

Zooplankton & *Trichodesmium* Phenomenon

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Zooplankton abundance has a direct relationship with *Trichodesmium* phenomenon. The main components of zooplankton during *Trichodesmium* blooms are cladocerans, copepods, decapod larvae, chaetognaths, fish eggs and larvae and appendicularians. There is a periodicity in the appearance of various groups of organisms and this seems to be repeated with the return of *Trichodesmium* phenomenon each year. There is no food relationship between zooplankton and *Trichodesmium* but the relationship is through enrichment caused by the bloom which promotes almost concurrently the growth of diatoms and dinoflagellates on which the herbivores feed. The herbivores are followed by carnivores.

In the nearshore waters of Goa, *Trichodesmium* phenomenon occurs every year from February to April or May¹. The enrichment this phenomenon provides to the sea, results in promoting the growth of certain groups of organisms in succession². The association of animal life with the bloom has been observed earlier and some details on the dominant organisms occurring with the bloom have already been given^{1,2}. Thus the relationship between zooplankton and *Trichodesmium*, though not through its consumption as food, is largely because of the occurrence of this phenomenon in the particular environment. In this communication, an account on the abundance of different groups and species of zooplankton in relation to the bloom seasons of 1975, 1977 and 1978 is presented. No sampling could be made during the 1976 season.

Materials and Methods

Zooplankton samples were collected during March-May 1975, Feb.-May 1977 and Jan.-April 1978 from the bloom area off Goa waters (Fig. 1). The depth of the area of collection ranged between 7 and 20 m. Surface horizontal hauls of 5 min duration were taken with an HT net (mouth area 0.25 m² and mesh size 0.3 mm) provided with a flow meter. Duplicate samples were collected from each location and the average was taken for drawing conclusions. Sampling was done between 0900 and 1100 hrs. During the 1975 season, a few samples were collected between 5 and 10m depth. For determining the effect of disintegration of *Trichodesmium* on the abundance of zooplankton, a few surface tows were obtained from the patches where blooms were decaying.

Zooplankton hauls from the bloom area always contained large quantities of *Trichodesmium* which were removed as far as possible before determining the

displacement volume. For estimating the numerical abundance of the common species, 20% of each sample was analysed; but for determining the occurrence of miscellaneous species or groups found in small numbers, the entire sample was examined. Gelatinous organisms such as salps, *Beroe*, etc. were not included in the total biomass. A conversion factor of 1 ml = 56 mg dry weight obtained from 12 estimations, carried out during the present investigation, was used for converting the displacement volume of zooplankton into dry weight. Mean oxidizable carbon content of zooplankton in the bloom area was determined by the

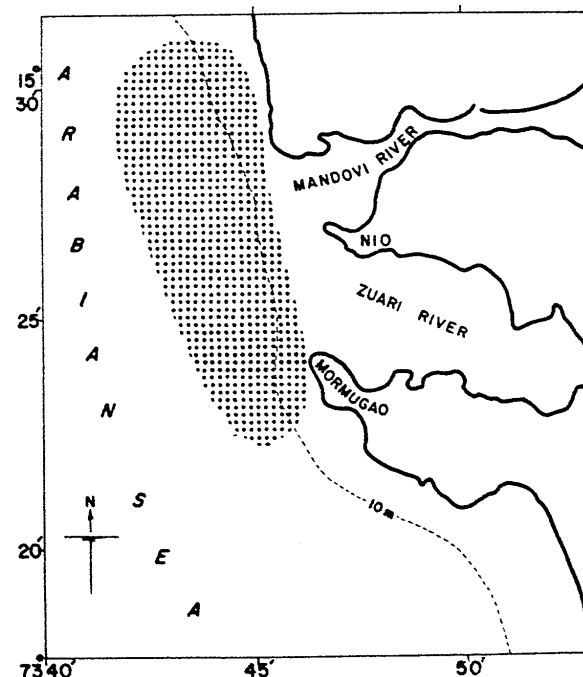


Fig. 1—Goa coast showing the region (stippled area) where observations on zooplankton populations were made during *Trichodesmium* seasons of 1975, 1977 and 1978

wet oxidation method³ and this was found to be 34.5% of the dry weight. The rate of zooplankton (secondary) production was estimated by the method of Cushing⁴.

Results and Discussion

Zooplankton biomass—Earlier studies on the zooplankton biomass based on 7 samples collected during April and May 1977 when the *Trichodesmium* phenomenon was declining, showed 3 peaks—one on 22nd April largely contributed by cladocerans, the 2nd on 10th May contributed by copepods and the 3rd on 28th May largely contributed by the carnivores².

