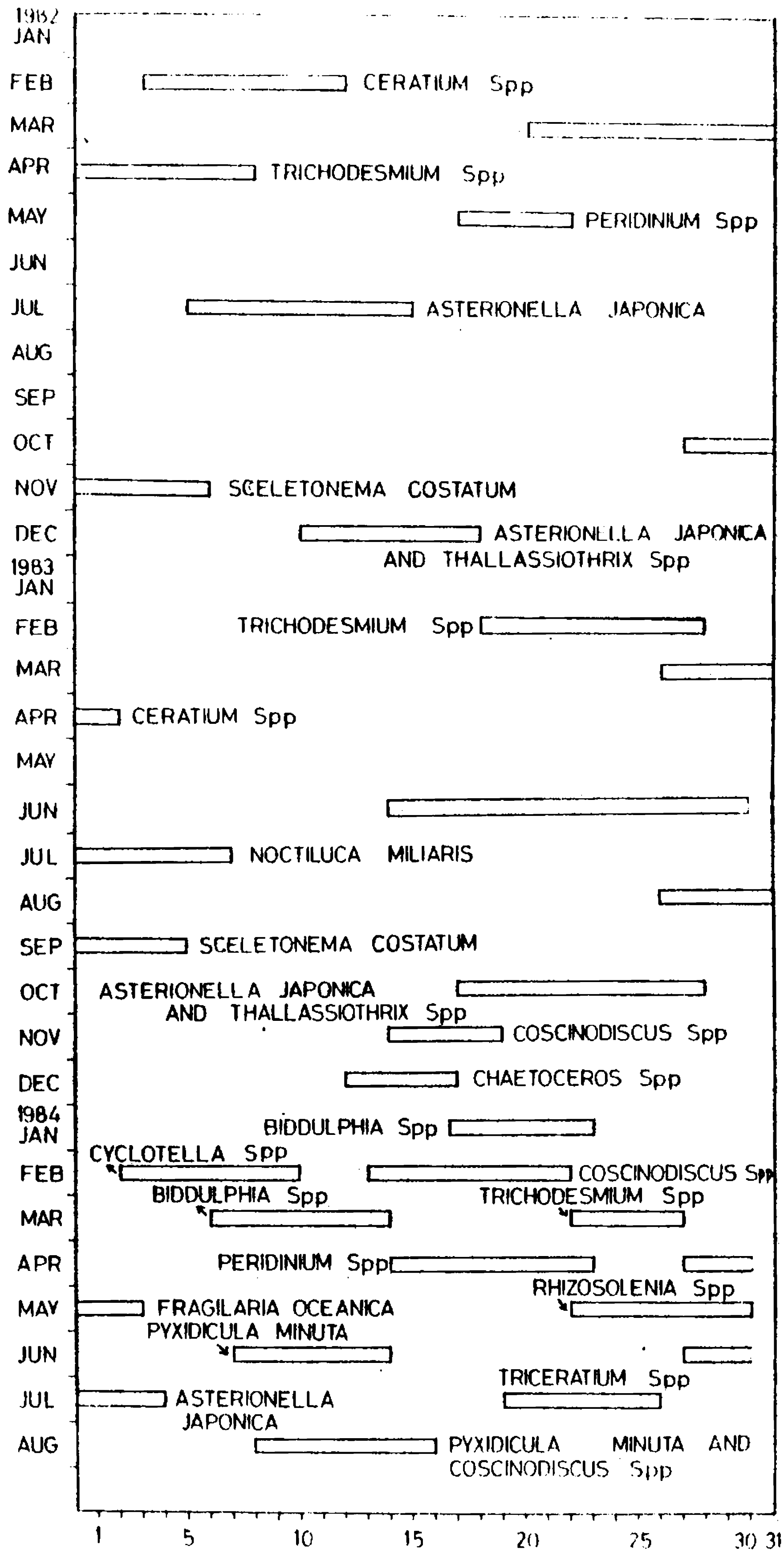
This diatom bloom appeared only in July 1984. The 7 days bloom showed the cell counts between 40 cells/ml to 682 cells/ml.

Pyxidicula minuta Grunow and *Coscinodiscus* spp.

This mixed diatom bloom made its appearance during August 1984. It lasted for 7 days and the cell counts increased from 40 cells/ml to 580 cells/ml.

During the period of study from February 1982 to August 1984 a total number of 25 phytoplankton blooms were observed (Fig.29). The observations which were made in the bloomed region shows that each bloom has got characteristic colour as mentioned in the observation (Plate II). It was interesting to note that the diatom blooms and red tides of blue green alga are favourable to the pelagic fishes (Plate Ia,b,c and d) and the dinoflagellate red tides shows the short term impact on the pelagic fishes like the avoidance of the bloomed regions.

Fig.29. The period of occurrence of phytoplankton blooms during February 1982 to August 1984.



1982 JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1983 JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1984 JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
CERATIUM Spp
TRICHODESMIUM Spp
PERIDINIUM Spp
ASTERIONELLA JAPONICA
SCELETONEMA COSTATUM
ASTERIONELLA JAPONICA AND THALLASSIOTHRIX Spp
TRICHODESMIUM Spp
CERATIUM Spp
NOCTILUCA MILIARIS
SCELETONEMA COSTATUM
ASTERIONELLA JAPONICA AND THALLASSIOTHRIX Spp
COSCINODISCUS Spp
CHAETOCEROS Spp
BIDDULPHIA Spp
CYCLOTELLA Spp
COSCINODISCUS Spp
BIDDULPHIA Spp
TRICHODESMIUM Spp
PERIDINIUM Spp
RHIZOSOLENIA Spp
FRAGILARIA OCEANICA
PYXIDICULA MINUTA
TRICERATIUM Spp
ASTERIONELLA JAPONICA
PYXIDICULA MINUTA AND COSCINODISCUS Spp
1
5
10
15
20
25
30 31

Fig. 29.

Plate I - (a,b,c and d) pelagic fishes caught during various phytoplankton bloom periods along the south west coast of India.

Ia

Ib

Ic

Id

Plate II - A view of the streak of the bloom
(note colour change)

II

2. Gut content analysis of the pelagic fishes

It was seen from the observation of phytoplankton blooms that during the blooming of some phytoplankton pelagic fishes were found swimming freely in that region and the preliminary findings of the gut analysis of these fishes revealed that bloomed organisms were very common. At the same time shoals of pelagic fishes avoided certain blooms. With a view to make a detailed study about the blooming of the phytoplankton in relation to consumption by pelagic fishes, gut content analysis were carried out. The variety of fish collected from Quilon coast, Alleppey coast and Calicut coast were given separately.

Quilon coast

The variety of fish collected for gut content analysis during the period of study from September 1983 to August 1984 were as follows:-

Caranx sexfasciatus Quoy and Gaimard, 1824; *Chirocentrus dorab* (Forsskål, 1775); *Kowala thoracata* (Fowler, 1941); *Pellona ditchela* Valenciennes, 1847; *Sardinella fimbriata* (Valenciennes, 1847); *Sardinella longiceps* Valenciennes, 1847; *Stolephorus heterolobus* (Rüppell, 1837); *Stolephorus indicus* (van Hasselt, 1823); *Thryssa malabarica* (Bloch, 1795); *Thryssa mystax*

(Schneider, 1801); Hemiramphus marginatus (Forsskål, 1775); Gazza minuta (Bloch, 1797); Leiognathus splendens (Cuvier, 1829); Secutor insidiator (Bloch, 1787); Rastrelliger kanagurta (Cuvier, 1817); Sarda orientalis (Temminck and Schlegel, 1844) and Scomberomorus guttatus (Bloch and Schneider, 1801).

The gut contents for each variety of fish were tabulated in Table XXVI and details were given below:-

Caranx sexfasciatus Quoy and Gaimard, 1824

Samples were available during September, October, November, December 1983 and January, March, April, May, June, July and August 1984.

September - Rhizosolenia spp. were rare. Zooplankton and algae were very common.

October - Coscinodiscus spp. were frequent. Sceletonema costatum (Greville) Cleve were rare. Zooplankton were common.

November - Coscinodiscus spp. and zooplankton were common.

December - Coscinodiscus spp. were very common. Zooplankton were rare.

January - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton and algae were very common.

March - *Triceratium* spp. were common. *Chaetoceros* spp. were rare and zooplankton were frequent.

April - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton were very common.

May - *Cyclotella* spp., *Biddulphia* spp., *Fragilaria oceanica* Cleve and zooplankton were frequent.

June - *Pyxidicula minuta* Grunow were common. *Biddulphia* spp. and zooplankton were frequent.

July - *Pyxidicula minuta* Grunow were common. *Noctiluca miliaris* Surirey were rare and zooplankton were frequent.

August - *Coscinodiscus* spp. and *Pyxidicula minuta* Grunow were common.

Chirocentrus dorab (Forsskål, 1775)

Samples were available during November and December 1983.

November - *Coscinodiscus* spp. were frequent and algae were common.

December - *Coscinodiscus* spp. were frequent and algae were common.

Kowala thoracata (Fowler, 1941)

Samples were available only in August 1984.

August - *Fragilaria oceanica* Cleve were common. *Pyxidicula minuta* Grunow, *Coscinodiscus* spp. were frequent and zooplankton were rare.

Pellona ditchela Valenciennes, 1847

Samples were available only in August 1984.

August - *Pyxidicula minuta* Grunow were common and zooplankton were frequent.

Sardinella fimbriata (Valenciennes, 1847)

Samples were available during September and October 1983.

September - *Coscinodiscus* spp. were common. *Rhizosolenia* spp., *Biddulphia* spp., *Cerataulina bergonii* Peragallo, *Ceratium* spp. and algae were rare.

October - *Coscinodiscus* spp. were common and zooplankton were frequent.

Sardinella longiceps Valenciennes, 1847

Samples were available during September, October, November 1983 and February, March, April, May and June 1984.

September - *Fragilaria oceanica* Cleve were common. *Rhizosolenia* spp. were frequent and *Ceratium* spp. were rare.

October - *Coscinodiscus* spp. were rare and zooplankton and algae were very common.

November - *Triceratium* spp. were common, *Coscinodiscus* spp. were frequent. *Cerataulina bergonii* Peragallo and zooplankton were rare.

February - *Cyclotella* spp. were very common, *Coscinodiscus* spp., *Triceratium* spp., *Peridinium* spp. and zooplankton were rare.

March - *Cyclotella* spp., *Pleurosigma* spp., and Ceratium spp. noticed to be frequent. *Skeletonema costatum* (Greville) Cleve, *Melosira sulcata* (Ehrenberg) Kutzing, *Dinophysis* spp., *Noctiluca miliaris* Surirey, *Anabaena* spp. and algae were rare.

April - *Fragilaria oceanica* Cleve were common. *Biddulphia* spp. noticed to be frequent. *Skeletonema costatum* (Greville) Cleve, *Stephanopyxis* spp., *Pleurosigma* spp. and zooplankton noted to be rare.

May - *Triceratium* spp., *Navicula* spp., *Dinophysis* spp. were frequent. *Melosira sulcata* (Ehrenberg) Kützing, *Cyclotella* spp., *Coscinodiscus* spp., *Rhizosolenia* spp., *Biddulphia* spp., *Pleurosigma* spp., *Ceratium* spp., *Peridinium* spp., *Trichodesmium* spp., *Nostoc* spp. and zooplankton were rare.

June - *Melosira sulcata* (Ehrenberg) Kützing were common, *Pyxidicula minuta* Grunow, *Fragilaria oceanica* Cleve and *Ceratium* spp. were frequent. *Dinophysis* spp. and zooplankton were rare.

Stolephorus heterolobus (Rüppell, 1837)

Samples were available during October, November 1983 and March, June 1984.

October - *Coscinodiscus* spp. and *Biddulphia* spp. were frequent. Zooplankton were common.

November - *Coscinodiscus* spp. and zooplankton were common.

March - *Cyclotella* spp. and zooplankton were common

June - *Pyxidicula minuta* Grunow and *Cyclotella* spp. were frequent and zooplankton were common.

Stolephorus indicus (van Hasselt, 1823)

Samples were available only in November 1983.

November - *Coscinodiscus* spp. were common. *Biddulphia* spp., *Ceratium* spp. and algae were rare.

Thryssa malabarica (Bloch, 1795)

Samples were available during September, October 1983 and February, June, July and August 1984.

September - *Biddulphia* spp. were rare. Zooplankton were very common.

October - *Coscinodiscus* spp. and *Biddulphia* spp. were frequent and zooplankton were common.

February - *Coscinodiscus* spp. were very common. *Chaetoceros* spp., *Nitzschia* spp., *Peridinium* spp. and zooplankton were rare.

June - *Cyclotella* spp. were common. *Melosira sulcata* (Ehrenberg) Kützing were frequent. *Peridinium* spp. and zooplankton were rare.

July - *Pyxidicula minuta* Grunow were common. *Fragilaria oceanica* Cleve were rare and zooplankton and algae were frequent.

August - *Pyxidicula minuta* Grunow and *Fragilaria oceanica* Cleve were frequent. *Melosira sulcata* (Ehrenberg) Kützing and zooplankton were rare.

Thryssa mystax (Schneider, 1801)

Samples were available only in February 1984.

February - *Coscinodiscus* spp. and *Biddulphia* spp. were frequent. Zooplankton and algae were common.

Hemiramphus marginatus (Foreskål, 1775)

Samples were available only in August 1984.

August - *Pyxidicula minuta* Grunow were common. *Fragilaria oceanica* Cleve were frequent. *Stephanopyxis* and zooplankton were rare.

Gazza minuta (Bloch, 1797)

Samples were available only in January 1984.

January - *Coscinodiscus* spp. were frequent. Zooplankton were common.

Leiognathus splendens (Cuvier, 1829)

Samples were available during September, October, November, December 1983 and January, April, May, June and July 1984.

