

## Incidence of Red Water Along South Kerala Coast

P VENUGOPAL, P HARIDAS, M MADHUPRATAP\* & T S S RAO\*

National Institute of Oceanography, Regional Centre, Cochin 682018

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Incidence of red water along the Kerala coast at 2 localities, off Quilon and Cochin, in August 1976 and 1977 is reported. High concentrations of *Noctiluca miliaris* (up to  $7.71 \times 10^5/m^3$  in 1977) are associated with these occurrences. They completely dominate the plankton community contributing >90% of the numbers. High production of diatoms initiated by nutrient-rich and fairly high saline upwelled waters appears to cause the bloom of the dinoflagellate *Noctiluca*.

Occurrence of discoloured water associated with the blooms of certain planktonic species, referred to as red water or red tide has been reported from many parts of the world. It is common in the productive tropical and subtropical areas, where the turn over rates of organic matter are very high, but is rare in the high latitudes. Some of the causative species of red water produce toxic substances, but the toxins get dissipated quickly. Under special circumstances, however, these organisms and toxins they produce become abundant and if this situation persists mass mortalities of fish and other organisms may occur. The events that lead to the formation of red tides usually escape detection so that their sequence is not clearly understood.

Along the Indian coast, there are several reports on *Trichodesmium* blooms<sup>1-3</sup>. Among dinoflagellates, *Noctiluca*, *Gonyaulax*, *Gymnodinium*, *Peridinium* and *Conchlodenium* are known to be associated with outbreaks of red water<sup>4-6</sup>. Incidence of red water off Cochin and Quilon associated with swarming of *Noctiluca miliaris* is reported here.

### Materials and Methods

Discoloured water was found to enter the Cochin harbour area (09° 30'N, 76° 15'E), through the mouth of the estuary during high tide. This brownish red water was present for a week (12.8.77 to 18.8.77). The intensity of discoloration weakened on 16.8.77 but increased again by 18.8.77, whereafter it disappeared. Red water associated with large numbers of *Noctiluca* was also observed on 17.8.1976, off Quilon and Cochin.

Three stations, one in the outer channel at fairway buoy (st 1) in the sea and 2 stations at the exit of Matancherry (st 2) and Ernakulam (st 3) channels at

the mouth of Cochin backwaters (st 2 and 3 about 7 km away from st 1) were sampled during the week. Water samples were collected at the surface, mid-depth and near the bottom; plankton samples were collected by a fine meshed HT net (65  $\mu$ ) provided with a flow meter, in subsurface horizontal tows. Visible transparency depths were measured using Secchi disc. Temperature, salinity and oxygen at different depths, at these stations were also recorded.

Surface water samples were allowed to settle in a sedimentation chamber and cell counts were taken after decanting the supernatant. Chlorophyll *a* estimations were made according to the method recommended<sup>7</sup>. Estimations of inorganic  $PO_4-P^8$ ,  $NO_2-N^9$  and  $NO_3-N^{10,11}$  were done. Counts from plankton samples were converted into numbers/ $m^3$  using flowmeter data. Coefficient of community<sup>12</sup> (cc) and percentage of similarity of community<sup>13</sup> (PSc) were calculated from the above data to estimate the affinity between samples. A single set of plankton samples were taken off Quilon and Cochin in August 1976, using HT net.

### Results and Discussion

Phytoplankton cell counts (numbers/litre) during the period of observation are given in Table 1. The community was dominated by diatoms and the bulk of standing stock was contributed by 4 to 5 species only. Total cell counts were high and ranged from  $1.25 \times 10^5$  to  $6.05 \times 10^5$ /litre. Earlier studies<sup>14-17</sup> showed dominance of diatoms in the phytoplankton community during this season. Surface chlorophyll *a* values ranged between 18 and 35 mg/ $m^3$  which agreed fairly well with the reported values for this month<sup>15</sup>. Considering the contribution of nanoplankton, which is known to be considerable in these waters, the amount of primary organic matter available to the

\*Present address: National Institute of Oceanography, Dona Paula, Goa 403004

Table 1—Phytoplankton Cell Counts (Numbers/Litre)