The total zooplankton biomass during the 3 bloom seasons is shown in Fig. 2 in relation to the intensity of *Trichodesmium* bloom. The increase and decrease in zooplankton biomass were directly related to the density of the bloom. In all the 3 seasons, generally, the peaks and troughs in the zooplankton abundance coincided with high and low counts of *Trichodesmium*.

Such a relationship between zooplankton and *Trichodesmium* raises the question as to what could possibly be the reason for zooplankton to be attracted by the bloom particularly when it is known that *Trichodesmium* does not form the food of zooplankton¹. As has been noted earlier, the enrichment caused by *Trichodesmium* promotes the growth of other algae and bimodal peaks of other algae have been shown by Devassy *et al.*¹. The common species of diatoms found in association with the blooms were *Nitzschia closterium*, *N. seriata*, *Navicula* spp and *Chaetoceros* spp¹. With the decline of *Trichodesmium* bloom, the abundance of diatoms also gets considerably reduced. This pattern of concomitant abundance of *Trichodesmium* and diatoms continues throughout the bloom season. Possibly, the congregation of zooplankton, especially of herbivores in the bloom patches, is for feeding on other algae associated with the *Trichodesmium* bloom.

The average values of zooplankton biomass (mg dry wt/100 m³) for the 3 seasons were January, 165; February, 470; March, 448; April, 504; and May, 269.

The above data indicate an increase in zooplankton abundance from January to April (3-fold) and its decline in May. Assuming that zooplankton organisms are uniformly distributed in the water column, the biomass obtained at the surface was converted into column biomass which was in turn used for the computation of secondary production. The average production of zooplankton in the bloom area was 167 mg C m²/day. During the season, the total zooplankton (secondary) production for the entire area (Fig. 1) measuring 54.6 km² would be 1.38 × 10³ tonnes in terms of zooplankton carbon.

Zooplankton composition—The dominant organisms in the bloom area were copepods, decapod

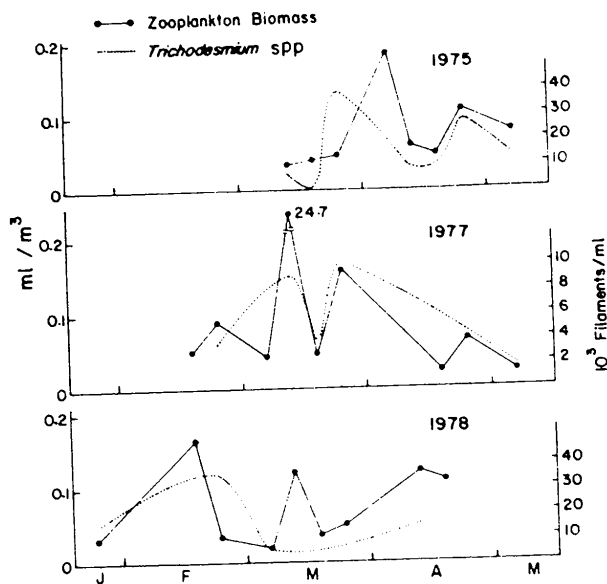


Fig. 2—Zooplankton biomass during the 3 seasons of *Trichodesmium* bloom

larvae, chaetognaths, cladocerans, fish eggs, etc.¹. They appeared in succession following the bloom. Cladocerans were the first group of zooplankton organisms to appear in large numbers followed by copepods and gelatinous forms (carnivores)². The abundance and composition of each group of zooplankton during the bloom season were as follows:

Cladocera: Three peaks of cladocerans were seen during the 1977 season of *Trichodesmium* bloom whereas only 2 were recorded during the 1978 season (Fig. 3). Since the observations in 1975 season were started late, only one peak of cladocerans could be recorded. *Evadne tergestina* occurred in much larger numbers in the samples than *Penilia avirostris* (Fig. 3).

Copepoda: Three peaks were recorded during each season (Fig. 4). In March/April when the bloom is at its peak, copepods attained maximum density (Fig. 4).

The different species of copepods present during the peak bloom seasons of 1977 and 1978 are given in Table 1. In February, *Temora turbinata* was the dominant species. In March, *Centropages furcatus* and *Acrocalanus gibber* became more abundant while in April, *Acartia erythraea* occurred in maximum numbers along with *T. turbinata* and *C. furcatus* (Table 1). Most of the species found in the bloom area were phytophagous and a few species like *C. furcatus* omnivorous⁵.