September - *Fragilaria oceanica* Cleve noticed to be common. *Ceratium* spp. were frequent. *Melosira sulcata* (Ehrenberg) Kützing and *Biddulphia* spp. and zooplankton were rare.

October - Biddulphia spp. were common. *Coscinodiscus* spp. were frequent. Zooplankton and algae were rare.

November - *Biddulphia* spp. and *Ceratium* spp. were rare. *Coscinodiscus* spp.,zooplankton and algae were frequent.

December - *Coscinodiscus* spp. were frequent. Zooplankton and algae were common.

January - *Coscinodiscus* spp. and zooplankton were common.

April - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton were very common.

May - *Rhizosolenia* spp. were common. *Triceratium* spp. were frequent. Zooplankton were rare.

June - *Cyclotella* spp. were common. Zooplankton and algae were frequent.

July - *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. and zooplankton were frequent.

Secutor insidiator (Bloch, 1787)

Samples were available during September, November, December 1983 and March, April and May 1984.

September - *Coscinodiscus* spp., *Thalassiosira* spp., *Rhizosolenia* spp., *Biddulphia* spp., *Cerataulina bergonii* Peragallo were rare. Zooplankton and algae were frequent.

November - *Biddulphia* spp. were common. *Cerataulina bergonii* Peragallo were rare. Zooplankton were frequent.

December - *Biddulphia* spp. were common. *Coscinodiscus* spp., *Cerataulina bergonii* Peragallo and zooplankton were rare.

March - *Cyclotella* spp. were common. Zooplankton were frequent.

April - *Sceletonema costatum* (Greville) Cleve were frequent. Zooplankton were common.

May - *Rhizosolenia* spp. were common. *Triceratium* spp. were frequent. *Biddulphia* spp. and zooplankton were rare.

Rastrelliger kanagurta (Cuvier, 1817)

Samples were available during September, November 1983 and April, August 1984.

September - *Fragilaria oceanica* Cleve were common. *Ceratium* spp. were frequent. *Cyclotella* spp., *Rhizosolenia* spp., *Biddulphia* spp., *Triceratium* spp. and zooplankton were rare.

November - *Coscinodiscus* spp. were frequent. *Rhizosolenia* spp., *Cerataulina bergonii* Peragallo and *Ceratium* spp. were rare and zooplankton were frequent.

April - *Melosira sulcata* (Ehrenberg) Kutzing, *Cyclotella* spp., *Coscinodiscus* spp., *Triceratium* spp., *Navicula* spp. and *Ceratium* spp. noticed to be rare. Zooplankton and algae were frequent.

August - *Pyxidicula minuta* Grunow, *Coscinodiscus* spp. and *Fragilaria oceanica* Cleve were frequent. *Melosira sulcata* (Ehrenberg) Kützing, *Cyclotella* spp. and *Ceratium* spp. were rare.

Sarda orientalis (Temminck and Schlegel, 1844)

Samples were available only in August 1984.

August - *Pyxidicula minuta* Grunow were common. Zooplankton and algae were frequent.

Scomberomorus guttatus (Bloch and Schneider, 1801)

Samples were available only in August 1984.

August - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton and algae were very common.

<u>Alleppey coast</u>

The variety of fish collected for gut content analysis during the period of study from September 1983 to August 1984 were as follows:-

<u>Caranx sexfasciatus</u> Quoy and Gaimard, 1824; <u>Chirocentrus dorab</u> (Forsskål, 1775); <u>Kowala thoracata</u> (Fowler, 1941); <u>Pellona ditchela</u> Valenciennes, 1847; <u>Sardinella fimbriata</u> (Valenciennes, 1847); <u>Sardinella longiceps</u> Valenciennes, 1847; <u>Stolephorus heterolobus</u> (Rüppell, 1837); <u>Stolephorus indicus</u> (van Hasselt, 1823); <u>Thryssa malabarica</u> (Bloch, 1795); <u>Thryssa mystax</u> (Schneider, 1801); <u>Hemiramphus marginatus</u> (Forsskål, 1775); <u>Lactarius lactarius</u> (Bloch and Schneider, 1801); <u>Leiognathus splendens</u> (Cuvier, 1829); <u>Secutor insidiator</u> (Bloch, 1787); <u>Liza tade</u> (Forsskål, 1775); <u>Scatophagus argus</u> (Bloch, 1788); <u>Katsuwonus pelamis</u> (Linnaeus, 1758); <u>Rastrelliger kanagurta</u> (Cuvier, 1817); <u>Scomberomorus guttatus</u> (Bloch and Schneider, 1801); and <u>Pampus chinensis</u> (Euphrasen, 1788).

The gut contents for each variety of fish were tabulated in Table XXVII and details were given below:-

<u>Caranx sexfasciatus</u> Quoy and Gaimard, 1824

Samples were available during September, October, November, December 1983 and during January, February, March, April, June and August 1984.

September - <u>Melosira sulcata</u> (Ehrenberg) Kützing, <u>Rhizosolenia</u> spp. and <u>Biddulphia</u> spp. noted to be rare and zooplankton found to be common.

October - The <u>Rhizosolenia</u> spp. found tobe rare and <u>Biddulphia</u> spp. noted to be frequent. The zooplankton were common.

November - <u>Biddulphia</u> spp. noted to be frequent. The <u>Ceratium</u> spp. were rare and zooplankton were common.

December - <u>Biddulphia</u> spp. observed to be common. <u>Coscinodiscus</u> spp. and zooplankton were frequent.

January - <u>Coscinodiscus</u> spp. noted to be common. <u>Rhizosolenia</u> spp. and <u>Pleurosigma</u> spp. were rare and zooplankton and algae were frequent.

February - <u>Coscinodiscus</u> spp. found to be common, <u>Dinophysis</u> spp. and <u>Peridinium</u> spp. found to be rare. Zooplankton noted to be frequent.

March - <u>Triceratium</u> spp. and zooplankton found to be common.

April - *Cyclotella* spp. noted to be common. *Pleurosigma* spp. and *Triceratium* spp. noted to be rare. Zooplankton found to be frequent.

June - *Pyxidicula minuta* Grunow noted to be common and *Melosira sulcata* (Ehrenberg) Kützing and *Navicula* spp. found to be rare.

August - *Pyxidicula minuta* Grunow found to be common. *Coscinodiscus* spp. and zooplankton noted to be frequent.

Chirocentrus dorab (Forsskål, 1775)

Samples were available only during September 1983 and June 1984.

September - *Rhizosolenia* spp. noted to be rare. Zooplankton and algae found to be very common.

June - No diatoms, dinoflagellates and blue green algae were available. Only zooplankton and algae noted to be very common.

Kowala thoracata (Fowler, 1941)

Samples were available only during November 1983.

November - *Coscinodiscus* spp. and *Biddulphia* spp. noted to be frequent. *Chaetoceros* spp. and *Eucampia* spp. found to be rare. Zooplankton and algae found to be rare.

<u>*Pellona ditchela*</u> Valenciennes, 1847

Samples were available during June, July and August 1984.

June - <u>*Pyxidicula minuta*</u> Grunow noted to be common and zooplankton found to be frequent.

July - <u>*Pyxidicula minuta*</u> Grunow were common and zooplankton found to be frequent.

August - <u>*Pyxidicula minuta*</u> Grunow and zooplankton were frequent.

<u>*Sardinella fimbriata*</u> (Valenciennes, 1847)

Samples were available during September, October and November 1983.

September - <u>*Rhizosolenia*</u> spp. noted to be very common and <u>*Biddulphia*</u> spp. found to be rare.

October - <u>*Coscinodiscus*</u> spp. noted to be frequent and <u>*Biddulphia*</u> spp. found to be rare. Zooplankton and algae were common.

November - <u>*Coscinodiscus*</u> spp. and zooplankton and algae were common.

<u>*Sardinella longiceps*</u> Valenciennes, 1847

Samples were available during September, November, December 1983 and March, April and July 1984.

September - *Rhizosolenia* spp. noted to be very common and zooplankton noted to be rare.

November - *Coscinodiscus* spp. found to be common. *Rhizosolenia* spp. and *Pleurosigma* noted to be rare and zooplankton were frequent.

December - *Coscinodiscus* spp. found to be rare. *Biddulphia* spp. and zooplankton were frequent.

March - *Biddulphia* spp. were frequent. *Pleurosigma* spp. were common. *Skeletonema costatum* (Greville) Cleve, *Ceratium* spp., *Noctiluca miliaris* Surirey and zooplankton noted to be rare.

April - *Cyclotella* spp., *Biddulphia* spp., *Triceratium* spp. and zooplankton found to be frequent. *Coscinodiscus* spp. and *Ceratium* spp. noted to be rare.

July - *Pyxidicula minuta* Grunow noted to be common. *Fragilaria oceanica* Cleve and *Navicula* spp. noted to be rare. Zooplankton found to be frequent.

Stolephorus heterolobus (Rüppell, 1837)

Samples were available during November 1983, January, February and March 1984.

November - *Coscinodiscus* spp. and zooplankton noted to be common.

January - *Coscinodiscus* spp. and *Biddulphia* spp. were frequent. *Cyclotella* spp., *Fragilaria oceanica* Cleve and zooplankton noted to be rare.

February - *Coscinodiscus* spp. noted to be frequent. *Cyclotella* spp., *Triceratium* spp. and *Dinophysis* spp. found to be rare.

March - *Rhizosolenia* spp. noted to be frequent. *Dinophysis* spp. were rare. Algae were common.

Stolephorus indicus (van Hasselt, 1823)

Samples were available during November 1983, March, April, May, June, July and August 1984.

November - *Coscinodiscus* spp. were common. *Eucampia* spp., *Triceratium* spp. and *Biddulphia* spp. were rare. Zooplankton noted to be frequent.

March - *Biddulphia* spp. noted to be common. *Triceratium* spp., *Pleurosigma* spp., *Ceratium* spp. and *Dinophysis* spp. noted to be rare.

April - *Melosira sulcata* (Ehrenberg) Kützing and *Ceratium* spp. noted to be rare. Zooplankton and algae were very common.

May - *Pyxidicula minuta* Grunow, *Biddulphia* spp. and zooplankton found to be frequent. *Noctiluca miliaris* Suriray noted to be rare.

June - *Cerataulina bergonii* Peragallo were rare. Zooplankton and algae were very common.

July - *Pyxidicula minuta* Grunow, *Coscinodiscus* spp. and zooplankton found to be frequent.

August - *Pyxidicula minuta* Grunow noted to be common. *Fragilaria oceanica* Cleve were frequent. *Coscinodiscus* spp. and *Stephanopyxis* spp. were rare.

Thryssa malabarica (Bloch, 1795)

Samples were available during November, December 1983, April and June 1984.

November - *Coscinodiscus* spp. were common. *Cerataulina bergonii* Peragallo and *Biddulphia* spp. were rare. Zooplankton were frequent.

December - *Biddulphia* spp. were common. *Cerataulina bergonii* Peragallo were rare and zooplankton were frequent.

April - No diatoms, dinoflagellates or blue green algae were present. Zooplankton and algae were very common.

June - No diatoms, dinoflagellates or blue green algae were present. Zooplankton were very common.

<u>*Thryssa mystax*</u> (Schneider, 1801)

Samples were available only in November 1983.

November - <u>*Coscinodiscus*</u> spp. were common. <u>*Biddulphia*</u> spp., zooplankton and algae were frequent.

<u>*Hemiramphus marginatus*</u> (Forsskål, 1775)

Samples were available during September 1983, May and June 1984.

September - <u>*Coscinodiscus*</u> spp., <u>*Rhizosolenia*</u> spp. and <u>*Biddulphia*</u> spp. were rare. Zooplankton, algae were frequent.

May - <u>*Fragilaria oceanica*</u> Cleve were common. <u>*Pyxidicula minuta*</u> Grunow, <u>*Stephanopyxis*</u> spp., <u>*Biddulphia*</u> spp. and zooplankton noted to be rare.

June - <u>*Pyxidicula minuta*</u> Grunow noted to be common. Zooplankton found to be frequent.

<u>*Lactarius lactarius*</u> (Bloch and Schneider, 1801)

Samples were available only in September 1983.

September - <u>*Coscinodiscus*</u> spp. were common. <u>*Rhizosolenia*</u> spp. were rare. Zooplankton noted to be frequent.

Leiognathus splendens (Cuvier, 1829)

Samples were available during November, December 1983, January, February, March, April, May and July 1984.

November - Coscinodiscus spp. and zooplankton noted to be common.

December - Coscinodiscus spp. noted to be frequent. Fragilaria oceanica Cleve noted to be rare and zooplankton were common.

January - Coscinodiscus spp. were observed common. Cyclotella spp. noted to be frequent. Fragilaria oceanica Cleve and zooplankton were rare.

February - Coscinodiscus spp. were common, Biddulphia spp. were frequent. Rhizosolenia spp., Ceratium spp., Peridinium spp. and zooplankton were rare.

March - Biddulphia spp. were common. Ceratium spp., zooplankton and algae were frequent.

April - Cyclotella spp. were common. Dinophysis spp. were rare and zooplankton were frequent.

May - Pyxidicula minuta Grunow, Biddulphia spp., Pleurosigma spp., Peridinium spp., Prorocentrum micans Ehrenberg were rare and zooplankton were common.

July - Pyxidicula minuta Grunow and Coscinodiscus spp. noted to be frequent. Fragilaria oceanica Cleve and zooplankton were rare.

Secutor insidiator (Bloch, 1787)

Samples were available during November 1983, January and April 1984.

November - No diatoms, dinoflagellates or blue green algae were observed. Algae were noted to be very common.

January - *Coscinodiscus* spp. noted to be common. *Biddulphia* spp. were frequent and zooplankton were rare.

April - *Cyclotella* spp. were common. Zooplankton were frequent.

