

Figure 3. Distribution of monthly average wave power.

Table 3. Comparison of wave power for annual, fair-weather and rough-weather seasons

Data	Wave power (kW m^{-1})		
	Annual	Fair-weather	Rough-weather
Sea and swell	4.6	2.2	7.1
Swell	13.1	4.6	21.6

provide much higher values of wave power than the combined sea and swell statistics. The low values obtained from sea and swell statistics may be attributed to the fact that rough seas are avoided by ships and the information is therefore absent in the data.

1. Goldsmith, V. and Stan Sofer, *J. Earth Sci.* 1983, 32, 1.
2. Laing, A. K., *J. Climate Appl. Met.*, 1985, 24, 481.
3. *Wave Statistics of the Arabian Sea*, Naval Physical and Oceanographic Laboratory, Cochin, 1978, p. 204.
4. *Wave (Swell) Atlas for Arabian Sea and Bay of Bengal*, National Institute of Oceanography, Goa, 1982, p. 385.
5. Narayana Swamy, G., Kesava Das, V. and Varkey, M. J., *Mahasagar*, 1976, 9, 63.
6. Raju, V. S. and Ravindran, M., *Wave energy in the Indian Context*, Contributions in Marine Sciences, National Institute of Oceanography, Goa, 1987, pp. 199–209.
7. Dattatri Jade and Renukaradhya, P. S., *Waterways*, 1983, 97, 505.
8. Muraleedharan, G., Unnikrishnan Nair, N. and Kurup, P. G., Proceedings of the Second National Workshop on Wave Studies

and Applications (to appear), 1989.

9. Muraleedharan, G., Kurup, P.G. and Unnikrishnan Nair, N., Proceedings of the Third National Conference on Dock and Harbour Engineering, 1989, vol. 1, pp. 31–34.
10. Reddy, M. P. M., *Mahasagar*, 1970, 27 (supplement).

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Occurrence of a brisingid (phylum Echinodermata) in the Central Indian Ocean Basin

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A unique organism belonging to genus *Freyella* (phylum Echinodermata, family Brisingidae) was photographed at 12 locations at abyssal depths (beyond 5000 m) of the Central Indian Ocean Basin. Unlike other species of this genus, this particular organism has spine-like, unarticulated arms, which vary in number from 11 to 23. The ratio of the diameter of the central disc to arm length is 1 : 7. The organism was found on sediment substrate, rock exposures, as well as nodule deposits. This is a new depth record (beyond 3000 m) for this genus, and is probably a new species.

DURING surveys for polymetallic nodules in the Central Indian Ocean Basin (CIOB), 1034 seabed photographs were obtained using boomerang cameras and deep-sea towed cameras. The present study reports a peculiar echinoderm observed in 12 of the photographs (Figure 1).

The central disc of the organism would appear to be flat, with a number of spine-like arms all around it in a horizontal plane. The disc is 1.5 to 3.5 cm in diameter