Other crustaceans: The abundance of other crustaceans in the bloom area is given in Table 2. Decapod larvae formed the next most abundant group after cladocerans and copepods. Stomatopod larvae and amphipods were also fairly abundant. Euphausiids were rarely seen. *Lucifer hanseni* and brachyuran zoea constituted an appreciable part of decapod larvae with

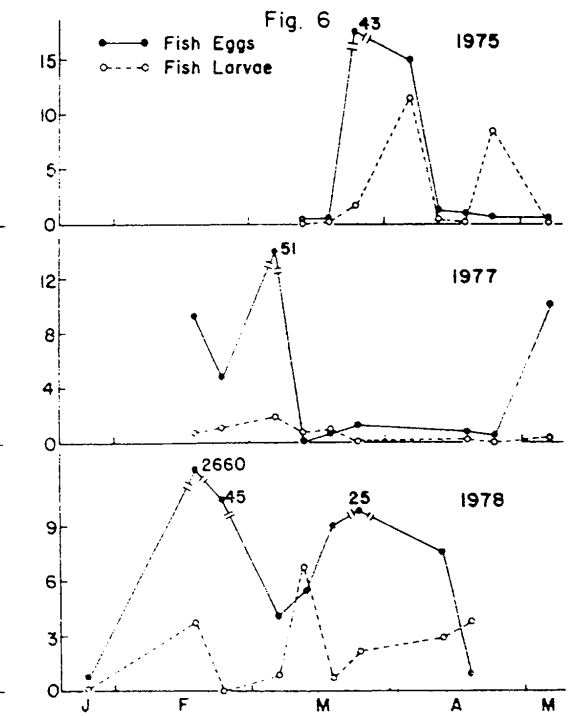
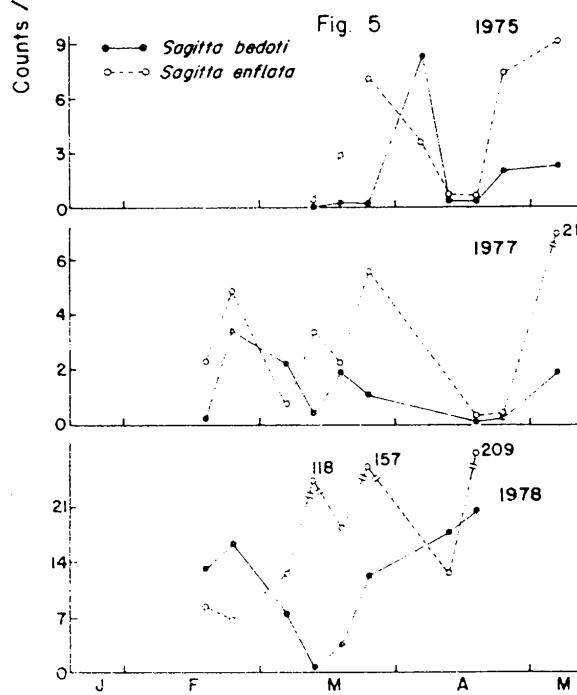
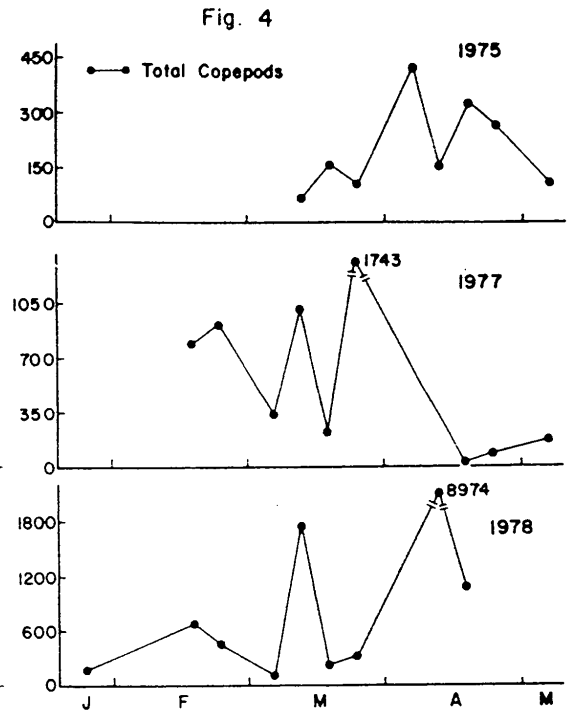
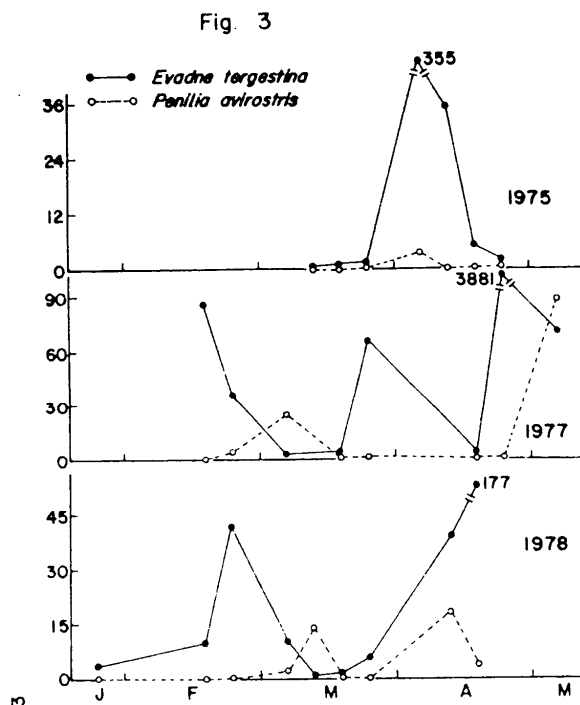