Liza tade (Forsskål, 1775)

Samples were available only in June 1984.

June - *Pyxidicula minuta* Grunow were common. Zooplankton were frequent.

Scatophagus argus (Bloch, 1788)

Samples were available only in July 1984.

July - *Pyxidicula minuta* Grunow were rare and *Trichodesmium* spp. were very common.

Katsuwonus pelamis (Linnaeus, 1758)

Samples were available only in June 1984.

June - *Pyxidicula minuta* Grunow and zooplankton were common.

Rastrelliger kanagurta (Cuvier, 1817)

Samples were available during November 1983, June and August 1984.

November - *Biddulphia* spp., *Cerataulina bergonii* Peragallo, *Fragilaria oceanica* Cleve and *Pleurosigma* spp. noted to be rare. Zooplankton were common.

June - *Fragilaria oceanica* Cleve were common. *Pyxidicula minuta* Grunow noted to be frequent. *Melosira sulcata* (Ehrenberg) Kützing were rare.

August - *Pyxidicula minuta* Grunow, *Coscinodiscus* spp. and *Fragilaria oceanica* Cleve were frequent. *Melosira sulcata* (Ehrenberg) Kützing, *Cyclotella* spp., *Ceratium* spp., Zooplankton and algae were rare.

Scomberomorus guttatus (Bloch and Schneider, 1801)

Samples were available during June and August 1984.

June - *Fragilaria oceanica* Cleve were common. *Navicula* spp. noted to be frequent. *Pyxidicula minuta* Grunow, *Prorocentrum micans* Ehrenberg and zooplankton were rare.

August - No diatoms, dinoflagellates or blue green algae were noted. Zooplankton and algae were very common.

Pampus chinensis (Euphrasen, 1788)

Samples were available during September, October, November 1983 and April 1984.

September - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton were very common.

October - _Coscinodiscus_ spp. and zooplankton were common.

November - _Coscinodiscus_ spp., _Biddulphia_ spp., _Fragilaria oceanica_ Cleve and zooplankton were frequent.

April - _Cyclotella_ spp. and zooplankton were common.

Calicut coast

The variety of fish collected for gut content analysis during the period of study from September 1983 to August 1984 were as follows:-

Caranx sexfasciatus Quoy and Gaimard, 1824; _Gnathanodon speciosus_ (Forsskål, 1775); _Kowala thoracata_ (Fowler, 1941); _Ilisha melastoma_ (Schneider, 1801); _Sardinella fimbriata_ (Valenciennes, 1847); _Sardinella longiceps_ Valenciennes, 1847; _Stolephorus heterolobus_

(Rüppell, 1837); *Stolephorus indicus* (van Hasselt, 1823); *Thryssa malabarica* (Bloch, 1795); *Thryssa mystax* (Schneider, 1801); *Hemiramphus marginatus* (Forsskål, 1775); *Gazza minuta* (Bloch, 1797); *Leiognathus splendens* (Cuvier, 1829); *Secutor insidiator* (Bloch, 1787); *Sphyraena obtusata* Cuvier, 1829; *Rastrelliger kanagurta* (Cuvier, 1817); *Sarda orientalis* (Temminck and Schlegel, 1844) and *Pampus chinensis* (Euphrasen, 1788).

The gut contents for each variety of fish were tabulated in Table XXVIII and details were given below:-

Caranx sexfasciatus Quoy and Gaimard, 1824

Samples were available during October, November, December 1983 and February, March and May 1984.

October - *Coscinodiscus* spp. noted to be common. *Cerataulina bergonii* Peragallo and *Rhizosolenia* spp. were rare and zooplankton were frequent.

November - *Coscinodiscus* spp. were frequent and other algae were common.

December - *Coscinodiscus* spp. and zooplankton were common.

February - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton were very common.

March - Coscinodiscus spp. were very common. Peridinium spp. and zooplankton noted to be rare.

May - Rhizosolenia spp. were common, Melosira sulcata (Ehrenberg) Kützing, Cyclotella spp., Triceratium spp. and Biddulphia spp. were rare. Zooplankton were frequent.

Gnathanodon speciosus (Forsskål, 1775)

Samples were available only in October 1983.

October - Coscinodiscus spp. were common. Rhizosolenia spp. and Biddulphia spp. noticed to be rare and zooplankton were frequent.

Kowala thoracata (Fowler, 1941)

Samples were available during November 1983 and January, February, March, April, May and August 1984.

November - Coscinodiscus spp. were frequent. Zooplankton and algae were common.

January - Coscinodiscus spp. noted to be frequent and zooplankton were common.

February - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton were very common.

March - *Cyclotella* spp. were common, *Coscinodiscus* spp. noted to be frequent. *Leptocylindrus* spp., *Biddulphia* spp., *Pleurosigma* spp., *Navicula* spp., *Peridinium* spp. and algae were rare.

April - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton were very common.

May - *Pleurosigma* spp. and *Navicula* spp. were frequent and zooplankton were common.

August - *Pyxidicula minuta* Grunow were common. *Coscinodiscus* spp. were frequent and zooplankton were rare.

Ilisha melastoma (Schneider, 1801)

Samples were available during January 1984.

January - *Coscinodiscus* spp. noted to be frequent. *Rhizosolenia* spp. and *Cerataulina bergonii* Peragallo were rare. Algae were common.

Sardinella fimbriata (Valenciennes, 1847)

Samples were available during October 1983, January and February 1984.

October - *Coscinodiscus* spp. were common. *Biddulphia* spp. were frequent. *Melosira sulcata* (Ehrenberg) Kützing and algae were rare.

January - *Cyclotella* spp. were common.
Coscinodiscus spp. were frequent.
Navicula spp. and zooplankton noted to be rare.

February - *Triceratium* spp., *Fragilaria oceanica* Cleve, *Pleurosigma* spp., *Navicula* spp. noted to be rare. *Cyclotella* spp., *Biddulphia* spp., zooplankton and algae were frequent.

Sardinella longiceps Valenciennes, 1847

Samples were available during December 1983, January, February, March, June, July and August 1984.

December - *Coscinodiscus* spp. and *Biddulphia* spp. were frequent. Zooplankton and algae were common.

January - *Coscinodiscus* spp. were frequent and zooplankton were common.

February - *Cyclotella* spp. were common and zooplankton were frequent.

March - *Pleurosigma* spp. and *Navicula* spp. were frequent. *Peridinium* spp. and zooplankton were rare.

June - *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. were frequent. *Fragilaria oceanica* Cleve and *Pleurosigma* spp. were rare. Zooplankton and algae were frequent.

July - *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. were frequent. Zooplankton were common.

August - *Pyxidicula minuta* Grunow were common. *Coscinodiscus* spp., zooplankton and algae were frequent.

Stolephorus heterolobus (Rüppell, 1837)

Samples were available during January, February and April 1984.

January - *Biddulphia* spp. and *Coscinodiscus* spp. noted to be frequent and zooplankton were common.

February - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton and algae noted to be very common.

April - *Pleurosigma* spp. and *Ceratium* spp. were rare and zooplankton were common.

Stolephorus indicus (van Hasselt, 1823)

Samples were available during November, December 1983, January, February, March, April and August 1984.

November - *Coscinodiscus* spp., *Biddulphia* spp., and zooplankton were frequent.

December - *Coscinodiscus* spp., *Biddulphia* spp. and zooplankton were frequent.

January - *Coscinodiscus* spp. were common and zooplankton noted to be frequent.

February - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton noted to be very common.

March - *Coscinodiscus* spp. noticed to be very common and zooplankton and algae were rare.

April - *Ceratium* spp. were rare and zooplankton were common.

August - *Pyxidicula minuta* Grunow noted to be common. *Coscinodiscus* spp. were frequent. *Fragilaria oceanica* Cleve and zooplankton were rare.

Thryssa malabarica (Bloch, 1795)

Samples were available during September, October, November 1983 and January, February, March, April and May 1984.

September - *Coscinodiscus* spp. and *Fragilaria oceanica* Cleve noted to be frequent. Zooplankton were common.

October	-	*Fragilaria oceanica* Cleve were common. *Melosira sulcata* (Ehrenberg) Kützing were rare. *Coscinodiscus* spp. and zooplankton were frequent.
November	-	*Coscinodiscus* spp. and zooplankton were common.
January	-	*Rhizosolenia* spp. and *Biddulphia* spp. were frequent and zooplankton were common.
February	-	*Cyclotella* spp. were common. *Biddulphia* spp. and zooplankton were frequent.
March	-	*Coscinodiscus* spp. and zooplankton were common.
April	-	*Cyclotella* spp. were common. *Ceratium* spp. and *Noctiluca miliaris* Suriray were rare and zooplankton were frequent.
May	-	*Melosira sulcata* (Ehrenberg) Kützing were rare. *Cyclotella* spp., *Ceratium* spp. and zooplankton were frequent.

Thryssa mystax (Schneider, 1801)

Samples were available only in October 1983.

October	-	*Chaetoceros* spp., *Cerataulina bergonii* Peragallo and *Ceratium* spp. were rare. *Coscinodiscus* spp. and zooplankton were frequent.

<u>*Hemiramphus marginatus*</u> (Forsskål, 1775)

Samples were available only in January 1984.

January - <u>*Biddulphia*</u> spp. were common, <u>*Coscinodiscus*</u> spp. were frequent. <u>*Chaetoceros*</u> spp., <u>*Cerataulina bergonii*</u> Peragallo, <u>*Pleurosigma*</u> spp. and zooplankton were rare.

<u>*Gazza minuta*</u> (Bloch, 1797)

Samples were available only in February 1984.

February - No diatoms, dinoflagellates or blue green algae were seen. Zooplankton noted to be very common.

<u>*Leiognathus splendens*</u> (Cuvier, 1829)

Samples were available during September, October 1983 and February, March, May and June 1984.

September - <u>*Fragilaria oceanica*</u> Cleve were rare. <u>*Coscinodiscus*</u> spp., <u>*Biddulphia*</u> spp. and zooplankton were frequent.

October - <u>*Coscinodiscus*</u> spp. and zooplankton were common.

February - <u>*Triceratium*</u> spp., <u>*Fragilaria oceanica*</u> Cleve and zooplankton noted to be frequent.

March - *Cyclotella* spp. and *Coscinodiscus* spp. were frequent. Zooplankton were rare.

May - *Rhizosolenia* spp. noted to be common. *Cyclotella* spp. were frequent. *Pleurosigma* spp. and zooplankton were rare.

June - *Cyclotella* spp. and *Coscinodiscus* spp. were frequent. Zooplankton were rare.

Secutor insidiator (Bloch, 1787)

Samples were available during October 1983, February and May 1984.

October - *Rhizosolenia* spp. were common. *Biddulphia* spp. and *Cerataulina bergonii* Peragello were rare. Zooplankton and algae were frequent.

February - *Cyclotella* spp. and *Triceratium* spp. were common.

May - *Cyclotella* spp. and zooplankton were common.

Sphyraena obtusata Cuvier, 1829

Samples were available only in May 1984.

May - *Triceratium* spp., zooplankton and algae were common.

Rastrelliger kanagurta (Cuvier, 1817)

Samples were available only in November 1983.

November - Coscinodiscus spp. were common. Cerataulina bergonii Peragallo. Pleurosigma spp. and Ceratium spp. were rare and zooplankton were frequent.

Sarda orientalis (Temminck and Schlegel, 1844)

Samples were available during February and May 1984.

February - Cyclotella spp. were very common and zooplankton were rare.

May - Cyclotella spp. were very common. Pleurosigma spp. and algae were rare.

Pampus chinensis (Euphrasen, 1788)

Samples were available only in May 1984.

May - Cyclotella spp. were common. Rhizosolenia spp. were frequent. Pleurosigma spp. and algae were rare.

It can be concluded that the Coscinodiscus spp. bloom appeared in November 1983 and February 1984. Caranx sexfasciatus Quoy and Gaimard, 1824 of the Calicut coast showed that Coscinodiscus spp. were common in October 1983, December 1983, frequent in November 1983 and very common in March 1984. The samples of the Quilon coast showed it was frequent in October 1983, common in November 1983 and very common in December 1983. The samples of the Alleppey coast revealed it as common in January and February 1984. In Gnathanodon speciosus (Forsskål, 1775) it was common during October 1983 in the samples of Calicut coast. In Chirocentrus dorab (Forsskål, 1775), Coscinodiscus spp. were frequent in the samples of Quilon coast during November and December 1983. In Kowala thoracata (Fowler, 1941), Coscinodiscus spp. appeared frequent during November 1983 and January 1984 of the Calicut coast. Sardinella fimbriata (Valenciennes, 1847) of the Alleppey showed it to be frequent in October 1983 and common in November 1983. But the samples of the Quilon coast noted that it was common during October 1983. The Calicut coast samples revealed that it was common in October 1983 and frequent in January 1984. Sardinella longiceps Valenciennes, 1847 of the Alleppey coast showed that the Coscinodiscus spp. were common in November 1983, but it was only frequent during that season in the samples of Quilon coast. The samples of the Calicut coast showed that it was frequent during January 1984. Stolephorus heterolobus (Rüppell, 1837) samples of the Alleppey coast noted it that it was common in November 1983 and frequent in January 1984. The samples of the Quilon coast showed that it was frequent in October 1983 and common in November 1983. The Quilon samples of the Stolephorus indicus (van Hasselt, 1823) showed that it was common in November 1983. In January 1984 it was common in samples of the Calicut coast. The samples of the Alleppey coast revealed that Coscinodiscus spp. were common in November 1983. The samples from Quilon of Thryssa malabarica (Bloch, 1795) showed it was frequent in October 1983 and very common in February 1984 but in Alleppey it was common in November 1983. The Calicut samples showed it was common during November 1983 and March 1984. The Quilon coast samples of the Thryssa mystax (Schneider, 1801) showed that it was frequent in February 1984. In Alleppey it was common in November 1983. During October 1983 it was frequent in Calicut coast samples. In Leiognathus splendens (Cuvier, 1829), Coscinodiscus spp. were frequent in November 1983 and December 1983 in Quilon. In Alleppey it was common in November 1983, January 1984 and February 1984. In October it was common in Calicut samples. In Secutor insidiator (Bloch, 1787) it appeared common in the samples of Alleppey coast during January 1984. The Rastrelliger kanagurta (Cuvier, 1817) samples of the Quilon coast showed it to be frequent in November 1983 and it was common in the samples of Calicut coast during that season. In Pampus chinensis (Euphrasen, 1788) it was common in October and frequent in November 1983 in the Alleppey samples.

