

## TRICHODESMIUM RED TIDES IN THE ARABIAN SEA

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### ABSTRACT

Massive *Trichodesmium* Red Tides occur in the Arabian Sea during the premonsoon season every year. Associated with these Red Tides high inorganic  $PO_4$ -P,  $NH_4$ -N and  $NO_3$ -N have been observed in the sea. High chl *a* and  $^{14}C$  uptake values were also observed along with the Red Tides. During the period other phytoplankton organisms were abundant and some diatoms appeared in profusion in association with *Trichodesmium* Red Tides. Zooplankton organisms were also found to be fairly abundant in the Red Tide patches as compared to Red Tide-free areas. This blue green alga is not much favoured as food by fishes, neither has any mortality of fish or any other animal ever been observed in association with these Red Tides. The ability of *Trichodesmium* to fix atmospheric nitrogen and the subsequent release of inorganic nutrients during their decay enriches the environment which leads to proliferation and succession of other planktonic organisms.

### INTRODUCTION

The term "Red Tide" refers to bloom formations in massive proportions of certain dinoflagellates in the world oceans during certain periods of the year, when physical and chemical conditions are conducive for their development. Though usually referred to as "Red Tide" because they cause discolouration of the sea water which borders on a tinge of red, the resulting colour of the seawater can also be grey, green, orange or a blend of all these colours. Red Tide formation of toxic dinoflagellates such as *Gymnodinium* or *Gonyaulax* is a frequent and well documented phenomenon in temperate seas. The process can be viewed as an interaction between the natural growth of the populations and concentration both vertically, by swimming or buoyancy towards the top of the water column, and horizontally by converging water currents whereby surface materials from a wide area accumulate in a discrete region where there are downward movements<sup>1</sup>. Such a process also explains the

frequent occurrence of dinoflagellate blooms in thermal fronts<sup>2</sup>.

In tropical waters the formation of Red Tides is very often associated with *Trichodesmium* (*Oscillatoria*, according to Sournia<sup>3</sup>) blooms, though *Noctiluca* Red Tides also occur frequently. *Trichodesmium* Red Tides have been reported from almost all over the tropical seas of the world and the enormity of such Red Tides can be best understood by the observations of Wood<sup>4</sup> that *Trichodesmium* Red Tide extended about 1600 km and occupied an area of 52000 sq km. In the tropical Indian Ocean, Red Tides of *Trichodesmium erythraeum* are known to occur in great profusion in the Lakshadweep Sea<sup>5,6</sup>. During a cruise along the west coast of India in 1984, the author observed *Trichodesmium* Red Tide formations stretching for about 600 km with practically no visible interruption. Along the same coast, *Trichodesmium*, Red Tides were of regular occurrence at well-defined seasons and unlike the case with other dinoflagellate Red Tides, the causative factors for these Red Tides and their ecology are totally different. These Red Tides were comprised predominantly of *T. erythraeum*, although *T. thiebautii* has also been found to be present though not in significant numbers. In this brief communication, the results obtained from studies on *Trichodesmium* Red Tide over the last several years have been presented.

#### *General features of the sea during Trichodesmium Red Tides*

Along the west coast of India, *Trichodesmium* Red Tides appeared during February/March of every year and persisted till April/May. This period, referred to as premonsoon season is characterised by fair weather, calm sea conditions and abundant sunlight (insolation greater than  $10\text{h day}^{-1}$  and incident solar radiation,  $500\text{-}600\text{ cal cm}^{-2}\text{d}^{-1}$ ). Sea surface temperature varied from 27 to 32°C, and salinity from 35 to 36.6%. Tidal currents close to the shore were weak, with an average speed of  $50\text{ cm sec}^{-1}$  during the flood and  $40\text{ cm sec}^{-1}$  during the ebb. During the premonsoon season, coastal circulation of water was counter-clockwise with speeds varying from 10 to  $15\text{ cm sec}^{-1}$ . Wave characteristics obtained from wave recorders indicated that the sea-state and swell-state presented extremely calm conditions. The average onshore wind speed in premonsoon was about  $15\text{-}20\text{ km h}^{-1}$ .

