

## Succession of Organisms Following *Trichodesmium* Phenomenon

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Enrichment caused by *Trichodesmium* phenomenon is manifested in the environment by the appearance of a series of organisms in succession. In April and May, when *Trichodesmium* bloom is on the decline in Goa waters (Arabian Sea) and the sea conditions are still fairly uniform, a mixed diatom bloom comprising largely of *Chaetoceros* appears. This is followed by swarms of cladocerans mostly consisting of *Evadne*. Soon afterwards the cladocerans are succeeded by dinoflagellates and green algae. At this stage, *Noctiluca* becomes the most predominant organism. The dinoflagellates are soon followed by swarms of copepods and finally the carnivores (siphonophores and *Sagitta*) make their appearance in large numbers. Thus, within 2 months, concomittent with the decline of *Trichodesmium* bloom, rapid changes occur in the population density of planktonic life of the sea when one set of organisms gets replaced by another and each time the community gets reorganized.

In a recent communication, the occurrence of *Trichodesmium* phenomenon in the coastal waters of Goa (Arabian Sea) has been reported<sup>1</sup>. This phenomenon occurs in the form of thick blooms of the blue-green alga *Trichodesmium erythraeum* at a time when the sea is calm and has fairly uniform conditions of temperature and salinity. The interesting features of this phenomenon are the intermittent appearance and disappearance of the bloom which is mainly confined to the surface, the annual periodicity of the bloom from February to May, the colour to the water it imparts, the enrichment to the sea it gives and the growth of other organisms it promotes<sup>1</sup>. This communication gives details of community succession occurring in the nearshore waters of Goa during the period when the bloom was declining.

Succession occurs when the environmental conditions become exceptionally favourable for certain organisms to appear in abundance. Thus the fairly rapid or abrupt changes occurring in the environment are associated with the abundance of one organism or a group of organisms replacing the others. According to Smyada<sup>2</sup>, environmental disturbances produce changes in many growth variables upsetting the previous equilibrium and leading the community to reorganize itself.

### Materials and Methods

The period of study was from April to May 1977 when the *Trichodesmium* phenomenon was declining. An area was selected in the sea, beyond 10 m depth, where the bloom was in profusion earlier (Fig. 1) and this site was worked 7 times in quick succession at intervals of 3 to 12 days. Water samples were collected

from 0, 2, 5 and 10 m depths. Temperature, salinity, dissolved oxygen, inorganic  $PO_4\text{-P}$ ,  $NO_3\text{-N}$ ,  $NO_2\text{-N}$  were measured along with  $^{14}C$  uptake, particulate organic carbon (POC), chlorophyll *a*, pheopigments, cell counts and zooplankton biomass and composition.

An HT net (0.22 mm mesh width) provided with a flow meter was used for the horizontal zooplankton hauls from the surface. The biomass was expressed as ml/m<sup>3</sup>.  $^{14}C$  uptake was studied by the procedure reported earlier<sup>1</sup>. For phytoplankton counts, 500 ml of water sample was collected and fixed in Lugol's iodine and preserved in 3% formalin.

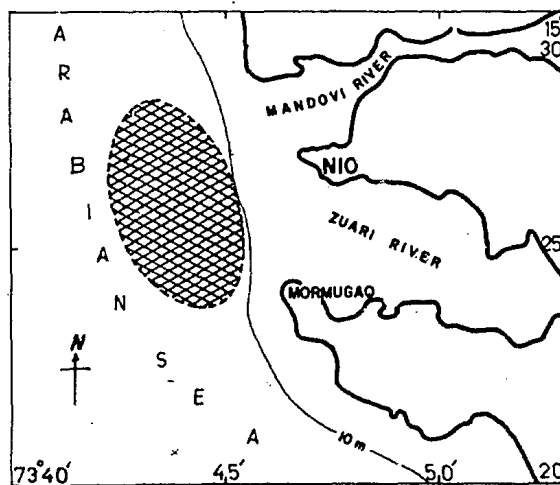


Fig. 1—Goa coast where *Trichodesmium* phenomenon occurs every year [Shaded region shows area where observations were made during April and May 1977 on community succession]