The *Biddulphia* spp. bloom appeared in January and March 1984. In Calicut coast samples of *Sardinella fimbriata* (Valenciennes, 1847) it was frequent in February 1984 and in *Sardinella longiceps* Valenciennes, 1847 it was frequent in December 1984. In *Stolephorus heterolobus* (Rüppell, 1837) it was frequent in January in the samples of Alleppey and Calicut. In *Stolephorus indicus* (van Hasselt, 1823), *Biddulphia* spp. were common in March 1984 of Alleppey samples and frequent in December 1983 of Calicut samples. In *Thryssa malabarica* (Bloch, 1795) it was common in December 1983 in Alleppey samples and frequent in January and February 1984 in Calicut samples. In *Thryssa mystax* (Schneider, 1801) samples of the Quilon coast showed that it was frequent during February 1984. The *Hemiramphus marginatus* (Forsskål, 1775) samples of the Calicut showed that it was common in January 1984. The *Leiognathus splendens* (Cuvier, 1829) samples of Alleppey coast showed that it was frequent in February 1984 and common in March 1984. The *Secutor insidiator* (Bloch, 1787) samples of the Quilon coast revealed that it was common in December 1983 but it was frequent in January 1984 in Alleppey samples.

Cyclotella spp. bloom appeared in February 1984. In *Kowala thoracata* (Fowler, 1941) of the Calicut region it was noted to be common in March 1984 and in *Sardinella fimbriata* (Valenciennes, 1847) it was common in January and frequent in February 1984; it was common in *Sardinella longiceps* during February 1984 but in Quilon region the same fish revealed that it was very common in February and frequent in March 1984. In *Stolephorus heterolobus* (Rüppell, 1837) of the Quilon region *Cyclotella* spp. were common in March 1984. *Thryssa malabarica* (Bloch, 1795) of the Calicut region showed it to be common in February 1984. In *Leiognathus splendens* (Cuvier, 1829) it was frequent in March 1984 and in *Secutor insidiator* (Bloch, 1787) it was common in February 1984. The Quilon samples showed that it was common in March 1984. In *Sarda orientalis* (Temminck and Schlegel, 1844) *Cyclotella* spp. were very common in February 1984.

Fragilaria oceanica Cleve bloom appeared in April 1984. It was noted to be common in the guts of *Sardinella longiceps* Valenciennes, 1847 of Quilon region during that period and in *Hemiramphus marginatus* (Forsskål, 1775) of the Alleppey coast revealed that it was common in May 1984.

Rhizosolenia spp. bloom appeared in May 1984. In *Leiognathus splendens* (Cuvier, 1829) of the Calicut and Quilon revealed that it was common in May 1984. In *Secutor insidiator* (Bloch, 1787) of the Quilon also showed it to be common during that period. The *Pampus chinensis* (Euphrasen, 1788) of the Calicut revealed it to be frequent in May 1984.

Pyxidicula minuta Grunow bloom appeared in June 1984 and a mixed bloom of *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. appeared in August 1984. In *Caranx sexfasciatus* Quoy and Gaimard, 1824, *Pyxidicula minuta* Grunow were common during June, July and August and *Coscinodiscus* spp. were common in August of Quilon and *Pyxidicula minuta* Grunow were common in June 1984 of Alleppey; but it was common and *Coscinodiscus* spp. were frequent in August 1984. In *Kowala thoracata* (Fowler, 1941) *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. were frequent in August 1984 of Quilon. The August 1984 samples of Calicut showed *Pyxidicula minuta* Grunow were common and *Coscinodiscus* spp. were frequent. In *Pellona ditchela* Valenciennes, 1847, *Pyxidicula minuta* Grunow were common in August 1984 of Quilon. It was common in June, and July 1984 of Alleppey. In *Sardinella longiceps* Valenciennes, 1847 June 1984 samples of Quilon showed it to be frequent but Alleppey region samples revealed it to be common in July and frequent in June, July and common in August 1984 of Calicut and *Coscinodiscus* spp. appeared to be frequent in August 1984. *Stolephorus heterolobus* (Rüppell, 1837) of Quilon revealed *Pyxidicula minuta* Grunow were frequent in June. *Stolephorus indicus* (van Hasselt, 1823) of Alleppey showed *Pyxidicula minuta* Grunow to be frequent in July 1984 and common in August 1984. The Calicut samples showed *Pyxidicula minuta* Grunow were common and Coscinodiscus spp. were frequent in August 1984. The Quilon samples of *Thryssa malabarica* (Bloch, 1795) showed *Pyxidicula minuta* Grunow common in July 1984 and frequent in August 1984 but in *Hemiramphus marginatus* (Forsskål, 1775) it was common in August 1984 but noted to be common in June of Alleppey. In *Leiognathus splendens* (Cuvier, 1829) *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. were frequent in July 1984 in Quilon and Alleppey samples but in *Katsuwonus pelamis* (Linnaeus, 1758) *Pyxidicula* minuta Grunow were common in June of Alleppey. The *Rastrelliger kanagurta* (Cuvier, 1817) *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. were frequent during August 1984 of Quilon. In June and August 1984 *Pyxidicula minuta* Grunow were frequent and *Coscinodiscus* spp. were frequent in August

1984 of Alleppey. In *Sarda orientalis* (Temminck and Schlegel, 1842) *Pyxidicula minuta* Grunow were common during August 1984 in samples of Quilon

The study helped to point out that phytoplankton directly and indirectly plays a vital role in the feed of the pelagic fishes. It was interesting to mention that when the phytoplankton were rare in the guts which were analysed more copepods were made its appearance. The copepods are the selective filter feeders which in turn feeds of diatoms which indirectly serves the purpose of a feed for the fish and aids in the survival and growth of it. While observing the gut contents it was noted that the diet composition of some of the pelagic fishes is some what similar to the earlier studies made by (Bhimachar and George 1952, Sam Bennet 1973, Noble 1962,1965; Dhulkhed 1965 and Kagwade 1964).

At the same time it is interesting to compare the blooming of the phytoplankton with the gut contents of the pelagic fishes. It revealed some interesting observation that during the season of blooming of certain phytoplankton, before or after that like *Coscinodiscus* spp., *Biddulphia* spp., *Cyclotella* spp., *Fragilaria oceanica* Cleve, *Rhizosolenia* spp., *Pyxidicula minuta* Grunow the abundance of these organisms were coincided in the general feed of the pelagic fishes. The *Coscinodiscus* spp. is present throughout the season in almost all the samples. Dhulkhed (1972 a,b) and Nair (1973) noted that the food of oil sardine consisted mainly of *Coscinodiscus* spp. Similarly Abdul Hakkin and Dwivedi (1977) noticed the abundance of *Coscinodiscus* spp. in the guts and environment. The foregoing study aids to the certain extent for the explanation of the visual observation of the blooms.

V. DISCUSSION

The marine environment forms a rich ecosystem where various forms are supported by interdependence on one another. Not only is this productive zone important from the ecological point of view but from human stand point, it is of considerable value as source of food and economy. Unlike the generation of food on land, the tapping of nutrients from oceanic and coastal water bodies do involve very little economical investment. From this angle, the development and maintenance of such species as fish forms a field of investigation of vital significance.

Eventhough the various biological components in the oceanic and coastal systems are regulated by the existence of a dynamic equilibrium, there are certain key elements which can change the balance. The phytoplankton belong to this category and their status as primary producers and serving as feed for fish etc. makes them crucial factors. Hence the presence of these drifting organisms are to be studied carefully to maximally exploit resources from sea. The blooming phenomenon is to be looked at from this angle. The significance of red tides as probable sources of increased feed or having adverse effects has already been discussed (Revikala and Ramamurthy 1984).

It is essential to exploit to a great extent all the available fish resources. In the light of the increased human consumption the production has to be increased (FAO 1983). There are definite views that increase in world fish production currently is inadequate to meet the demand target, at its present rate of growth (FAO 1984a). There has not been any considerable increase in the total fish landings along the Indian coasts from 1951 to 1965 (Virabhadra Rao 1973). This also holds good for the pelagic fish which forms a major fishery. Eventhough pelagic fish consume mostly plankton either directly or indirectly, the life cycle and species maintenance of the demersal fish are dependent on these organisms as the larval forms of fish feed on them (URI CF Newsletter 1983). Exploring the avenue of increased feed to sustain more fish by way of blooms of phytoplankton is major approach at utilization of biological resources to increase fishery. An estimated annual landings from 1951 to 1965 showed that the various countries bordering Indian Ocean, India supplied 40.5% of total fish catch. Fish from south west coast of India was the major contributor (31.5%) of Indian fishery (Virabhadra Rao 1973). He suggested that the fishery is not exploited maximally attributing it to lack of use of proper fishing gear. However, methods based on predictability of presence of fish shoals in a particular area also should enhance fish production. This could be done based on the existence of phytoplankton blooms which are favourable to fish.

However, the reports of the blooming phenomenon from the Indian coastal waters have been sporadic. An orderly analysis of the various reported blooms along Indian coastal waters from 1963 to 1982 was made (Devikala and Ramamurthy 1984). From the analysis it emerges that blooming phenomena should be observed systematically and analysed in the light of its impact on pelagic fishery. The observation made during the present study is the outcome of the study on the occurrence of blooms along south west coast of India. It is interesting to note that during the period from February 1982 to August 1984 several blooms of diatoms, dinoflagellates and blue green algae developed along the south west coast of India. Out of the total blooms, 17 were caused by diatoms, 5 by dinoflagellates and 3 by blue green algae. The blue green algae Trichodesmium spp. bloomed during 1982,1983 and 1984. The blooms occurred almost during the same time i.e. February to April. The red tide of Trichodesmium spp. during 1982 was of longer duration (13 to 14 days) as compared to the one that appeared in 1983 (7 to 8 days) and 1984 (5 to 6 days). However, no adverse effects on fish were observed during these blooms and lot of fishes swim in that region. Ramamurthy et al. (1972) had earlier observed occurrence of Trichodesmium erythraeum bloom during March of 1972 along Goa coast in the

Arabian Sea. The *Trichodesmium* spp. bloom occurred annually along the Indian coast but there were no adverse effects due to this bloom (Revikala and Ramamurthy 1984). Similar to the present observation Verlancar (1978) observed no adverse effects on fishery due to the bloom. However, Prabhu *et al.* (1971) came to the conclusion that *Trichodesmium* spp. has adverse effects on the fishery off Mangalore coast. A similar negative impact was suggested on tuna fishery off Minicoy Island (Nagabhushanum 1967). Panikkar (1967) noted mass mortality in the Arabian Sea due to *Trichodesmium* spp. bloom or *Noctiluca* sp. bloom. However Ramamurthy (1970) analysed the blooming of this blue green algae and its impact on fishery from 1965 to 1968 and summarised that no ill effects were present. Mackerels landed abundantly and even consumption of these fish by sea gulls showed no toxic effects. Present data are also similar to that of the observation made by Ramamurthy (1980). Eleuterius *et al.* (1981) reported from the coastal waters of Mississippi and adjacent waters of the gulf of Mexico that the fish apparently avoided the bloom but no mortality was observed. It is interesting to note that the red tide of *Trichodesmium* spp. always occurs during the summer months of February to April along the Indian coastal waters. It is possible that hot weather conditions due to lack of strong winds (less than 4 to 5 knots) and prevalence of comparatively calmer waters could be one of the contributing factors for the bloom (Ramamurthy *et al.*, 1972). But for an isolated report of Sato *et al.* (1966) which related red tide of *Trichodesmium* spp. in north eastern Brazil with Tamandare fever there were no reported occurrence of adverse effects due to this bloom or during present observation.

The red water phenomenon due to *Ceratium* spp. occurred during February 1982 and March to April 1983 off the various observation centres along the south west coast of India. Eventhough the 1982 bloom was longer in duration (8 to 9 days) as compared to red tide of 1983 (6 to 7 days) the cell counts were similar as judged by the cell numbers. Observation of *Ceratium* spp. bloom along the South west coast of India i.e. off Calicut was made earlier but no effect on fishery was investigated (George 1953). In the present study no direct effect of toxicity was recorded although fishes were not caught from the bloom area.

Peridinium spp. produced red tides along the south west coast of India during May 1982 and April 1984. Analysis of the blooming pattern showed that the phenomenon appeared almost simultaneously off Quilon, off Alleppey and off Calicut during May 1982. Again it appeared in April 1984 and it showed the cell counts less than 1982 red tide. Adverse effect on fishery was not observed in both blooms eventhough no fish shoals were caught from the bloomed region. A similar bloom of Peridinium spp. on the south west coast of Calicut during 1950 to 1951 was reported (George 1953).

Subba Rao (1969) has reported earlier the occurrence of Asterionella japonica bloom along Indian coastal waters. The Asterionella japonica Cleve bloomed during July 1982 and June to July 1984 along the south west coast of India. Current study reveals that fish shoals could be located in the area and no undesirable effects were noticed. It is also interesting to note that a mixed bloom of Asterionella japonica Cleve and Thalassiothrix spp. developed towards the end of 1982 at all the observation centres. The blooming, however, lasted only for 6 to 7 days with lot of fishes swarmed in the streaks and patches of bloom. A similar mixed bloom occurred during October 1983. During October to November 1982 and August to September 1983 Skeletonema costatum (Greville) Cleve bloomed along the south west coast; like other diatom blooms this was also favourable to fishes. Ganapati and Raman (1979) had observed a similar bloom of Skeletonema sp. off the coast of Visakhapatnam which was attributed to pollution.