Species	12.8.77			16.8.77			18.8.77	
	St 1	St 2	St 3	St 1	St 2	St 3	St 1	St 2
<i>Ceratium bergonsii</i>	50,000	+	15,000	—	2,500	5,000	+	5,000
<i>Coscinodiscus marginatus</i>	—	+	—	—	5,000	50,000	—	—
<i>Coscinodiscus</i> sp.	50,000	+	+	—	2,500	—	+	—
<i>Pleurosigma elongatum</i>	55,000	—	—	—	—	—	—	—
<i>P. normanii</i>	—	—	—	—	5,000	50,000	—	—
<i>Nitzschia sigma</i>	52,000	—	—	—	+	—	+	—
<i>N. longisima</i>	50,000	+	+	50,000	2,500	20,000	1,50,000	+
<i>N. closterium</i>	—	50,000	—	—	—	—	50,000	—
<i>Bidulphia sinensis</i>	—	—	—	—	—	—	50,000	—
<i>Bidulphia</i> sp.	—	50,000	—	—	—	—	—	—
<i>Trichodesmium</i> sp.	—	—	—	—	—	50,000	—	—
<i>Skeletonema costatum</i>	—	+	2,00,000	1,10,000	17,500	—	3,00,000	5,50,000
<i>Rhabdonema</i> sp.	+	+	+	+	3,000	+	—	+
<i>Chaetoceros</i> sp.	+	+	—	+	2,500	—	—	—
<i>Thalassionema</i> sp.	—	—	—	10,000	—	—	—	—
<i>Asterionema</i> sp.	—	—	—	—	+	—	—	—
<i>Navicula</i> sp.	58,000	1,50,000	—	50,000	—	—	50,000	50,000

+, Present; —, absent

grazers, would be much higher than what would appear in Table 1.

An interesting feature observed was the total absence of *Noctiluca* in the comparatively low saline surface layer of the water column; the species was collected only in the plankton tows from 1 to 2 m below the surface. *Noctiluca* which is able to some extent select and maintain its position in the water column<sup>18</sup> seemed to prefer higher saline subsurface layers.

Biomass of zooplankton was very high (1.8-4 ml/m<sup>3</sup>). *Noctiluca* dominated the catch and contributed to >90% of the numbers. Cumulative concentrations of other groups of zooplankton varied between 3900 and 32750/m<sup>3</sup>. Zooplankton observed in samples taken from Cochin and Quilon were in good condition and not adversely affected by the *Noctiluca* bloom. *Noctiluca* counts varied from  $3.01 \times 10^5 - 7.71 \times 10^5/m^3$  at Cochin in 1977 and  $2.4 \times 10^5 - 4.1 \times 10^5/m^3$  during 1976 red water at Quilon and Cochin. Values of PSc and cc were consistently high (from 93 to 99 and 50 to 65 respectively) indicating high affinity between samples and also that the same population was being sampled.

Temperature, salinity and  $\sigma_t$  values (Table 2) showed stratified nature of the water column. The cold high saline water found at deeper layers was identified as the upwelled Arabian Sea water, based on its  $\sigma_t$ . Upwelling along the Kerala coast and the intrusion of this upwelled water into the lower reaches of the estuary during this season have previously been reported<sup>19-22</sup>. Measurements made near the surface showed an increase in salinity by 8‰ and a drop in temperature by 2°C within 1 m, showing that the discontinuity was very close to the surface. Fresh water

discharged from the estuary during monsoon<sup>20,23</sup> and presence of upwelled water at the subsurface levels contribute towards an increase in vertical stability in the coastal waters. Qasim *et al.*<sup>24</sup> found an increase in primary production during the monsoon season when there was high vertical stability.

The nutrient values were lower compared to the reported figures<sup>22</sup>, except in the case of inorganic PO<sub>4</sub>-P, which was higher on the first day of observation. The low values of inorganic nutrients and the decreasing trend in their concentrations throughout the period of observation indicated that these were being actively utilized by the fairly large standing stock of phytoplankton.

Dissolved oxygen values were generally low and did not show much variation. While the low values at the bottom and mid depths indicated the presence of upwelled water, those at the surface were probably due to the uptake of oxygen for the break-up of large quantities of organic matter brought down with the river discharge. Low light penetration (Secchi disk depth - 0.33 to 1 m) also indicated high seston content in the water<sup>25</sup>. Kurian<sup>26</sup> observed red water caused by *Noctiluca* in the lower reaches of the Cochin backwaters and reported low surface oxygen values during that period. Aiyar<sup>27</sup> reporting on red water off Madras has suggested that *Noctiluca* blooms deplete dissolved oxygen.