**Results and Discussion**

Some of the environmental features during the period of study are shown in Fig. 2. Both temperature and salinity increased in April and May while dissolved oxygen showed a decline. The decline in oxygen may be because the bloom was decaying. From the values of  $PO_4\text{-P}$ ,  $NO_3\text{-N}$  and  $NH_4\text{-N}$  which remained high in April and early part of May (Fig. 2), the enrichment of the environment is clearly evident. Towards the end of May,  $PO_4\text{-P}$  values became very low while  $NO_3\text{-N}$  and  $NH_4\text{-N}$  showed peaks when *Trichodesmium* was decaying.

Fig. 3 gives the values of particulate organic carbon,  $^{14}C$  uptake, chlorophyll *a* and pheopigments on different days of study. All these were high during the later part of the bloom and showed irregular fluctuations when the bloom was disappearing. However, pheopigments increased considerably when *Trichodesmium* was decaying. Similarly, POC also became high on 28th May which was the last day of observation (Fig. 3).

During the first series of observations which was started on 19th April 1977, a visible change in the colour of water was noticed. This was because of a mixed diatom bloom near the surface comprising largely of *Chaetoceros curvisetus*, *C. lorenzianus*, *C. laciniosus* and other *Chaetoceros* spp (Fig. 4). *C. curvisetus* alone contributed 37.8% of the total phytoplankton counts. Several other diatoms, a few dinoflagellates and green algae were also abundant in addition to blue-green algae (Fig. 4). Samples collected from below the surface at 2, 5 and 10 m depths showed appreciable quantities of *C. curvisetus*—about 34, 45 and 40% of total counts at the 3 depths respectively. Other dominant diatoms were *Ceratulina* sp., *Skeletonema costatum* and *Rhizosolenia* spp. Thus the diatoms alone contributed 95.6, 98.4, 98.2 and 99.6% of the total phytoplankton at 0, 2, 5 and 10 m depths respectively. In the adjacent areas, where bloom was not seen earlier, *Chaetoceros* species were not so abundant.