Unlike reports from other coasts where phytoplankton bloom causes toxicity there are not many reports on generation of toxicity in Indian coast by these blooms. Recently a report from the Kumbla near Mangalore has been made regarding isolation of toxin from clams and oysters and suggested that dinoflagellates may be responsible for such accumulation. However more investigation on these lines is necessary to establish the direct link between the dinoflagellates, clams and oysters (Karunasagar et al., 1984 and Fishing Chimes 1984d). Most of the adverse effects recorded were either the short term impact like avoidance of the bloom area by fishes as in the present study or poor catch of fish during red tide (Bhimachar and George 1950, Prabhu et al., 1965, Jagabhushanam 1967 and Prabhu et al., 1971). However, several factors can contribute to adverse effects. Negative impact could be due to even choking of gills of fish during such blooms as Trichodesmium spp. by cluster of filaments (Desikachary 1959). It is also possible that certain toxin may not be active under certain climatic conditions (Schradie and Bliss 1962). The non-toxicity of such species of Gonyaulax spp. in Indian coastal waters during bloom (Prakash and Sarma 1964) and report of toxicity due to the same organism from other coasts (as mentioned earlier in the review of previous work) could be due to the factors mentioned above. This holds good for the Chaetoceros spp.

bloom also observed during the present study which did not have any undesirable effect where as oyster kills were noticed during bloom in gulf beach (Gunter and Lyles 1979).

Avoidanse to blooming organism by fish was also detected during the red tide of *Noctiluca miliaris* Surirey which took place during June to July 1983. However, toxic effects were not detectable. Raghu Prasad (1953,1958) observed in the Palk Bay and Mandapam that red water phenomena caused by *Noctiluca* sp. are inimical to fisheries and an inverse relationship exists between swarm of *Noctiluca* sp. and pelagic fishery. Unlike the report of Thomas (1979) on *Noctiluca* sp. bloom which occurred at Lysekil, Sweden in July 1978, the frequency of appearance being once in every seven to ten years the *Noctiluca* sp. bloom appeared at irregular intervals along the Indian coast (Revikala and Ramamurthy 1984). The observations made by Revikala and Ramamurthy on the occurrence of phytoplankton blooms and marine fish landings during two decades from 1963-1982 did not show any linear or inversal relationship. But it concluded that the peak marine fish landings was observed in 1975 and 1978 though *Trichodesmium* spp. blooms appeared. In 1976, 1977 and 1981 though there were occurrence of *Noctiluca* sp. blooms, but nevertheless the marine fish landings did not show any significant fluctuation. The conclusion was that such adverse blooms has got some short term effect on the pelagic fishes like avoidance of the bloomed area along the Indian coast. However, such short term movements will not have any adverse significance on the annual total marine fish landings.

Coscinodiscus spp. blooms developed along the south west coast during 1983 and 1984. Like other diatom blooms this bloom was also favourable to the fishery i.e. pelagic fishes found swimming in that area. In the present study the development of *Chaetoceros* spp. bloom during December 1982 did not have any negative effect on pelagic fishery.

A diatom bloom of *Biddulphia* spp. appeared in January and March 1984. During both these blooms fishes were found swimming in the bloomed area. Another diatom bloom *Cyclotella* spp. appeared in February 1984. A bloom of *Fragilaria oceanica* Cleve made its appearance in April to May 1984. Subrahmanyan (1959) and Govindan (1972) noted that the *Fragilaria* sp. bloom coincided with the oil sardine fishery. Devassy (1974) reported the bloom of *Fragilaria* sp. from the Mangalore coast. The present study noted lot of pelagic fishes in the bloomed region. A bloom of *Rhizosolenia* spp. was observed in May 1984. The 7 days bloom was favourable to the pelagic fishes. The

Pyxidicula minuta Grunow bloom was noted in June 1984 and in August 1984 a mixed bloom of *Pyxidicula minuta* Grunow and *Coscinodiscus* spp. appeared, and in the mixed bloom the *Pyxidicula minuta* Grunow dominated and it can be seen that when both these blooms appeared lot of pelagic fishes appeared in that region. In the month of July 1984 a bloom of *Triceratium* spp. was observed and lot of pelagic fishes were noticed in the bloomed region. In the region of diatoms blooms which were observed in the present study lot of pelagic fishes swims freely. So also the case with the blue green algae bloom. But the red tides of dinoflagellates were avoided by the pelagic fishes.

Gut content analysis revealed that like Subrahmanyan (1959), fishes favours non setoid types than the setoid types. The diatoms like *Pyxidicula minuta* Grunow, *Coscinodiscus* spp., *Cyclotella* spp., *Fragilaria oceanica* Cleve, *Rhizosolenia* spp. and *Biddulphia* spp. were seen more in the gut of these fishes (as mentioned in the gut content analysis of the pelagic fishes); during, before and after the bloom period. It is possible that such blooms that develop several times and are favourable to fish can be induced if the conditions for their development are studied. Gut content analysis of the fishes caught from the blooming area showed very common of the bloomed organism. It is interesting to note from the gut content analysis of fishes that most of the phytoplankton, that bloomed were present in the guts of most of the samples of pelagic fishes. The gut content analysis also revealed that the organisms like Coscinodiscus spp. were observed throughout the year. The visual observation of avoidance of dinoflagellate blooms like Ceratium spp., Noctiluca miliaris Suriray and Peridinium spp. blooms were noted in the feed by the absence of this organism during the season of the bloom.

The presence of mackerels due to the availability of additional feed supply was already reported (Virabhadra Rao 1973 and Sadananda Rao et al., 1973). According to Govindan (1972) there seemed to be some correlation exists between the bloom of Fragilaria oceanica and oil sardines on the basis of feeding habits. Fraser (1962) studied that the richest fisheries of the world are related to the areas of plankton production and Hart (1966) noted that fisheries may be profoundly affected by the blooms. Such observation could be utilised to further induce blooming.

Basically the strategies to exploit the red tides could be done in two ways. One approach is to find out the blooms which are beneficial to fish. The other aspect will be to regulate the formation of those blooms that have adverse effects. Several efforts could be made in the direction of biological control mechanisms, has been suggested by some workers (Kutt and Martin 1975, Chew 1983).

It is possible that in future some toxic blooms may develop along the east and west coasts of India and proper control measures can be planned. The data generated on the characterization of the various blooms should also help to predict the presence of fish shoals if similar blooms occur in future.

The need for increased fish landings had already been stressed. More research has to be directed towards increasing pelagic fishery. This is in the light of the fact that 50% of the total world catch is pelagic fish (FAO 1983). Average consumption of the fish is expected to rise approximately 13 kg to over 15 kg by the year 2000. The demand growth will be greatest in the developing countries due to population growth (FAO 1983). India, hence, has to develop means to increase the catch. However, pelagic fish landings data from 1970 to 1980 shows that there has been hardly any increase in catch in one decade (MPEDA 1981, 1982 and CMFRI 1982, 1983 and Fishing Chimes 1984b). The yield of fish, started declining till 1982. Even if there is slight increase in 1982, the major fishes like oil sardine and mackerel showed a decline (CMFRI 1983, Fishing Chimes 1984a). According to Ramalingam (1984) the total marine fish landing along south west coast of India started declining from 1973 to 1982. Fishing Chimes (1984a) noted that the short fall in mackerels and sardine has not compensated the increase of anchoviella and tuna.

From the present systematic analysis of blooms it becomes clear that blooms of various phytoplankton occur along the south west coast of India. Also significant is the fact that most of the blooms are favourable to the pelagic fishery. This fact could be used to exploit the usefulness of these organisms as an increased food supply. Once systematic analysis of phytoplankton blooms along the Indian coast is made one should be able to predict régions of availability of more fish and exploit the resources better. With the generation of more data on the various factors governing formation of red tides and systematic characterization of blooms appearing in future one should be able to see whether specific blooms occur repeatedly in future. This would enable one to forecast their development and thereby directing fishery efforts towards those regions and in turn for a better fishery.

VI. SUMMARY

The present study was undertaken to observe the phytoplankton (diatoms, dinoflagellates and blue green algae) blooms occurring along the south west coast of India at various seasons from February 1982 to August 1984.

The centres selected for observation and collection of samples were off Quilon ($8^{\circ}54'N - 76^{\circ}36'E$), off Alleppey ($9^{\circ}24'N - 76^{\circ}18'E$) and off Calicut ($11^{\circ}6'N - 75^{\circ}48'E$) between 5 to 8 fathoms.

A total number of 25 phytoplankton blooms were studied. Characterization of the phytoplankton blooms includes observing the cell counts (cells/ml) from the day of its appearance till its disappearance. The appearance, duration and locality of the blooms were also noted. The details were given below.

Organisms constituting the bloom	Year and period	Duration	Cell counts (cells/ml)	
			Minimum	Maximum
	1982	**Days**		
Ceratium spp.	3rd February to 12th February	8 to 9	41	712
Trichodesmium spp.	20th March to 8th April	13 to 14	40	1360
Peridinium spp.	17th May to 22nd May	5 to 6	52	824
Asterionella japonica Cleve	5th July to 15th July	7 to 10	40	1680
Sceletonema costatum (Greville) Cleve	27th October to 6th November	8 to 9	40	950
Asterionella japonica Cleve and *Thalliassiothrix* spp.	10th December to 18th December	6 to 7	40	712
	1983			
Trichodesmium spp.	18th February to 28th February	7 to 8	40	982
Ceratium spp.	26th March to 2nd April	6 to 7	40	684
Noctiluca miliaris Surirey	14th June to 7th July	9 to 10	40	984
Sceletonema costatum (Greville) Cleve	26th August to 5th September	8	40	940
Asterionella japonica Cleve and *Thalliassiothrix* spp.	17th October to 28th October	9	40	842

Organisms constituting the bloom	Year and period	Duration	Cell counts (cells/ml)	
			Minimum	Maximum
Coscinodiscus spp.	14th November to 19th November	5	58	480
Chaetoceros spp.	12th December to 17th December	5	60	520
	1984			
Biddulphia spp.	16th January to 23rd January	5 to 6	52	528
Cyclotella spp.	2nd February to 10th February	7	40	682
Coscinodiscus spp.	13th February to 22nd February	8	40	662
Biddulphia spp.	6th March to 14th March	7	40	756
Trichodesmium spp.	22nd March to 27th March	5 to 6	40	788
Peridinium spp.	14th April to 23rd April	6 to 7	40	582
Fragilaria oceanica Cleve	27th April to 3rd May	6	40	628
Rhizosolenia spp.	22nd May to 30th May	7	40	834
Pyxidicula minuta Grunow	7th June to 14th June	6	54	676
Asterionella japonica Cleve	27th June to 4th July	7	40	560
Triceratium spp.	19th July to 26th July	7	40	682
Pyxidicula minuta Grunow and *Coscinodiscus* spp.	8th August to 16th August	7	40	580

Out of the total blooms, 17 were caused by diatoms, 5 by dinoflagellates and 3 by blue green algae. In the region of diatom and blue green alga blooms lot of pelagic fishes were seen. Fishes avoided the dinoflagellate blooms but no mortality, off odour or irritation were noticed.

The gut contents of the pelagic fishes found in the bloomed regions revealed that the bloomed organisms were very common in the guts.

An year round study of the gut content analysis of the pelagic fishes from September 1983 to August 1984 were done in order to see whether the bloomed organisms are included or not in the general feed. The pelagic fishes collected during various seasons from the coasts of Quilon, Alleppey and Calicut were listed below:-

Caranx sexfasciatus Quoy and Gaimard, 1824; Gnathanodon speciosus (Forsskål, 1775); Chirocentrus dorab (Forsskål, 1775); Kowala thoracata (Fowler, 1941); Ilisha melastoma (Schneider, 1801); Pellona ditchela Valenciennes, 1847; Sardinella fimbriata (Valenciennes, 1847; Sardinella longiceps Valenciennes, 1847; Stolephorus heterolobus (Rüppell, 1837); Stolephorus indicus (van Hasselt, 1823); Thryssa malabarica (Bloch, 1795); Thryssa mystax (Schneider, 1801); Hemiramphus marginatus (Forsskal, 1775); Lactarius lactarius (Bloch and Schneider, 1801); *Gazza minuta* (Bloch, 1797); *Leiognathus splendens* (Cuvier, 1829); *Secutor insidiator* (Bloch, 1787); *Liza tade* (Forsskål, 1775); *Scatophagus argus* (Bloch, 1788); *Sphyraena obtusata* Cuvier, 1829; *Katsuwonus pelamis* (Linnaeus, 1758); *Rastrelliger kanagurta* (Cuvier, 1817); *Sarda orientalis* (Temminck and Schlegel, 1844); *Scomberomorus guttatus* (Bloch and Schneider, 1801) and *Pampus chinensis* (Euphrasen, 1788).

The diatoms like *Pyxidicula minuta* Grunow, *Cyclotella* spp., *Coscinodiscus* spp., *Rhizosolenia* spp., *Biddulphia* spp. and *Fragilaria oceanica* Cleve were seen more in the guts of some of the pelagic fishes during, before and after the bloom period.

It can be concluded that such blooms that develop several times and are favourable to fish can act as an increased food supply. In future, one can direct the fishery efforts towards those regions if specific blooms occur repeatedly. This will help to increase to a certain extent the pelagic fishery.

VII. REFERENCES

Abdul Hakkim, V.M. and Dwivedi, S.N. 1977. The Ecological features and mackerel fishery off Goa. Geobios, 4: 88-92.