Fig. 3 to 6 Abundance of cladocerans (3) total copepods (4), chaetognaths (5) and fish eggs and larvae (6) during the 3 seasons of *Trichodesmium* bloom

their maximum density during March-April 1978 season (Table 2). In one of the collections taken on 29 March 1975, brachyuran zoea were very dominant (70/m³). A greater abundance of porcellanid larvae and other decapod larvae was observed during the 1978 season as compared to the earlier 2 seasons (Table 2).

The occurrence of different families belonging to decapod groups is given in Table 3. Alpheidae was very common throughout the bloom period. Pandalidae had the maximum abundance in March and April. Larvae of Paguridae and Processidae were absent in February. Hippolytidae and Sergestidae (excluding *Lucifer*) were rarely present. Penaeidae was found from February to March and *Metapenaeus dobsoni* constituted a major part of the penaeid larvae. Decapod larvae were caught in large numbers from 5 to 10 m depth.

Table 1—Species of Copepods Found in Association with *Trichodesmium* Seasons of 1977 and 1978

[Values given are percentages of the total copepods]

Species	February	March	April
<i>Canthocalanus pauper</i>	2.7	0.9	
<i>Eucalanus monachus</i>	2.1	3.7	
<i>Paracalanus</i> sp.	19.3	2.2	9.3
<i>Acrocalanus gibber</i>	2.6	25.3	1.5
<i>Acrocalanus</i> sp.			12.5
<i>Centropages furcatus</i>	8.9	36.7	14.1
<i>Temora turbinata</i>	40.6	5.1	19.7
<i>Labidocera minuta</i>		6.0	
<i>Acartia erythraea</i>	11.9	14.9	25.6
<i>A. spinicauda</i>	5.7	0.7	4.7
<i>A. southwelli</i>	6.2		6.3
<i>Acartia</i> sp.		4.5	
<i>Macrosetella</i> sp.			6.3

Chaetognatha: Chaetognatha were well represented in the collections (Fig. 5). Although several peaks were recorded in their abundance, maximum density was generally found towards the end of the bloom (Fig. 5). *Sagitta enflata* and *S. bedoti* were the common species. *S. enflata* was very dominant in most of the samples. Other species of chaetognaths found in the samples were *Krohnhitta pacifica*, *S. ferox*, *S. neglecta*, *S. pacifica*, *S. pulchra*, *S. regularis* and *S. robusta* (Table 4). The incidence of these species did not show any regular pattern. Of the 9 species found in the collections, *S. bedoti* and *S. neglecta* were neritic and the rest were oceanic⁶.

Fish eggs and larvae: Fish eggs and larvae were present in most of the collections. Eggs were more abundant than the larvae (Fig. 6). Fish eggs constituted a dominant group of zooplankton on 22 Feb. 1978 (total number, 2660/m³; Fig. 6). Peak occurrence of the eggs during the early part of the bloom was noted in March 1975, March 1977 and Feb. 1978 (Fig. 6). Quite often, the peaks in the abundance of fish larvae

Table 3—Different Families of Decapods* Occurring during *Trichodesmium* Seasons of 1977 and 1978

[Values given are percentages of other decapods given in Table 2]

Family	February	March	April
Sergestidae		6.0	
Penaeidae	54.5	0.5	
Pandalidae	5.8	44.8	70.8
Hippolytidae	2.9		
Alpheidae	36.8	38.7	28.4
Processidae		0.5	0.4
Paguridae		9.5	0.4

