

time after that, though there were daily fluctuations. However, the second surge on 1 June 2000 was of prolonged duration and high wind speeds were sustained for a longer time. Two heavy rainfall events, one over Mumbai on 17–18 May 2000 and the other over Karnataka coast on 6–7 June 2000 were observed. In both these events strong moisture convergence was observed, 1–2 days before heavy rainfall.

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A note on the plankton from Barren Island region, Andamans

Barren Island, located 75 nautical miles north-east of Port Blair in the Andaman Sea, is the only active volcanic island in India (Figure 1). A general description of the Barren Island region by Boden¹, dates back to 1902. Until now, only two scientific investigations have been made in and near this volcanic island. Rao and coworkers² gave a preliminary account of the fauna and flora found in the island. A subsequent report by Mustafa³ dealt with the general physicochemical characteristics of near-shore waters at a time when the volcano last erupted in 1991. During intense volcanic activity, the author noticed regions of low pH and high temperature in some shallow water columns in the immediate vicinity of the land mass.

This paper presents the results of surface-water plankton studies in the Barren Island region. These results relate to the cruise by *MV Bhikaiji Cama* during 11–12 November 2000.

Sampling was performed on 12 November 2000 from a smaller vessel deployed at N 12°17'21"; E 93°59'06",

roughly 0.5 km from the western shoreline of Barren Island. Physicochemical characteristics of surface sea water were measured using standard methods⁴. Plankton samples were taken using Heron-type nets (mouth area 0.197 m²) that used 65 and 350 µm mesh types for phyto and zoo portions, respectively. Nets were towed for 10 min in a seaward direction. Additionally, three 1-litre water samples were taken and treated with Lugol's solution. These samples were used for the estimation of phytoplankton density in accordance with the settlement procedure. Net plankton samples were preserved in 2 to 5% formalin buffered with borax. Zooplankton was in addition frozen with no formaldehyde treatment.

From 10.05 am until noon, surface water temperature varied between 29.1 and 29.5°C. Water pH was consistently about 8.1, while oxygen and salinity values were 5.7 mg l⁻¹ and 34.1 × 10⁻³, respectively. Transparency was profoundly high in the region around Barren Island. In three measurements made

at water depths 12, 25 and 150 m, Sechi readings were 12, 25 and 42.

Phytoplankton data in Table 1 address numerical abundance as well as per cent composition details. Phytoplankton density was extremely low and cell numbers in the three surface-water samples were fewer than 10² l⁻¹. The listing presents 38 species altogether, comprising of 20 diatoms, 17 dinoflagellates and a blue-green alga, *Trichodesmium erythraeum*. Per cent composition data show obvious prevalence of dinoflagellates and *T. erythraeum* over diatoms, consistent with the propensity of Andaman waters⁵. Notably, as many as 12 species of Peridiniales were represented in the present samples, of which 8 belonged to the genus *Ceratium*.

As seen from Table 2, foraminiferans, radiolarians and sponge larvae contributed to a large portion of the zooplankton. This pattern is in good agreement with the observations by Sorokin *et al.*⁶, who recorded high to very high percentage of protozoans in zooplankton taken

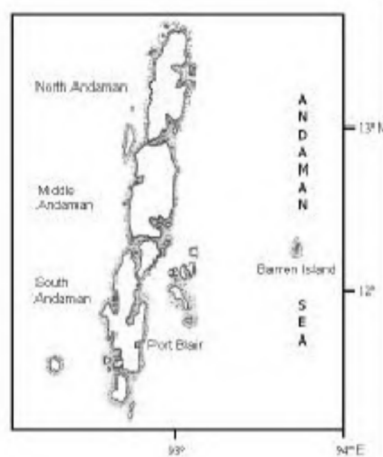


Figure 1. Location map showing the position of Barren Island in Andaman Sea.

from regions around underwater volcanoes in the Western Pacific. Other important zooplankton groups in the present samples were copepods and gastropods. Calanoids accounted for more than two-thirds of the copepods, followed by cyclopoids (23%) and herpacticoids (8%). Quite unusually, the copepods were strongly pigmented, appearing bright red in colour. The pigmentation was intensely deep as to cause the entire zooplankton sample look strikingly coloured.

Microscopic examination of the copepods was made using a CETI Spectrum microscope in conjunction with a video monitor. No evidence was found, in examinations up to 1000 \times (which the video monitor further magnified by about 2.5 times), of either plant or photosynthetic bacterial symbionts. Absorption spectrum (JASCO 7800 Spectrophotometer) for the copepod sample extracted in 90% acetone is shown in Figure 2. The scan presents long-wavelength absorption maximum at 470 nm and two minor peaks in the 630 and 730 nm regions. The major peak corresponds typically to carotenoids⁷, while the minor peaks probably represent chlorophyll-c⁸. The spectral characteristic suggests that the carotenoid is β -carotene related⁹, although it is not precisely known whether the compound is beta β -carotene or beta β -carotene-4,4'-dione (canthaxanthin) or a combination of the two.