Adams, J.A., Seaton, D.D., Buchanan, J.B. and Longbottom, M.R. 1968. Biological observations associated with the toxic phytoplankton bloom off the east coast. Nature, 220(5162): 24-25.

Ayres, P.A. and Cullum, M. 1978. Paralytic shellfish poisoning. An account of investigations into mussel toxicity in England 1968-'77. Fish. Res. Tech. Rep. Dir. Fish. Res. U.K. No.40, pp 23.

Balch, W.M. 1981. An apparent lunar tidal cycle of phytoplankton blooming and community succession in the Gulf of Maine. J. Exp. Mar. Biol. Ecol., 55(1): 65-77.

Banerji, S.K. 1973. An assessment of the exploited pelagic fisheries of the Indian seas. Proc. Symp. Living Resources of the seas around India, 114-136.

Barlow, R.G. 1982. Phytoplankton ecology in the southern Benguela Current. III. Dynamics of a bloom. J. Exp. Mar. Biol. Ecol., 63(3): 239-248.

Bhimachar, B.S. and George, P.C. 1950. Abrupt set backs in the fisheries of the Malabar and Kanara coasts and red water phenomenon as their probable cause. Proc. Ind. Acad. Sci., B. 31(6): 339-350.

Bhimachar, B.S. and George, P.C. 1952. Observations on the food and feeding of the Indian Mackerel, Rastrelliger canagurta. Proc. Ind. Acad. Sci., B. 36(3): 105-118.

Blasco, D. 1977. Red tide in the upwelling region of Baja California. Limnol. Oceanogr., 22(2): 255-263.

Bodungen, V.B.K., Brockel, V., Smetacek, V. and Zeitzschel, B. 1981. Growth and sedimentation of the phytoplankton spring bloom in the Bornholm Sea (Baltic Sea). Kieler Meeresforsch. 5: 49-60.

Bowman, T.E. and Lancaster, L.J. 1965. A bloom of the planktonic Blue Green Alga, Trichodesmium erythraeum, in the Tonga Islands. Limnol. Oceanogr., 10(2): 291-293.

Brongersma-Sanders, M. 1957. In treatise on marine ecology and paleo ecology. ed. by J.W. Hedgepeth. Geol. Soc. Am. Memoir., 67: 941-1010.

Brown, P.C., Hutchings, L. and Horstman, 1979. A redwater outbreak and associated fish mortality at Gordon's Bay near Cape Town (South Africa). Fish. Bull., Capetown, 11: 46-52.

Burke, J.M., Marchisotto, J., Mc Laughlin, J.J.A. and Provasoli, L. 1960. Analysis of the toxin produced by Gonyaulax catenella in axenic culture. Am. N.Y. Acad. Sci., 90: 837-842.

Carreto, J.I., Lasta, M.L., Negri, R. and Benavides, H. 1981. Red tides and toxicity of bivalve molluscs in the Argentine Sea. Publ. by Inst. Nac. Invest. Desarr. Pesq. Mar. Del. Plata (Argentina), No.399: pp 89.

Cassie, V. 1981. Non-toxic blooms of Prorocentrum micans (Dinophyceae) in the Karamea Bight. N.Z.J. Mar. Freshwat. Res., 15(2): 181-184.

Cassinari, E., Grillo, D., Princi, M., Specchi, M., Stravisi, F. and Valli, G. 1979. Observations on Noctiluca miliaris Suriray from the Gulf of Trieste. Proc. National Scientific Meeting. Publ. by CNR Rome (Italy), Vol.2, pp 937-948.

Chacko, P.J. and Mahadevan, S. 1956. Swarming of Trichodesmium erythraeum in waters of around Krusadai Island, Gulf of Mannar. Fish. Stn. Repts. and Year Book, April 1954 - March 1955, Govt. of Madras.

Chew, F. 1955. On the offshore circulation and convergence mechanism in the red tide region off the west coast of Florida. Trans. Amer. Geophys. Uni., 36: 963-971.

Chew, K.K.,1983. The potential importance of an endoparasite of Gonyaulax in PSP outbreaks. 186th American Chemical Society Meeting, Washington.

Chidambaram, K. and Unny, M.M. 1944. Note on the swarming of the planktonic algae Trichodesmium erythraeum in the Pamban area and its effect on the fauna. Curr. Sci., 13: 263.

Cho, C.H. 1977. On red water and water quality by plankton occurrence near Chungmu. Bull. Tongyeong. Fish. Jr. Coll., 12: 7-12.

Cho, C.H. 1978. On the *Gonyaulax* red tide in Jinhae Bay. *Bull. Korean Fish. Soc.*, *11*(2): 111-114.

Cho, C.H. 1981. On the *Gymnodinium* red tide in Jinhae Bay (Korea). *Bull. Korean Fish. Soc.*, *14*(4): 227-232.

CMFRI, 1980. Marine Fisheries Information Service, No.19, Cochin, India.

CMFRI, 1982. Marine Fisheries Information Service, No.41, Cochin, India.

CMFRI, 1983. Marine Fisheries Information Service, No.52, Cochin, India.

CMFRI, 1984. Mud Banks of Kerala Coast. Bull No.31, Cochin, India.

Collier, A. 1958. Some biochemical aspects of red tides and related oceanographic problems. *Limnol. Oceanogr.*, *3*(1): 33-39.

Connell, C.H. and Cross, J.B. 1950. Mass mortality of fish associated with the protozoan *Gonyaulax* in the Gulf of Mexico. *Science*, *112*: 359-363.

Conover, S.A.M. 1975. Nitrogen utilization during spring blooms of marine phytoplankton in Bedford Basin, Nova Scotia, Canada. *Mar. Biol.*, (Springer-Verlag), *32*(3): 247-261.

Conway, H.L. and Whitledge, T.E., 1979. Distribution fluxes and biological utilization of inorganic nitrogen during a spring bloom in the New York Bight. *J. Mar. Res.*, *37*(4): 657-668.

Cullen, J.J., Horrigan, S.G., Huntley, M.E. and Reid, F.M.H. 1982. Yellow water in La Jolla Bay, California, July 1980. I.A. bloom of the Dinoflagellate, Gymnodinium flavum Kofoid and Swezy. J. Exp. Mar. Biol. Ecol., 63(1): 67-80.

Dahril, T. and Shoji, I. 1981. Red tides in Nagasaki Bay (Japan) during the summer season of 1979. Bull. Fac. Fish. Nagasaki Univ., 50: 17-26.

Dale, B. and Yentsch, C.M. 1978. Red tide and paralytic shellfish poisoning. Oceanus, 21(3): 41-49.

Daniel, A., Nagabhushanam, A.K. and Krishnamurthy, P. 1978. On the occurrence of 'greenish yellow water' phenomenon caused by the swarming of Trichodesmium erythraeum Ehrenburg in the sea off Madras and its effect on the local marine fauna. J. Bombay Nat. Hist. Soc., 75(1): 88-95.

Daniel, A., Nagabhushanam, A.K. and Chakrapany, S. 1979. On bioluminescent Noctiluca swarms associated with the movement of extensive shoals of flying fishes and schools of dolphins in the northern Arabian Sea in February 1974. Rec. Zool. Surv. India, 75(1/4): 237-246.

Defant, A. 1961. Physical oceanography, Vol. I., Pergamon Press, Oxford, pp 644.

De Freitas, J.C. and Lunetta, J.E. 1982. Occurrence of a red tide in the littoral of Rio de Janeiro (Brazil). Cienc. Cult., 34(8): 1059-1061.

Desikachary, T.V. 1959. Cyanophyta Indian Council of Agricultural Research, New Delhi, pp 686.

Devassy, V.P. 1974. Observations on the bloom of a diatom *Fragilaria oceanica* Cleve. *Mahasagar*. *7*(1 and 2): 101-105.

Devassy, V.P. 1983. Plankton production associated with cold water incursion into the estuarine environment. *Mahasagar*. *16*(2): 221-233.

Devassy, V.P. and Bhattathiri, P.M.A. 1974. Phytoplankton ecology of the Cochin backwater. *Ind. J. mar. Sci.*, *3*(1): 46-50.

Devassy, V.P., Bhattathiri, P.M.A. and Qasim, S.Z. 1978. *Trichodesmium* phenomenon. *Ind. J. mar. Sci.*, *7*(3): 168-186.

Devassy, V.P., Bhattathiri, P.M.A. and Qasim, S.Z. 1979. Succession of organisms following *Trichodesmium* phenomenon. *Ind. J. mar. Sci.*, *8*(2): 89-93.

Devassy, V.P., Bhattathiri, P.M.A. and Radhakrishna, K. 1983. Primary production in the Bay of Bengal during August 1977. *Mahasagar*. *16*(4): 443-447.

Dhulkhed, M.H. 1968. Observations on the food and feeding habits of the Indian Oil Sardine *Sardinella longiceps*. Val. *Ind. J. Fish.*, *9*(1): 37-47.

Dhulkhed, M.H. 1972a. The food of small sized oil sardine of the Mangalore area. *Ind. J. Fish.*, *17*(1 and 2): 111-115.

Dhulkhed, M.H. 1972b. Food of the oil sardine taken by bottom nets and surface gill net in the Mangalore area. *Ind. J. Fish.*, *19*(1 and 2): 163-166.

Dodge, J.D. 1977. The early summer bloom of dinoflagellates in the North Sea, with special reference to 1971. *Mar. Biol.* (Springer-Verlag), *40*(4): 327-336.

Endo, T. and Nagata, H. 1984. Resting and germination of cysts of *Peridinium* spp. (Dinophyceae). *Bull. Plank. Soc. Japan*, *31*(1): 23-33.

Eleuterius, L., Perry, H., Eleuterius, C., Warren, J. and Caldwell, J. 1981. Causative analysis on a nearshore bloom of *Oscillatoria erythraea* (Trichodesmium) in the northern Gulf of Mexico. *N.E. Gulf Sci.*, *5*(1): 1-11.

Fâlkowski, P.G., Hopkins, T.S. and Walsh, J.J. 1980. An analysis of factors affecting oxygen depletion in the New York Bight. *J. mar. Res.*, *38*(3): 479-506.

FAO, 1974. Species of identification sheets for fishery purposes. Eastern Indian Ocean and Western Central Pacific, Rome.

FAO, 1976. Pelagic fishery investigation on the South West Coast of India. Final report of Norad and the Institute of Marine Research, Bergen.

FAO, 1983. Fact sheet world fisheries, Rev.4, Rome.

FAO, 1984a. World Fisheries Conference, Progress Report No.2, Rome.

FAO, 1984b. Species identification sheets for fishery purposes, Western Indian Ocean, Rome.

Fiala, M. 1982. Vitamin B_{12} and phytoplankton at the thermocline level in the North West Mediterranean. *Oceanol. Acta.*, *5*(3): 339-347.

Fishing Chimes, 1984a. Marginal increase in Marine Fish output. *3*(11): 65.

Fishing Chimes, 1984b. Development of Deep Sea Fishing. Pattern and Policy, *4*(1): 18-24.

Fishing Chimes, 1984c. News International. Infected sea food kills people. 4(2): 4.

Fishing Chimes, 1984d. Mangalore College of Fisheries warns clams consumers. 4(2): 51-52.

Fishing Chimes, 1984e. Marine production. 4(2): 75.

FMI, 1983. Poison seafood scares. 22(11 and 12): Highway Publications Ltd., London.

Fraser, J. 1962. Nature Adrift. G.T. Foulis and Co.Ltd., London, pp 178.

Fudge, H. 1977. The red tides of Malta. Mar. Biol., 39(4): 381-386.

Fung, Y.C. and Trott, L.B. 1973. The occurrence of a Noctiluca scintillans (Macartney) induced red tide in Hong Kong. Limnol. Oceanogr., 18(3): 472-476.

Ganapati, P.N. and Raman, A.V. 1979. Organic pollution and Sceletonema blooms in Visakhapatnam Harbour. Ind. J. mar. Sci., 8(3): 184-187.

Garver, J.L. and Lewin, J. 1981. Persistent blooms of Surf diatoms along the Pacific coast U.S.A. 1. Physical characteristics of the coastal region in relation to the distribution and abundance of the species. Estuar. Coast. Shelf. Sci., 12(2): 217-229.

Gates, J.A. and Wilson, W.B. 1960. The toxicity of Gonyaulax monilata Howell to Mugil cephalus. Limnol. Oceanogr., 5(2): 171-174.

George, P.C. 1953. The marine plankton of the coastal waters of Calicut with observations on the hydrological conditions. J. Zoo. Soc. India, 5(1): 76-107.

Govindan, T.K. 1972. The Oil Sardine. An energetic food and potential industrial raw material. Sea Food Export Jour., 4(8): 1-5.

Glover, H.E. 1978. Iron in Maine coastal waters, seasonal variation and its apparent correlation with a dinoflagellate bloom. Limnol. Oceanogr., 23(3): 534-537.

Grall, J.R. 1976. On a bloom of Gyrodinium aureolum Hulbert observed in the English Channel. Trav. Stn. Biol. Roscoff (Nouv. Ser.), 23: 19-22.

Gunter, G. 1979. Notes on sea beach ecology. Food sources on sandy beaches and localised diatom blooms bordering gulf beaches. Gulf Res. Rep., 6: 305-307.

Gunter, G. and Lyles, C.H. 1979. Localised plankton blooms and jubilees (fish kills) on the Gulf of(Mexico) Coast. Gulf Res. Rep., 6(3): 297-299.

Guzman, L. and Campodonico, I. 1978. Red tides in Chile. Interciencia, 3(3): 144-151.

Hart, T.J. 1966. Some observations on the relative abundance of marine phytoplankton population in nature. Some contemporary studies in marine science. Ed. Harold Barnes, George Allen and Unwin Ltd., London.