*Except *Lucifer*, porcellanid and brachyuran zoea

Table 2—Monthly Variation in Crustacean Component (Except Cladocerans and Copepods) in Zooplankton during *Trichodesmium* Seasons

[All values are average counts/100 m³ in each month]

	Stomatopod larvae	Amphipods	Euphausiids	<i>Lucifer hanseni</i>	Brachyuran zoea & megalopa	Porcellanid larvae	Other decapods
1975							
March	52	2	—	1781	2466	6	225
April	29	45	10	271	1244	35	745
May	6	—	—	54	—	4	29
1976							
Feb.	10	107	—	6157	599	132	609
March	6	3	2	4667	1054	77	411
April	2	—	—	2258	105	—	11
May	4	—	—	2836	821	56	172
1978							
Jan.	—	93	—	155	79	—	—
Feb.	—	140	—	709	587	14	468
March	71	39	—	12004	1398	729	2786
April	38	17	—	21633	5753	747	2007

coincided with those of the eggs. Larvae of Atherinidae, Engraulidae, Clupeidae and Perciformes were very common in the samples. The presence of fish eggs and larvae in association with the bloom indicates congregation of spawning fish in the bloom area. Since the eggs hatch out very quickly the larvae will have an abundance of food (phyto and zooplankton) in bloom patches. Hence the occurrence of fish eggs and larvae, in association with *Trichodesmium*, appears to be an adaptation by the adults to provide maximum food to the young ones during the bloom period.

Tables 4 and 5 give the numerical abundance of the remaining groups of zooplankton which were common in the collections. Coelenterates were represented mainly by siphonophores, hydromedusae, scyphomedusae and anthozoans. The last 2 groups were found only in a few samples (Table 4). Appendicularians were present throughout the period of observation. In April 1975, salps were very abundant (biomass, 1.3-10 ml/m³). Polychaetes and molluscan larvae were fairly well represented with their maximum abundance in April 1978. Incidence of *Creseis acicula* was low during the 1978 season.

Table 4—Miscellaneous Groups and Species Found in Zooplankton Samples during *Trichodesmium* Seasons

Organism	Period of occurrence
Anthozoa	April 1975
Scyphomedusae*	March 1977
Ctenophora	Jan.-April 1978
Platyhelminthes	Feb.-March 1977
Cyphonautes larvae	March 1975; Feb.-March 1977
Cavolinia* sp.	April 1975 and 1978
Atlantidae	Feb.-April 1977
Cirriped larvae	April 1977
Cypridina dentata	March-April 1978
Isopoda	April 1975 and 1978
Halobates	April 1975; March 1977
Brachiopod larvae	March 1977 and 1978
Krohnitta pacifica	March-April 1975; Feb.-March 1977; April 1978
Sagitta ferox	April 1975; Feb.-March 1977; Feb. 1978
S. neglecta	March 1975; Feb.-March 1977; March 1978
S. pacifica	March 1977
S. pulchra	March 1977; Feb.-March 1978
S. regularis	March-April 1977
S. robusta	April 1975; March 1977; March-April 1978

Some groups of zooplankton occurred only occasionally (Table 4). The ctenophore *Beroe* was found only during the 1978 season and contributed a substantial part of one of the zooplankton samples. Ostracods were seen in March-April 1978 and this group was represented by the single species *Cypridina dentata*. This is the most abundant planktonic ostracod in the offshore waters of the Arabian Sea and is seldom found in the nearshore waters⁷.

Diversity index—Diversity index for the different components of zooplankton was calculated using the Shannon-Wiener formula⁸. The values ranged between 2.8 and 3.95. The index was low during the early part of the bloom and high towards the end of the bloom season (April).

The relevance of *Trichodesmium* phenomenon to zooplankton is through enrichment of the environment with nutrients which enhances the production process and turn-over rates and thus promotes the growth of planktonic animals.

Table 5—Common Zooplankton Groups Occurring during *Trichodesmium* Seasons

[All values are average counts, 100 m³ for each month]

	Appendicularians	Salps	Polychaetes	Lamellibranches	Gastropods	<i>Creseis acicula</i>	Siphonophores	Medusae
1975								
March	25					25	a few	
April	170	130	2		98	294	do	13
May	105	55			5	2	moderate	3
1977								
Feb.	281		442	946	1224	56	do	61
March	591		54	933	10	24	a few	36
April	280		2				moderate	15
May	26		19	75	19	150	do	4
1978								
Jan.	224			3			a few	35
Feb.	3031		243		47		moderate	
March	238		60	579	176	1	a few	13
April	12127		2148	8956	1040	6	moderate	1129

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