Three days later, on 22nd April, a cladoceran swarm

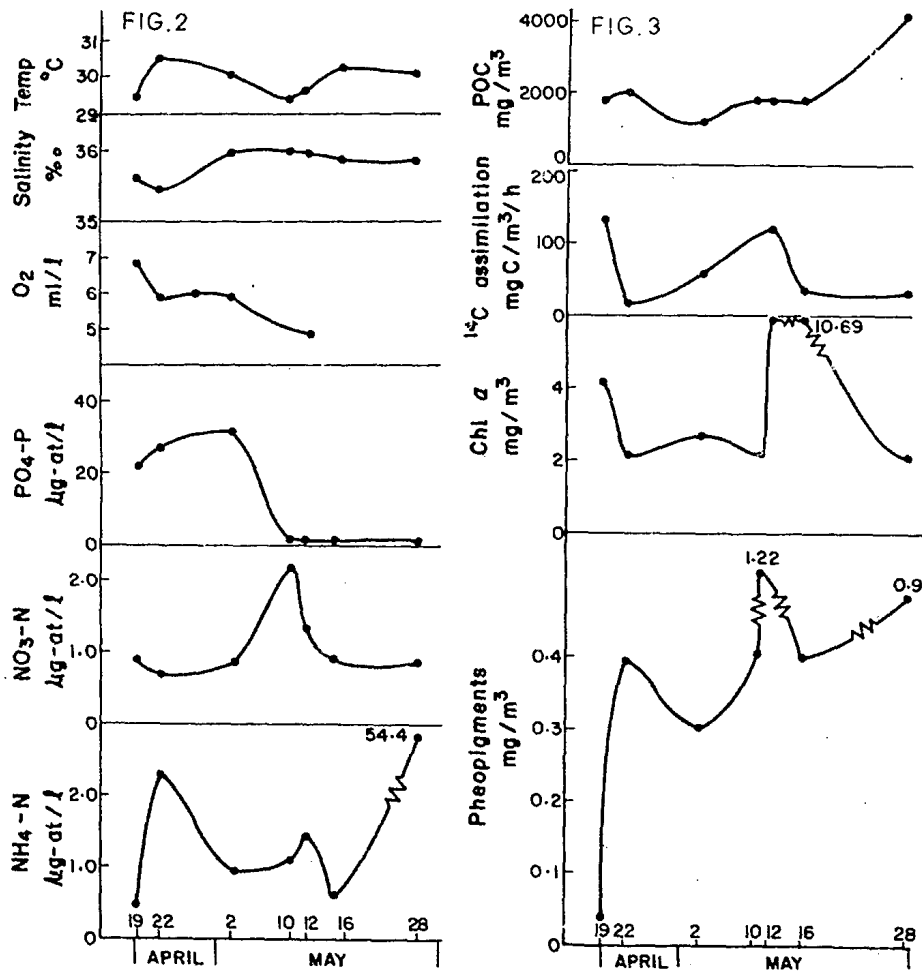


Fig. 2—Physical and chemical features of the area where *Trichodesmium* bloom was declining

Fig. 3—Particulate organic carbon (POC),  $^{14}C$  assimilation, chl *a* and pheopigments at the place of observation

was found at the same place (Fig. 4). The predominant cladoceran was *Evadne tergestina*. Numerically, *Evadne* alone contributed 975/m<sup>3</sup>, while all other organisms together constituted only 48/m<sup>3</sup>. Copepods with a population of 40/m<sup>3</sup>, formed the next abundant group (Fig. 4). At this stage, *Chaetoceros curvisetus*

was still present in appreciable numbers in the water column along with the other *Chaetoceros* species. However, in general the phytoplankton population dwindled rapidly presumably as a result of active grazing by the herbivore *Evadne*. Selvakumar<sup>3</sup> noted that when a cladoceran swarm, mainly consisting of