In examining red water caused by the blooming of non-autotrophic, positively buoyant forms like *Noctiluca*, physical factors are perhaps of greater importance in initiating and maintaining the blooms. Comparative abundance of this species in relation to salinity showed its preference to higher salinities, and

Table 2—Hydrographic Data at the Stations on Different Days of Observation

Day (in August 77)	Depth (m)	Temp (°C)	Salinity (‰)	$\sigma_t$	Oxygen (ml/l)	PO <sub>4</sub> -P ( $\mu\text{g at/l}$ )	NO <sub>2</sub> -N ( $\mu\text{g at/l}$ )	NO <sub>3</sub> -N ( $\mu\text{g at/l}$ )
Station 1								
12	0	28.5	26.9	15.5	2.3	6.6	0.4	2.9
	5	24.5	34.7	23.1	2.9	3.9	2.3	2.4
	10	24.1	34.5	23.3	3.6	3.3	2.3	4.2
16	0	25.8	23.8	14.6	2.6	0.9	0.8	1.7
	5	24.3	34.1	22.8	2.6	1.1	1.7	1.9
	10	23.9	34.7	23.5	3.6	2.0	0.9	1.2
18	0	26.8	20.2	12.5	2.4	1.6	0.7	1.3
	5	24.0	26.7	17.5	2.1	4.8	0.2	1.1
	10	23.9	35.1	23.7	1.8	2.5	0.7	0.6
Station 2								
12	0	27.6	22.3	12.9	2.6	6.9	0.8	2.5
	5	24.0	34.4	23.2	1.3	4.6	1.6	1.9
	10	24.0	33.5	22.6	1.6	2.9	1.6	2.2
16	0	27.6	15.6	7.9	2.6	1.8	1.4	1.9
	5	23.8	24.0	17.6	1.6	2.4	2.5	1.6
	10	23.5	30.9	20.6	2.0	0.9	2.5	1.6
Station 3								
12	0	29.0	16.0	7.9	3.0	7.9	1.1	5.1
	5	25.2	29.3	19.1	2.3	2.8	1.5	4.0
	10	25.2	34.3	22.8	2.9	4.7	1.2	3.8
16	0	26.7	22.0	12.9	2.0	1.9	1.4	3.1
	5	24.1	34.5	23.3	1.8	1.5	1.7	2.9
	10	23.8	34.5	23.2	2.0	1.2	2.1	1.3
18	0	27.7	20.1	11.2	2.6	4.4	0.8	2.3
	5	24.5	33.6	22.3	1.7	2.7	0.3	0.6
	10	24.5	32.7	21.6	2.5	4.7	0.2	0.5

on all occasions when they were reported to be prolific, the salinity values were between 32 and 35.4‰. Lower salinities at the surface (<26‰) during the present observations, effectively limited their occurrence at the surface. *Noctiluca* counts at the subsurface levels also decreased drastically (30,000 nos./m<sup>3</sup>) at st 2 on 16.8.77 where salinity at mid depths was low (24‰) while at st 1 and 3 on the same day they occurred in higher numbers ( $4 \times 10^5$  and  $3 \times 10^5$ /m<sup>3</sup>) when salinity values were 34.1 and 34.5‰ respectively. Analyses of field data from the Florida red tide area<sup>18</sup> showed that there is no real abundance of red tide organisms below 30.5‰ of salinity.

Along the southwest coast of India, occurrences of red water are reported between August and November which marks the end of the upwelling period along this coast. Earlier workers have also observed that *Noctiluca* blooms are preceded by rains and diatom maxima. Relationship between dinoflagellate abundance and lack of turbulence which is analogous to increase in vertical stability is well established<sup>28</sup>. High primary production along the southwest coast during the monsoons owing to nutrient enrichment of the waters from upwelling and estuarine discharges probably sets the stage for non-autotrophic forms like

*Noctiluca* to bloom. The observations by Sanders<sup>29</sup> that red tides occur in upwelling areas towards the end of upwelling period also point towards the need for some kind of preconditioning of the water by high diatom production before the dinoflagellates are able to bloom. Biological processes ensuing upwelling and nutrient enrichment which may become deterrent to fish and other life in the sea through oxygen depletion and red tide formations have been discussed<sup>30</sup>. They have noted that the period when the red tides are generally reported, September to November, coincides with the end of the upwelling season, when the weather is warmer with far longer hours of sunshine than during monsoon months. The environmental conditions both at Cochin and Quilon are similar during August and the recurring favourable conditions seem to initiate red tides over the years along the southwest coast of India.

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