#### *Physical characteristics*

The blooms were normally confined to an area between 5m and 25m isobaths, occurring generally in long bands or lanes parallel to the coast, though irregular and semi-circular patches were not uncommon. The Red Tides were mostly limited to the top few centimeters of the sea. At depths greater than

5 cm, the proportion of *Trichodesmium* spp. in the total phytoplankton biomass tended to become negligible.

#### *Chemical characteristics*

The variations in some of the measured chemical parameters were: dissolved oxygen from 3.85 to 6.7 ml l<sup>-1</sup>; inorganic nutrients viz. phosphate-phosphorus from 2.0 to 13.5 µg-at l<sup>-1</sup>; nitrate-nitrogen from 0.57 to 4.35 µg-at l<sup>-1</sup>; nitrite-nitrogen from 0.04 to 4.55 µg-at l<sup>-1</sup> and ammonia-nitrogen from 2.3 to 81.6 µg-at l<sup>-1</sup>. Generally nutrient concentrations were low during the early phase of the Red Tide. Of particular interest was the ammonium concentrations which increased sharply in the water column after every pulse of the bloom. Towards the end of the bloom season, concentrations of ammonium attained very high concentrations as given above.

#### *Biological features*

*Trichodesmium* clumps had highly variable number of filaments, ranging on an average from 50 to 100 filaments. A large clump contained upto 150-190 filaments. The density and profusion of the Red Tide also varied from year to year. During the period of study, from 1975 to 1979, *T. erythraeum* Red Tides had maximum densities of 38460, 8750, 14584, 1250 and 2156 filaments ml<sup>-1</sup> respectively<sup>7</sup> (also Devassy, unpublished).

Concurrent with the Red Tide formation, chl a concentrations increased from 1.07 to 591.4 mg m<sup>-3</sup> (1975) and from 1.44 to 540.5 mg m<sup>-3</sup> (1977). <sup>14</sup>C fixation was found to increase from 2.9 to 517.7 mgC m<sup>-2</sup>h<sup>-1</sup> (1975) and from 13.5 to 326.3 mgC m<sup>-2</sup>h<sup>-1</sup> (1977). During the bloom period chl a, phaeopigments and particulate organic carbon exhibited positive correlation with carbon assimilation. As the Red Tide formation advanced, phaeopigment concentrations were also found to increase rapidly.

#### *Trichodesmium and other algae*

A salient feature which could be observed was the association of *Trichodesmium* and diatoms, particularly that of *Nitzschia closterium*. Along with the *Trichodesmium* Red Tide, this diatom was also found to occur in bloom proportions. Immediately after the decline of the *Trichodesmium* Red Tide, several other diatoms proliferated. It is of interest to note that most of these diatoms were not so abundant in the Red Tide-free areas during the same period.

#### *Trichodesmium and zooplankton*

Contrary to the earlier belief that the zooplankton tend

to avoid *Trichodesmium* Red Tides, it was conclusively observed during the studies that zooplankton organisms were fairly well represented during the Red Tide and their total biomass in that area was not very different from Red Tide-free areas. Swarming of several zooplankton species in association with *Trichodesmium* Red Tide was also observed on the west coast of India<sup>8</sup>. However, this association did not necessarily represent *Trichodesmium* as a food source for zooplankton but rather the fact that the enrichment caused by declining Red Tide promoted growth of other algae, which in turn attracted herbivores to the Red Tide patches<sup>9</sup>.

#### *Trichodesmium and nitrogen flux*

The total annual conservative estimation of  $N_2$  fixation is  $4.79 \times 10^{12}$  g N and the greatest annual rate occurs in the Indian Ocean ( $3.12 \times 10^{12}$  g N  $yr^{-1}$ ). It is further estimated that on a global basis when pelagic  $N_2$  fixation is summed with that in marine sediments the oceans contribute 20 Tg N annually, somewhat more nitrogen than fixed in terrestrial ecosystems<sup>10</sup>.