Hasle, G.R. 1978. The inverted microscope method. In the phytoplankton manual (ed.) sournia, A. Publ: by UNESCO, Paris. Page Brothers (Norwich) Ltd., pp 337.

Hayashi, T. Shimizu, Y. and White, A. 1982. Toxin profile of herbivorous zooplankton during a Gonyaulax bloom in the Bay of Fundy. Bull. Jap. Soc. Sci. Fish., 48(11): 1673.

Heyl, M.G., Freeberg, L.R. and Dickinson, K.W. 1978. Dissolved oxygen during Gymnodinium breve blooms along the Florida west coast, 1976-1978. J. Environ. Sci. Health, 13A(10): 725-731.

Holmes, R.W., Williams, P.M. and Eppley, R.W. 1967. Red water in La Jolla Bay, 1964-1966. Limnol. Oceanogr., 12(3): 503-512.

Huntley, M.E. 1982. Yellow water in La Jolla Bay, California. July 1980. II. Suppression of zooplankton grazing. J. Exp. Mar. Biol. Ecol., 63(1): 81-91.

Hurst, J.W. and Yentsch, C.M. 1981. Patterns of intoxification of shellfish in the Gulf of Maine coastal waters. Can. J. Fish. Aquat. Sci., 38(2): 152-156.

Ilichev, V.J., Anikiev, V.V., Starodubtsev, E.G., Rodinov, N.A., Kulinich, N.M. and Shornikov, A.V. 1983. Observations on the distribution of red tide in Peter the Great Bay. Sov. J. Mar. Biol., 8(5): 234-236.

Ingle, R.M. and Martin, D.F. 1971. Prediction of the Florida red tide by means of the iron index. Environ. Letters, 1: 69-74.

James, P.S.B.R. 1972. On a bloom of Trichodesmium thiebautii in the Gulf of Mannar at Mandapam. Ind. J. Fish., 19(1 and 2): 205-207.

Jenkinson, I.R. and Connors, P.P. 1980. The occurrence of the red tide organism Gyrodinium aureolum Hulburt (Dinophyceae) around the south and west of Ireland in August and September 1979. J. Sherkin Isl., 1(1): 127–146.

Joseph, K.J. and Pillai, K. 1975. Seasonal and spatial distribution of phytoplankers in Cochin backwater. Bull. Dept. Mar. Sci. Univ. Cochin, 7(1): 171–180.

Kagwade, P.V. 1964. The food and feeding habits of the Indian oil sardine Sardinella longiceps Valenciennes. Ind. J. Fish., 11(1): 345–370.

Kamykowski, D. 1980. Sub thermocline maximums of the dinoflagellates Gymnodinium simplex (Lohmann) Kofoid and Swezy and Gonyaulax polygramma Stein. North east gulf Sci., 4(1): 39–43.

Karunasagar, I., Gowda, H.S.V., Subburaj, M., Venugopal, M.N. and Karunasagar, I. 1984. Outbreak of paralytic shellfish poisoning in Mangalore west coast of India. Curr. Sci., 53(5): 247–249.

Kat, M. 1983. Diarrhetic mussel poisoning in the Netherlands related to the dinoflagellate Dinophysis acuminata. Antonie Van Leeuwenhoek, 49(4–5): 417–427.

Kattner, G., Brockmann, U.H., Eberlein, K. and Hammer, K.D. 1982. Enclosed planktonic ecosystems during different stages of a spring bloom in south Norway. Netherlands J. Sea.Res., 16: 353–361.

Kim, Y.S. and Martin, D.F. 1974. Interrelationship of peace river parameters as a basis of the iron index. A predictive guide to the Florida red tide. Water Res., 8: 606–617.

Kofeid, C.A. and Swezy, O. 1921. The free living unarmored dinoflagellata. University of California Publications in Zoology, Memoirs, 5: 1-562.

Kutt, E.C. and Martin, D.F. 1975. Report on a biochemical red tide repressive agent. Environ. Letters, 9(2): 195-208.

Leahy, P. 1980. The effects of a dinoflagellate bloom in 1978 on the invertebrate fauna of the seashore in Dunmanus Bay Co. Cork Ireland. J. Sherkin Isl., 1(1): 119-125.

LeFevre, J. and Grall, J. R. 1970. On the relationships of Noctiluca swarming off the western coast of Brittany with hydrological features and plankton characteristics of the environment. J. Exp. Mar. Biol. Ecol., 4: 287-306.

Lembeye, V.G., Guzman, M.L. and Campodonico, G.I. 1975. Study on the toxic bloom caused by Gonyaulax catenella in the straits of Magellan. 3. Associated phytoplankton. Anal. Inst. Patagonia, 6(1-2): 197-208.

Mc Lachlan, A. 1980. Exposed sandy beaches as semi closed ecosystems. Mar. Environ. Res., 4: 59-63.

Mc Lachlan, A. and Lewin, J. 1981. Observations on surf phytoplankton blooms along the coasts of South Africa. Botanica Marina., 24(10): 553-557.

Mac Isaac, J.J. 1978. Diel cycles of inorganic nitrogen uptake in a natural phytoplankton population dominated by Gonyaulax polyedra. Limnol. Oceanogr., 23(1): 1-9.

Maclean, J.L. 1977. Observations on *Pyrodinium bahamense* plate, a toxic dinoflagellate, in Papua New Guinea. *Limnol. Oceanogr.*, *22*(2): 234-254.

Madhupratap, M., Devassy, V.P., Nair S.R.S. and Rao, T.S.S. 1980. Swarming of pelagic tunicates associated with phytoplankton bloom in the Bay of Bengal. *Indian. J. mar. Sci.*, *9*(1): 69-71.

Malone, T.C. 1978. The 1976 *Ceratium tripos* bloom in the New York Bight: Causes and consequences./ National Marine Fisheries Service, Seattle, WA (USA), NOAA. *Tech. Rep.*, pp 18.

Malone, T.C., Esaias, W. and Falkowski, P. 1976. Plankton dynamics and nutrient cycling. Part I. Water column processes. In oxygen depletion and associated benthic mortalities in New York Bight. Eds. Swanson, R.L., Sindermann, C.J., NOAA off. of Marine Pollution Assessment, Rockville, M.D.

Maretic, Z., Pojed, I., Zekic, R. and Bujan, M. 1978. Red tide due to dinoflagellates in the harbour of Pula. *Period. Biol.*, *80* (Suppl.I): 153-159.

Martin, D.F. and Martin, B.B. 1976. Aponin, a cytolytic factor towards the red tide organism, *Gymnodinium breve*. Biological assay and preliminary characterization. *J. Environ. Sci. Health A11* (10 and 11): 613-622.

MPEDA, 1977. Indian Fisheries 1947-1977. Publs by MPEDA, India, pp 96.

MPEDA, 1981. Statistics of the Marine Products Exports, No.13, Published by MPEDA, India.

MPEDA, 1982. Statistics of the Marine Products Exports, No.14. Published by MPEDA, India.

Mulligen, H.F. 1973. Probable causes for the 1972 red tide in the Cape Ann region of the Gulf of Maine. J. Fish. Res. Bd. Can., 30(9): 1363-1366.

Murphy, E.B., Steidinger, K.A., Roberts, B.S., Williams, J. and Jolley, J.W. Jr. 1975. An explanation for the Florida east coast Gymnodinium breve red tide of November 1972. Limnol. Oceanogr., 20(3): 481-486.

Nair, R.V. 1973. Indian Sardines, CSIR Zoological Monograph, No.2, pp 107.

Nair, P.V.R., Gopinathan,C.P., Balachandran, V.K., Mathew, K.J., Regunathan, A., Rao, D.S. and Murthy, A.V.S. 1984. Ecology of mud banks, phytoplankton productivity in Alleppey mud banks. Bulletin, No.31, 28-34, CMFRI, Cochin, India.

Nagabhushanam, A.K. 1967. On an unusually dense phytoplankton bloom around Minicoy Island (Arabian Sea) and its effect on the local tuna fisheries. Curr. Sci., 36(22): 611-612.

Needler, A.B. 1949. Paralytic shellfish poisoning and Gonyaulax tamarensis. J. Fish. Res. Bd. Can., 7(8): 490-504.

Newell, G.E. and Newell, R.C. 1963. Marine plankton Hutchinson Educational Ltd., London.

News and Views, 1968. Mussels not for eating. Nature, 220(5162): 13.

Noble, A. 1962. The food and feeding habits of the Indian Mackerel, Rastrelliger kanagurta (Cuvier) at Karwar. Ind. J. Fish., 9(2): 701-713.

Noble, A. 1965. The food and feeding habits of the Indian Oil Sardine Sardinella longiceps Valenciennes at Karwar. Ind. J. Fish., 12(1): 77-86.

Oshima, Y., Yasumoto, T., Kodama, M., Ogata, T., Fukuyo, Y., and Matsuura, F. 1982. Features of paralytic shellfish poisoning occurring in the Tohoku district (Japan). Bull. Jap. Soc. Sci. Fish., 48(4): 525-530.

Panikkar, N.K. 1967. Fishery resources of the Indian Ocean. Bull. Nat. Inst. Sci. India, 2(38): 811-831.

Parker, M., Minchin, D., Gatland, P.J. and Connonlly, P. 1981. Observations of blooms of Noctiluca of the South Coast of Ireland during summer 1977. Proc. Council meeting of the International Council for the exploration of the sea, Woods Hole, MA(USA).

Perry, H.M., Stuck, K.C. and Howse, H.D. 1979. First record of a bloom of Gonyaulax monilata in coastal waters of Mississippi. Gulf Res. Rep., 6(3): 313-316.

Pillay, T.V.R. 1952. A critique of the methods of study of food of fishes. J. Zoo. Soc. India, 4(2): 185-200.

Pingree, R.D., Holligan, P.M. and Head, R.N. 1977. Survival of dinoflagellate blooms in the western English Channel. Nature, 265(5591): 266-269.

Pomeroy, L.R., Haskin, H.H. and Ragotzkie, R.A. 1956. Observation on dinoflagellate blooms. Limnol. Oceanogr., 1(1): 54-60.

Prabhu, M.S., Ramamurthy, S., Kuthalingam, M.D.K. and Dhulkhed, M.H. 1965. On an unusual swarming of the planktonic blue green algae *Trichodesmium* spp. off Mangalore. *Curr. Sci.*, *34*(3): 95.

Prabhu, M.S., Ramamurthy, S., Dhulkhed, M.H. and Radhakrishnan, N.S. 1971. *Trichodesmium* bloom and the failure of oil sardine fishery. *Mahasagar*, *4*(2): 62-64.

Prakash, A. 1963. Source of paralytic shellfish toxin in the Bay of Fundy. *J. Fish. Res. Bd. Can.*, *20*(4): 983-996.

Prakash, A. 1975a. Land drainage as a factor in 'red tide' development. *Environ. Letters*, *9*(2): 121-128.

Prakash, A. 1975b. Dinoflagellates blooms - An overview 1. Proc. First International Conference on toxic dinoflagellate blooms Ed. Locicero, V.R. Wakefield, Massachusetts.

Prakash, A. and Sarma, A.H.V. 1964. On the occurrence of red water phenomenon on the west coast of India. *Curr. Sci.*, *33*(6): 168-170.

Prakash, A. and Taylor, F.J.R. 1966. A red water bloom of *Gonyaulax catenella* in the strait of Georgia and its relation to paralytic shellfish toxicity. *J. Fish. Res. Bd. Can.*, *23*(8): 1265-1270.

Prakash, A., Medcof, J.C. and Tennant, A.D. 1971. Paralytic shellfish poisoning in eastern Canada. *Bull. Fish. Res. Bd. Can.*, *177*: pp 87.

Pratt, D.M. 1965. The winter-spring diatom flowering in Narragansett Bay. Limnol. Oceanogr., 10(2): 173-184.

Qasim, S.Z. 1970. Some characteristics of a Trichodesmium bloom in the Laccadives. Deep Sea Res., 17(3): 655-660.

Qasim, S.Z. 1979. Occurrence of Trichodesmium phenomenon in the Strait of Malaca. Mahasagar, 12(3): 191-193.

Qasim, S.Z., Bhattathiri, P.M.A. and Devassy, V.P. 1972. The influence of salinity on the rate of photosynthesis and abundance of some tropical phytoplankton. Bull. Dept. Mar. Sci. Univ. Cochin, 12(2): 200-206.

Qasim, S.Z., Sumitra Vijayaraghavan, Joseph, K.J. and Balachandran, V.K. 1974. Contribution of microplankton and nannoplankton in the tropical waters of estuary. Ind. J. Mar. Sci., 3: 146-149.

Quayle, D.M. 1969. Paralytic shellfish poisoning in British Columbia. Bull. Fish. Res. Bd. Can., 168: pp 68.

Raghu Prasad, R. 1953. Swarming of Noctiluca in the Palk Bay and its effect on the 'Choodai' fishery with a note on the possible use of Noctiluca as an indicator species. Proc. Ind. Acad. Sci., 38: 40-46.

Raghu Prasad, R. 1956. Further studies on the plankton of the inshore waters off Mandapam. Ind. J. Fish., 3(1): 1-42.

Raghu Prasad, R. 1958. A note on the occurrence of feeding habits of Noctiluca and their effects on the plankton community and fisheries. Proc. Ind. Acad. Sci., B XLVII(6): 331-337.

Raghu Prasad, R. and Jayaraman, R. 1954. Preliminary studies on certain changes in the plankton and hydrological conditions associated with the swarming of Noctiluca. Proc. Ind. Acad. Sci., XL(1): 49-57.

Ramalingam, V. 1984. Status of fisheries in Kerala. Seminar on fisheries in Kerala review and future, Cochin. Organised by Industrial Fisheries.