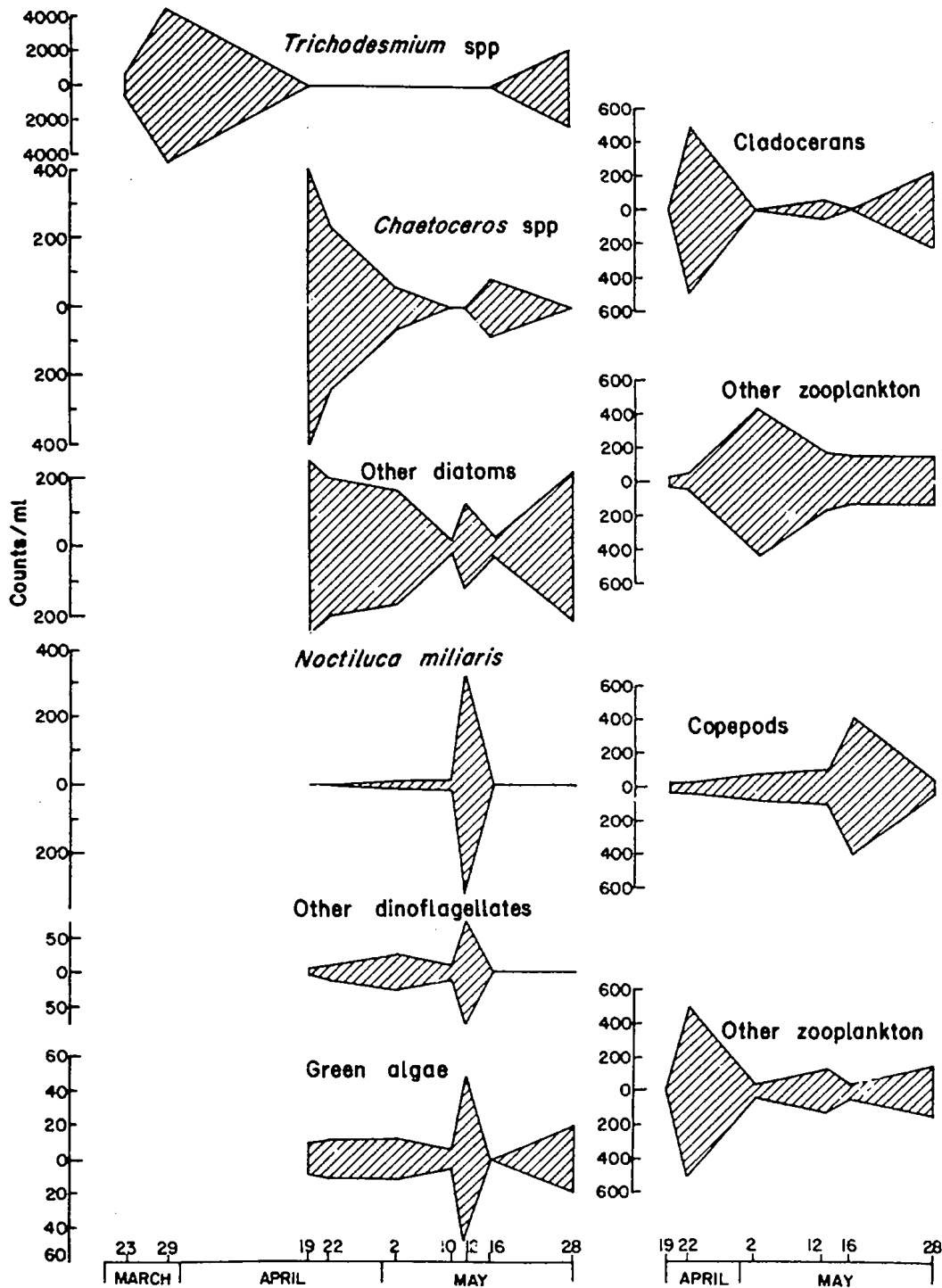


Fig. 4—Succession of organisms following *Trichodesmium* bloom [Topmost figure shows density of *Trichodesmium* bloom from 23 March to 28 May 1977. All other diagrams show abundance of different organisms from 19 April to 28 May 1977]

*E. tergestina*, occurred off Karwar and Goa, the most conspicuous phytoplankton organisms in the environment were diatoms (setoid forms) such as *Chaetoceros*, *Thalassiothrix* and *Nitzschia* and dinoflagellate *Ceratium*. This indicates a possible association between the cladocerans and diatoms. In the central Arabian Sea, an abundance of *E. tergestina* was earlier found from March to May<sup>4</sup>. In the coastal waters of Madras, maximum abundance of *E. tergestina* from March to May followed the diatom abundance<sup>5</sup>. High  $PO_4-P$  value in the water column when cladoceran swarm was recorded may partly be due to these organisms, as phosphorus is known to be exuded by the activity of cladocerans<sup>6</sup>.

On 2nd May, diatoms became few and dinoflagellates such as *Peridinium* spp began to appear in large numbers (Fig. 4). At 10 m depth, *Noctiluca miliaris* was also seen. On the 10th May, *Noctiluca* started appearing near the surface (2 m depth) and on 12th May a dense bloom of *Noctiluca miliaris* was observed in the same area (Fig. 4). This alone (640 cells/ml) contributed about 57% of the total phytoplankton population. Besides this, other dinoflagellates such as *Peridinium* spp, *Prorocentrum* spp, *Gymnodinium* sp., *Dinophysis miles* and *Ceratocorys* sp. also became abundant. Other organisms found in large numbers in association with dinoflagellates were green algae (Fig. 4). Diatoms generally were sparse at this time both in the bloom and non-bloom areas. Thus it is clear that dinoflagellates and green algae succeeded diatoms in their abundance. In other words, some kind of preconditioning of water was done before dinoflagellate bloom appeared<sup>7</sup>.