With the progress of the Red Tide, concentrations of phosphate, nitrate and ammonium increased in the seawater, which in turn promoted the growth of other algae. Based on the Red Tide density data and nutrient release rate in the laboratory, it was possible to calculate the quantity of nutrients regenerated after a "*Trichodesmium* season". Such estimates were 1200  $\mu g$ -at of phosphorus  $m^{-2}$  and 260  $\mu g$ -at of nitrogen  $m^{-2}$  in 1975. For 1977 Red Tide these values were 270  $\mu g$ -at of phosphorus  $m^{-2}$  and 60  $\mu g$ -at of nitrogen  $m^{-2}$ . Such a high rate of enrichment would unquestionably account for the proliferation of several diatoms after the *Trichodesmium* Red Tide. Laboratory experiments indicated that *Tetraselmis gracilis* in culture, when grown in the medium in which *Trichodesmium* was decaying, exhibited higher growth rate than the controls. However at very high concentration in which the two nutrients were found to be maximum, growth rates declined. This indicated that the nutrients released by this Red Tide did promote growth of other algae at low concentrations. In the sea, because of dilution, very high concentrations of nutrients associated with decaying *Trichodesmium* blooms would seldom occur.

#### *Species succession followed by Trichodesmium Red Tide*

After the decline of *Trichodesmium*, Red Tide, there appeared to exist a well-defined succession of other planktonic organisms. A closely studied Red Tide cycle in 1977 showed that after the decay of *Trichodesmium* a mixed diatom bloom comprising largely of *Chaetoceros* spp. occurred. This was followed by swarms of cladocerans consisting mainly of *Evadne* spp.

Soon afterwards, the cladocerans were succeeded by dinoflagellates and green algae. At this time, the dominant organism was *Noctiluca miliaris*. The dinoflagellates were soon followed by swarms of copepods and finally the carnivorous zooplankton (siphonophores and *Sagitta* spp.). This cycle, *Trichodesmium* other planktonic algae — herbivores — carnivores — clearly demonstrated the beneficial effects of *Trichodesmium* Red Tides on the plankton community<sup>9,11</sup>.

#### *Fish mortality*

Contrary to the ill-effects caused by other Red Tide organisms on fish, *Trichodesmium* Red Tide had no harmful effect on fish and fisheries. No fish or other animal mortality was ever observed during the entire study period. Trawl operations, both in Red Tide and Red Tide-free areas yielded fish catches similar in size and composition. Isolated instances of mortality of marine animals observed in sheltered areas of tide pools, were caused either by oxygen depletion or clogging of gills by *Trichodesmium* filaments, in the open coastal waters however this did not occur. During all these years of observations, no mortality of marine animals even in the midst of the thickest of Red Tides was observed which clearly demonstrated the non-toxic nature of these Red Tides. It is true that prolonged calm periods contributed to the concentration of positively buoyant organisms such as *Trichodesmium* in windrows and the drifting dead animals and other flotsam also tended to join this floating mass. However, *Trichodesmium* is neither a preferred food of marine animals. There are no conclusive records of any fish actively consuming this alga. The gut contents of several fishes examined have seldom revealed any significant quantities of this alga. Any such presence in the gut could be only as a result of accidental ingestion while negotiating the Red Tide patches.

In conclusion, it can be stated that *Trichodesmium* Red Tides play a vital role in the biological economy and nitrogen budget of tropical coastal waters. The role of *Trichodesmium* Red Tides becomes very significant because besides the two well known mechanisms of enrichment of tropical seas which are upwelling and biodegradation of organic matter a third phenomenon, which is of massive *Trichodesmium* Red Tides produced each year, becomes just as important. These Red Tides appear when the environment is impoverished with nutrients and by virtue of their ability to fix atmospheric nitrogen, do not have to compete with other planktonic algae. After decay of *Trichodesmium* Red Tides, the nutrients released promote development of other algae and thus *Trichodesmium* Red Tides help in an efficient recycling of nutrients. Besides, being non-

toxic, these Red Tides have no adverse effect on the planktonic food chain of the coastal environment.

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