Table 1. Phytoplankton data for three surface-water samples and a net sample

Group/organism	Cells or filaments l ⁻¹			Per cent composition
	Sample 1	Sample 2	Sample 3	Net sample
Diatoms				
Centrales				
<i>Actinocyclus undulatus</i>	1			
<i>Bacteriastrium comosum</i>				2.45
<i>Chaetoceros lorenzianus</i>	2		1	0.61
<i>Chaetoceros peruvianus</i>				0.61
<i>Climacodium frauenfeldianum</i>		2	2	0.61
<i>Coscinodiscus eccentricus</i>	2		7	3.68
<i>Eucampia conuta</i>	3	3		
<i>Leptocylindrus danicus</i>				0.61
<i>Planktoniella sol</i>		1		
<i>Rhizosolenia alata</i>	2	9	5	3.68
<i>Rhizosolenia crassispina</i>		1	1	1.84
<i>Rhizosolenia robusta</i>			1	1.23
<i>Rhizosolenia setigera</i>		2		
<i>Skeletonema costatum</i>				0.61
Pennales				
<i>Grammatophora undulata</i>	5			
<i>Navicula longa</i>	5			
<i>Pleurosigma carinatum</i>	8		5	6.75
<i>Pleurosigma elongatum</i>			5	
<i>Thalassiothrix longissima</i>			3	
<i>Trachyneis aspera</i>			1	
Dinoflagellates				
Dinophysiales				
<i>Noctiluca milaris</i>		1	1	1.84
<i>Ornithocercus steinii</i>		1		7.98
<i>Ornithocercus thumi</i>	1			
<i>Ornithocercus quadratus</i>	1			
<i>Prorocentrum micans</i>	1			
Peridinales				
<i>Ceratium azoricum</i>		2	2	
<i>Ceratium contortum</i>				3.07
<i>Ceratium dens</i>				3.07
<i>Ceratium furca</i>		3		
<i>Ceratium macroceros</i>				20.86
<i>Ceratium trichoceros</i>	2			1.23
<i>Ceratium tripos</i>				1.23
<i>Ceratium schmidt</i>				3.07
<i>Ceratocorys horrida</i>				1.23
<i>Protoperidinium conicum</i>			2	
<i>Protoperidinium oceanicum</i>			1	1.23
<i>Protoperidinium pendunculatum</i>	1			
Blue-green algae				
<i>Trichodesmium erythraeum</i>	35	50	29	32.52
Total	69	75	66	100.00

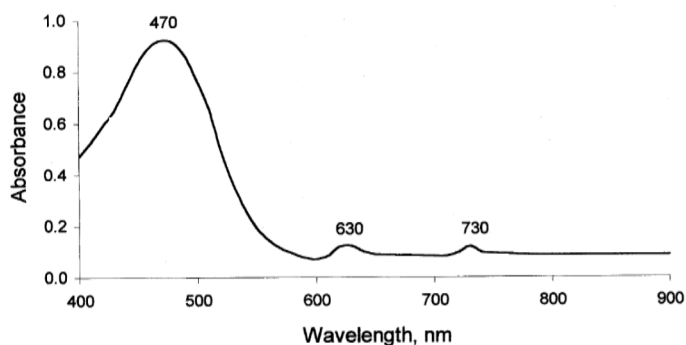


Figure 2. Absorption spectrum for copepod sample extracted in 90% acetone.

Table 2. Zooplankton composition data

Group	Per cent composition
Foraminiferans	15.1
Radiolarians	20.5
Porifera larvae	18.8
Siphonopores	1.2
Nauplii	0.9
Zoea	0.6
Decapods	0.3
Amphipods	0.9
Cladocerans	0.3
Copepods	14.6
Chaetognaths	3.4
Gastropods	11.4
Bivalves	2.2
Appendicularians	1.5
Tintinnids	1.5
Echinoderm larvae	0.9
Fish eggs	5.9
Total	100

One plausible interpretation of this unusual phenomenon in copepods is that the organisms concentrate the pigment as an adaptive response to intense UV radiation in the region of this study. No direct measurement has ever been made of the intensity of UV radiation in the Barren Island area. Nevertheless, the predictable effect of volcanic action on ozone depletion¹⁰, the exceptionally high visibility of the waters (this work), and the amount of radiation that one physically encounters here are, altogether, reasonably compatible with this presumption. The suggested process is analogous to the adaptation mechanism to UV radiation in certain species of corals¹¹, fishes¹², algae¹³ and phytoplankton¹⁴, through the production of photo-protective compounds.

As reviewed comprehensively by El-Sayed *et al.*¹⁵, stratospheric ozone depletion is now on a global scale, which has caused large concern about the effect of UV radiation on marine organisms. From studies in the Antarctic region in particular, where ozone depletion is most marked, marine organisms have been shown to synthesize sunscreen compounds. The most commonly found sunscreen compounds in marine organisms are mycosporine-like amino acids (MAAs)¹²⁻¹⁴. Unlike carotenoids, the MAAs lack colour and show characteristic absorption maximum in the 350 to 380 nm region.

Carotenoids, besides being biological pigments in plants and algae, are also potent antioxidant molecules that function as ultraviolet absorbers¹⁶. In ani-

mals, photo-protective pigments are generally rare and their presence is through the ingestion of prey or through translocation from symbionts¹⁵. The bright colouration in red lobster and pink salmon is known to be from canthaxanthin that these organisms derive from their natural diet¹⁷. The pigment performs photo-protective and antioxidant functions that are vital to the endurance of these organisms – from UV effects as well as on long migrations. The absence of photosynthetic symbionts (as verified by microscopy) suggests that the concentration of the red pigment was solely through ingestion of prey in the present case as well.

Bryon¹⁸ has occasionally noticed bright colouration in calanoid copepods from lake habitats. In this case, copepods were most darkly pigmented in the coldest lakes. The author suggested that the pigments were adaptive to the organisms, facilitating a metabolic increase that compensated for low-temperature effects. From an ecological perspective, Bryon deduced that pigments are hardly ever found in zooplankton, because the organisms are continuously exposed to visually-selective predators. The present results suggest a situation in which the benefit of pigmentation apparently outweighs the detriment of selective predation.

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