On 16th May, the *Noctiluca* bloom was followed by swarms of copepods which formed about 95% of the total zooplankton population (Fig. 4). *Acrocalanus gracilis* (246/m<sup>3</sup>), *A. monachus* (236/m<sup>3</sup>) and *Acartia erythraea* (147/m<sup>3</sup>) were the most dominant species. These copepods are known to be herbivorous<sup>8-9</sup>. Dinoflagellate population starts dwindling probably because of intense grazing of these herbivores on them. At this time, *Chaetoceros* sp. was still present, while the other phytoplankton organisms became sparse (Fig. 4).

on 28th May, a dense *Trichodesmium* bloom was again seen in coastal waters (Fig. 4) and close to the site where the diatom and dinoflagellate blooms were seen earlier, a swarm of gelatinous organisms was observed (Table 1). Siphonophores (0.074 ml/m<sup>3</sup>) and chaetognaths (0.025 ml/m<sup>3</sup>) formed an appreciable part of the biomass. However, numerically *Evadne tergestina* (21/m<sup>3</sup>) was still the most dominant species. Chaetognaths comprised *Sagitta enflata*, *S. robusta* and *S. bedoti*. Of these, *S. enflata* was most abundant (Table 1).

Total zooplankton biomass for the period of observation is shown in Fig. 5. Towards the end of April, when *Trichodesmium* bloom was declining, zooplankton biomass attained its first peak. This was largely contributed by cladocerans. In early and mid May, copepods largely contributed towards the second peak (Fig. 5) and their abundance kept fluctuating till carnivores begin to predominate. Towards the end of May, the highest biomass (Fig. 5) recorded was largely contributed by the carnivorous gelatinous forms (Table 1).

In a marine community, organisms are distributed according to the position they occupy in their trophic chain. The animals which occupy higher trophic level have a wider distribution in space and time from the areas of enrichment in the sea<sup>10</sup>. The present investigations seem to support this concept of ecology as the series of community succession which appeared in Goa waters was well marked. The phytoplankton blooms were followed by swarming of herbivores and finally the community ended up in a greater abundance of carnivores which were widely dispersed and occupied a much larger area. Siphonophores and chaetognaths appeared later and their population maxima was attained after a time-lag of about 4 months from the initial appearance of *Trichodesmium* bloom. Community succession, therefore, was probably a result of the interaction between different environmental factors which induced biological interrelationship and population explosion of certain organisms. This, in all probability, was due to

Table 1—Zooplankton Composition during the Swarm of Gelatinous Forms Seen on 28.5.77

	counts/m <sup>3</sup>		counts/m <sup>3</sup>
Siphonophores	93	Polychaetes	1
<i>Sagitta enflata</i>	18	<i>Cresels acicula</i>	1.2
<i>Sagitta robusta</i>	0.12	Ostracods	0.12
<i>Sagitta bedoti</i>	0.12	Appendicularians	0.04
<i>Evadne tergestina</i>	210	Cirripeds	0.12
Copepods	36	Other larval decapods	0.12
Lucifers	1	Lamellibranchs	2

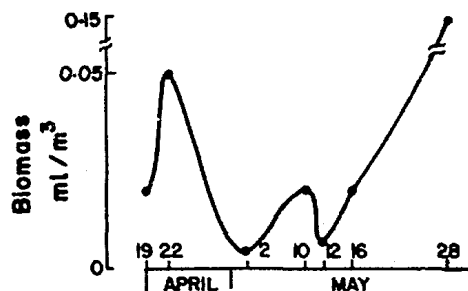


Fig. 5—Zooplankton biomass during April and May when *Trichodesmium* bloom was declining

*Trichodesmium* phenomenon which produced enrichment and promoted the growth of certain sets of organisms one after the other.

**Acknowledgement**

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