Ramamurthy, V.D. 1970. Antibacterial activity traceable to marine blue green alga Trichodesmium erythraeum in the gastro intestinal contents of two pelagic fishes. Hydrobiologia, 36(1): 159-163.

Ramamurthy, V.D. 1973. Infra red spectral analysis of antibacterial substance isolated from Trichodesmium erythraeum (Marine blue green alga). Hydrobiologia, 41(2): 247-250.

Ramamurthy, V.D. 1975. An analytical study of the role of various factors causing red tide outbreaks of Trichodesmium as deduced from field and laboratory observation. Environ. Letters, 9(2): 179-193.

Ramamurthy, V.D. 1980. Studies on red water phenomenon with special reference to Trichodesmium sp. on the Central and North West Coast of the Arabian Sea during 1970 to 1975. Proc. Symp. the coastal and marine environment of the red sea, Gulf of Aden and Tropical western Indian Ocean, Khartoum, 2: 583-591.

Ramamurthy, V.D., Alfred Selvakumar, R. and Bhargava, R.M.S. 1972. Studies on the blooms of Trichodesmium erythraeum (EHR) in the waters of the Central west coast of India. Curr. Sci., 41(22): 803-805.

Rangarajan, K. and Marichamy, R. 1972. Seasonal changes in the temperature, salinity and plankton volume at Port Blair, Andamans. Ind. J. Fish., 19(1 and 2): 60-69.

Ray, S.M. and Aldrich, D.V. 1967. Ecological interactions of toxic dinoflagellates and molluscs in the Gulf of Mexico. Animal Toxins, 75-83. Editors Russel, F.E. and Saunders, P.R. Pergamon Press, Oxford and New York.

Reguera, B. 1983. The importance of heavy rains in the initiation of Skeletonema costatum blooms in the Bay of Santander. Br. Phycol. J., 18(2): 209.

Reid, P.C., Hunt, H.G. and Jones, T.D. 1982. An exceptionally large and early bloom of diatoms in the southern bight of the North Sea, January to April 1977. Br. Phycol. J., 17(2): 238.

Revikala, S. and Ramamurthy, V.D. 1984. An analytical study of the phytoplankton blooms along the Indian coasts from 1963 to 1982. Annales Del Institute De Ciencias Del Mar Y Limnologia 11(1).

Robinson, G.A. 1968. Distribution of Gonyaulax tamarensis Lebour in the western north sea in April, May and June 1968. Nature, 220(5162): 22-23.

Roden, C.M., Ryan, T. and Lennon, H.J. 1980. Observations on the 1978 red tide in Roaring water bay Co Cork. J. Sherkin Isl., 1(1): 105-118.

Rounsefell, G.A. 1975. Ecology, utilization and management of marine fisheries. The C.V. Mosby Company, Saint Louis, pp 516.

Russel, F.E. 1965. Marine Toxins and Venomous and Poisonous Marine Animals. General chemistry and zoo-toxicology of marine poisons. In Advances in Marine Biology. Ed. Russel F.S. Academic Press, pp 397.

Rudi Hermes, 1983. Red tide in Philippines. Fish. Tech. News. No.6, Published by FAO, Rome.

Sadananda Rao, D., Ramamirtham, C.P. and Krishnan, T.S. 1973. Oceanographic features and abundance of the pelagic fisheries along the west coast of India. Proc. Symp. Living Res. of the seas around India. 400-417.

Sakthivel, M. and Haridas, P. 1974. Synchronization in the occurrence of Trichodesmium bloom and swarming of Cresis acicula Rang (Pteropoda) and Penilia avirostris Dana (Cladocera) in the area off Cochin. Mahasagar. 7(1 and 2): 61-67.

Santha Joseph, P. 1975. Seasonal distribution of phytoplankton in the Vellar Estuary. Ind. J. Mar. Sci., 4(2): 198-200.

Santha Joseph, P. 1982. Temporal variability of phytoplankters in Vellar Estuary. Ind. J. Mar. Sci., 11(1): 63-69.

Sam Bennet, P. 1973. Fluctuation in the Indian Oil Sardine fishery - An explanation. Proc. Symp. Living Resources of the seas around India, 234-240.

Sampayo, M.A. de. M. and Cabecadas, G. 1981. Occurrence of red water off Algarve (Portugal, July 1980). Bolm. Inst. nac. Invest. Pescas Lisboa. 5: 63-87.

Sasner, J.J.Jr. 1973. Marine Pharmacognosy. Ed. Dean F. Martin and George M. Padilla. Academic Press, New York and London, pp 317.

Sato, Shigekatsu, Nogueira, M., Paranagua and Eshinazi, E. 1966. On the mechanism of red tide of Trichodesmium in recife North Eastern Brazil with some considerations of the relation to human disease Tamandare fever. Commercial Fisheries. Abstracts, 20(10): 11.

Schantz, E.J. 1970. Properties and products of algae. Proc. Symp. on the culture of algae held in New York, Ed. Zajic, Plenum Press, New York and London, pp 154.

Scheuer, P.J. 1978. Marine Natural Products Chemical and Biological Perspectives, Vol. I. Academic Press, New York, San Francisco and London, pp 308.

Schradie, J. and Bliss, C.A. 1962. The cultivation and toxicity of Gonyaulax polyedra. Lloydia, 25: 214-221.

Seliger, H.H., Carpenter, J.H., Loftus, M., Biggley, W.H. and Mc Elroy, W.D. 1971. Bioluminescence and phytoplankton successions in Bahia fosforescente, Puerto Rico. Limnol. Oceanogr., 16(4): 608-622.

Shimizu, Y. 1983. Unexpected developments in red tide research. Maritimes, 27(1): 4-6.

Sommer, H. and Meyer, K.F. 1937. Paralytic shellfish poisoning. A.M.A. Arch Pathol., 24: 560-598.

Sorokin Yu.I. and Konovalova, L.M. 1973. Production and decomposition of organic matter in a bay of the Japan Sea during the winter diatom bloom. Limnol. Oceanogr., 18(6): 962-966.

Stanier, R.Y., Doudoroff, M. and Adelberg, E.A. 1974. General Microbiology. Macmillan, India, pp 873.

Steidinger, K.A. 1975. Basic factors influencing red tides. In Proc. first international conference on toxic dinoflagellate blooms, ed: Locicero, V.R. Massachusetts Science and Technology Foundation, Wakefield. Mass., 153-162.

Steidinger, K.A. and Haddad, K. 1981. Biologic and hydrographic aspects of red tides. Bio. Science, 31(11): 814-819.

Subba Rao, D.V. 1969. Asterionella japonica bloom and discolouration off Waltair, Bay of Bengal. Limnol. Oceanogr., 14(4): 632-634.

Subrahmanyan, R. 1946. A systematic account of the marine plankton diatoms of the Madras coast. Proc. Ind. Acad. Sci., 85-196.

Subrahmanyan, R. 1959. Studies on the phytoplankton of the west coast of India, Part I. Quantitative and qualitative fluctuation of the total phytoplankton crop, the zooplankton crop and their interrelationship with remarks on the magnitude of the standing crop and production of matter and their relationship to fish landings. Proc. Ind. Acad. Sci., BL(3): 113-187.

Sweeney, B.M. 1976. Red tides. Nat. Hist., (NY), 85(7): 78-83.

Swift, E.V. 1982. The causes of fire in the sea. Maritimes, 3-5.

Taguchi, S. 1981. Seasonal studies of the dinoflagellate Ceratium longiceps (Bailey) Gran, in the Bedford Basin, Canada. J. Exp. Mar. Biol. Ecol., 55(2-3): 115-131.

Thomas, L.P. 1979. Red water at Lysekil. Sea Front. 25(4): 229-233.

Tsunogai, S. and Watanabe, Y. 1983. Role of dissolved Silicate in the occurrence of a phytoplankton bloom. J. Oceano. Soc. Japan, 39(5): 231-239.

Tsunogai, S., Suzuki, T. and Kurata, T. 1983. Is the blooming of blue green algae in the Kuroshio region induced by the airborne, dust, Kosa? Proc. Abs. IUGG/IAPSO, Hamburg, Germany, 15-27.

Tyler, M.A. and Seliger, H.H. 1978. Annual subsurface transport of a red tide dinoflagellate to its bloom area: Water circulation patterns and organism distribution in the Chesapeake Bay. Limnol. Oceanogr., 23(2): 227-246.

Tyler, M.A. and Seliger, H.H. 1981. Selection for a red tide organism: Physiological responses to the physical environment. Limnol. Oceanogr., 26(2): 310-324.

Tyler, M.A., Coats, D.W. and Anderson, D.M. 1982. Encystment in a dynamic environment. Deposition of dinoflagellate cysts by a frontal convergence. Mar. Ecol. Prog. Ser., 7(2): 163-178.

Umezaki, I. 1961. The marine blue green algae of Japan. Memoirs of the College of Agriculture, pp 149.

URI Commercial Fisheries News Letter, 1983. Fish and their food - Plankton - the basic food of the oceans. 1-7 Published by Univ. Rhode Island.

Venugopal, P., Haridas, P., Madhupratap, M. and Rao, T.S.S. 1979. Incidence of red water along south Kerala coast. Ind. J. mar. Sci., 8(2): 94-97.

Verlancar, X.N. 1978. Some observations on the Trichodesmium bloom along the south west coast of India. Mahasagar, 11(3 and 4): 221-224.

Vijayalekshmi, R. Nair, Devassy, V.P. and Qasim, S.Z. 1980. Zooplankton and Trichodesmium phenomenon. Ind. J. mar. Sci., 9(1): 1-6.

Virabhadra Rao, K. 1973. Distribution pattern of the major exploited marine fishery resources of India. Proc. Symp. Living Resources of the seas around India, 18-101.

Watnnabe, K., Hino, A. and Hirano, R. 1980. Some observations on 1978 red tide blooms in Shonai estuary, Shizuoka prefecture. Bull. Plankt. Soc. Japan, 27(2): 87-98.

Wimpenny, R.S. 1966. The plankton of the sea. Faber and Faber Ltd., 24 Russell Square, London, pp 426.

White, A.W. 1977. Dinoflagellate toxins as probable cause of an Atlantic herring (Clupea harengus harengus) Kill and Pteropods as apparent vector. J. Fish. Res. Bd. Can., 34(12): 2421-2424.

White, A.W. 1979. Dinoflagellate toxins in phytoplankton and zooplankton fractions during a bloom of Gonyaulax excavata. Ed. Taylor, D.L. and Seliger, H.H. In toxic dinoflagellate blooms. Developments in marine biology, Vol.I, Elsevier North Holland, New York, NY, pp 381-384. Proc. 2nd International Conference on Toxic Dinoflagellate Bloom.

White, A.W. 1980. Recurrence of kills of Atlantic herring (Clupea harengus) caused by dinoflagellate toxins transferred through herbivorous zooplankton. Can. J. Fish. Aquat. Sci., 37(12): 2262-2265.

White, A.W. 1983. Paralytic shellfish toxins and finfish. 186th American Chemical Society Meeting, Washington, D.C.

White, A.W. and Lewis, C.M. 1982. Resting cysts of the toxic, red tide dinoflagellate Gonyaulax excavata in Bay of Fundy sediments. Can. J. Fish. Aquat. Sci. 39(8): 1185-1194.

Wood, E.J.F. 1965. Marine Microbial Ecology. Chapman and Hall Ltd., London, pp 243.

Wood, P.C. 1968. Dinoflagellate crop in the North Sea. Nature, 220(5162): 21.

Wyatt, T. and Horwood, J. 1973. A model which generates red tides. Nature, 244: 238.

Yasumoto, T., Oshima, Y., Sugawara, W., Fukuyo, Y., Oguri, H., Igarashi, T. and Fujita, N. 1980. Identification of Dinophysis fortii as the causative organism of diarrhetic shellfish poisoning. Bull. Jap. Soc. Sci. Fish., 46(11): 1405-1411.

Yentsch, C.M. 1977. Progress towards an environmental predictive index for toxic dinoflagellate blooms. Proc. Natl. Shellfish Sanit. Workshop (U.S.), No.10, 142-151.

Yoshida, Y. and Numata, K. 1982. Accumulation and movement of Chattonella sp. in Kagoshima Bay and Suho Nada. Bull. Jap. Soc. Sci. Fish., 48(10): 1401-1405.

Sweeney, B.M. 1976. Red tides. Nat. Hist., (NY), 85(7): 78-83.

Swift, E.V. 1982. The causes of fire in the sea. Maritimes, 3-5.

Taguchi, S. 1981. Seasonal studies of the dinoflagellate *Ceratium longiceps* (Bailey) Gran, in the Bedford Basin, Canada. J. Exp. Mar. Biol. Ecol., 55(2-3): 115-131.

Thomas, L.P. 1979. Red water at Lysekil. Sea Front. 25(4): 229-233.

Tsunogoi, S. and Watanabe, Y. 1983. Role of dissolved silicate in the occurrence of a phytoplankton bloom. J. Oceano. Soc. Japan, 39(5): 231-239.

Tsunogoi, S., Suzuki, T. and Kurata, T. 1983. Is the blooming of blue green algae in the Kuroshio region induced by the airborne, dust, Kosa? Proc. Abs. IUGG/IAPSO, Hamburg, Germany, 15-27.

Tyler, M.A. and Seliger, H.H. 1978. Annual subsurface transport of a red tide dinoflagellate to its bloom area: Water circulation patterns and organism distribution in the Chesapeake Bay. Limnol. Oceanogr., 23(2): 227-246.

Tyler, M.A. and Seliger, H.H. 1981. Selection for a red tide organism: Physiological responses to the physical environment. Limnol. Oceanogr., 26(2): 310-324.

Tyler, M.A., Coats, D.W. and Anderson, D.M. 1982. Encystment in a dynamic environment. Deposition of dinoflagellate cysts by a frontal convergence. Mar. Ecol. Prog. Ser., 7(2): 163-178.