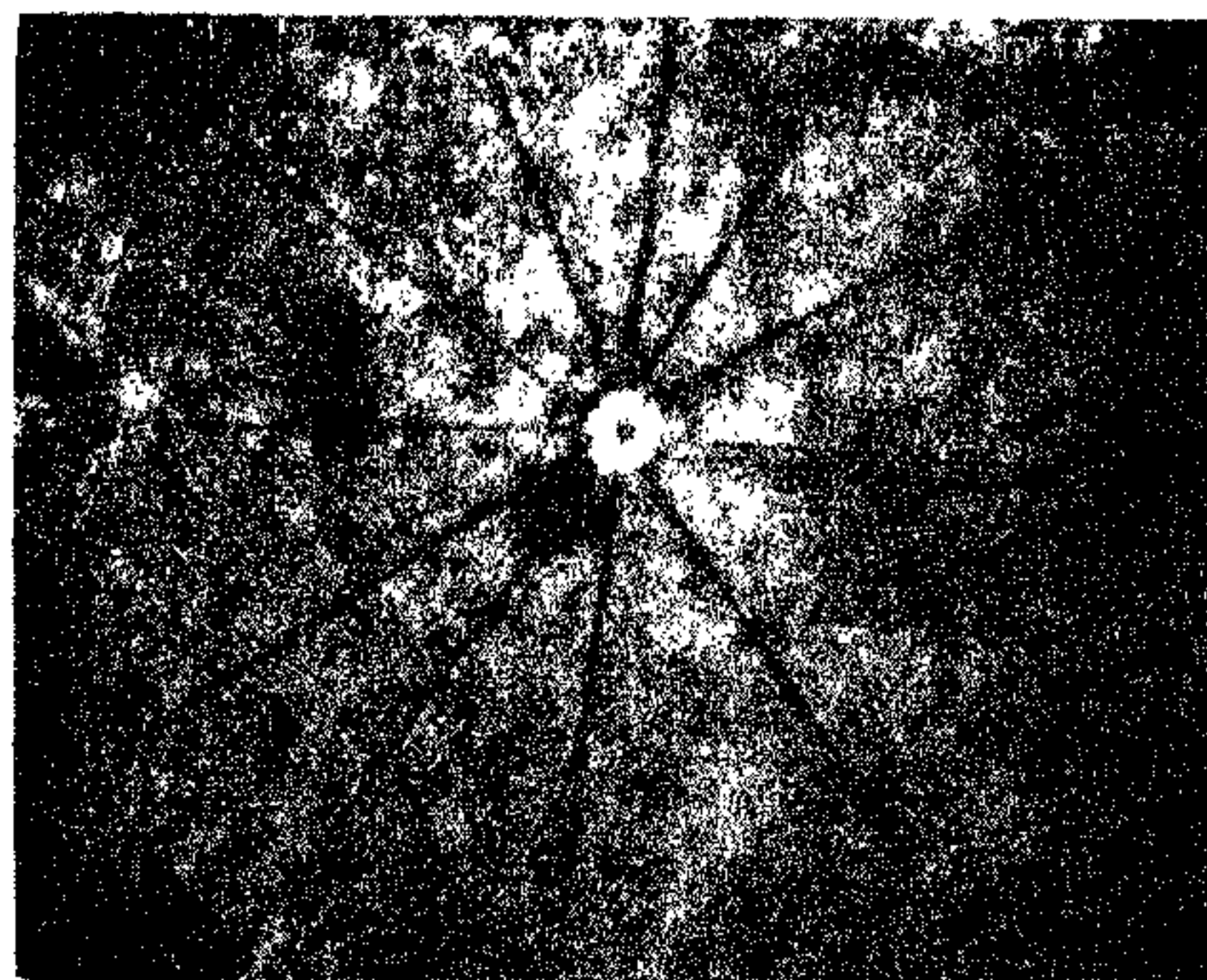


Figure 1. Seabed photograph showing a brisingid (phylum Echinodermata) on a sediment substrate at 5120 m (area of photo 40 cm × 52 cm).

Table 1. Salient features of occurrence of brisingids in the Central Indian Ocean Basin.

Lat. (°S)	Long. (°E)	Depth (m)	Substrate	Dimensions of organism		No. of arms
				Disc diameter (cm)	Arm length (cm)	
10° 2'	75.50	5200	Sediment	3.0	22.5	11
11° 50'	73.25	5180	Sediment	3.5	24.5	20
11° 59'	79.63	5190	Sediment	3.0	19.5	18
12° 12'	76.50	5100	Sed. + Nod.	3.5	23.0	16
12° 12.5'	76.00	5200	Sed. + Nod.	2.5	16.0	11
12° 50'	76.125	5275	Sed. + Nod.	1.5	11.0	16
12° 60'	76.37	5250	Sed. + Rock	1.6	11.7	12
12° 12'	75.00	5217	Sediment	3.0	21.0	20
13° 35'	74.77	5020	Sed. + Nod.	2.5	17.0	19
13° 65'	79.00	5400	Sed. + Rock	2.5	18.0	15
13° 25'	73.75	5100	Sediment	2.0	15.0	12
14° 9'	78.25	5025	Sediment	3.0	22.0	23

with small bright spots along its edge. These spots could also be raised structures on the border of the disc. The radiating arms are straight and slender, with no visible signs of articulation. They vary in number from 11 to 23, and between 11 and 24.5 cm in length. The length is fairly constant within a specimen, but varies with disc diameter (Table 1). The ratio of disc diameter to arm length is 1:7. The total length of the animal across the radial arms varies between 23.5 and 52.5 cm.

Several studies on abyssal fauna of the world oceans¹⁻³ as well as more specific references to echinoderms⁴⁻⁸ were checked for identification of this organism; but none of the animals described resembled this particular species. In a recent personal communication, Dr F. J. Madsen (Zoological Museum, Denmark) identified this specimen as possibly belonging to the genus *Freyella* (order Euclasterida, suborder Brisingina, family Brisingidae). Members of the order Euclasterida possess six or more slender arms on a small disc-shaped body. Many species also bear spines on their arms. Our specimen compares very well with the characteristics of the members of the family Brisingidae, many of which have an extremely small disc and very long, narrow cylindrical arms, which may vary from 6 to 50 in number⁴. Interestingly, the arms of our specimen are spine-like, straight and slender, with no visible articulation or flexibility, unlike those of the known species of *Freyella*. This genus has not yet been reported beyond 3000 m (Dr F. J. Madsen, pers. commun.) The organism described here was photographed between 5020 and 5400 m. It may therefore be a hitherto unreported deep-sea species and a new depth record for this genus.

Photographs taken in this area have shown 135 different organisms belonging to seven phyla. Thousands of freefall grab samples have been taken in the area, in which only four bathypelagic fish, two brittle stars, two sea stars and three pennatulids were collected in good condition. Many grabs yielded biogenic fragments, jelly-

like masses, or completely crushed organisms, which were unidentifiable. None of the grabs yielded anything like our specimen. It evidently would appear not to survive the decompression effect. Alternatively, the organism might also escape through the net of the freefall sampler. Photographic evidence has, therefore, been the only means of recording their existence. About 1.2% of the photographs taken in the survey area (distributed over the entire CIOB, Figure 2), showed the presence of this species.

The organism was found on different substrates such as sediment, nodules and rocky exposures, indicating its

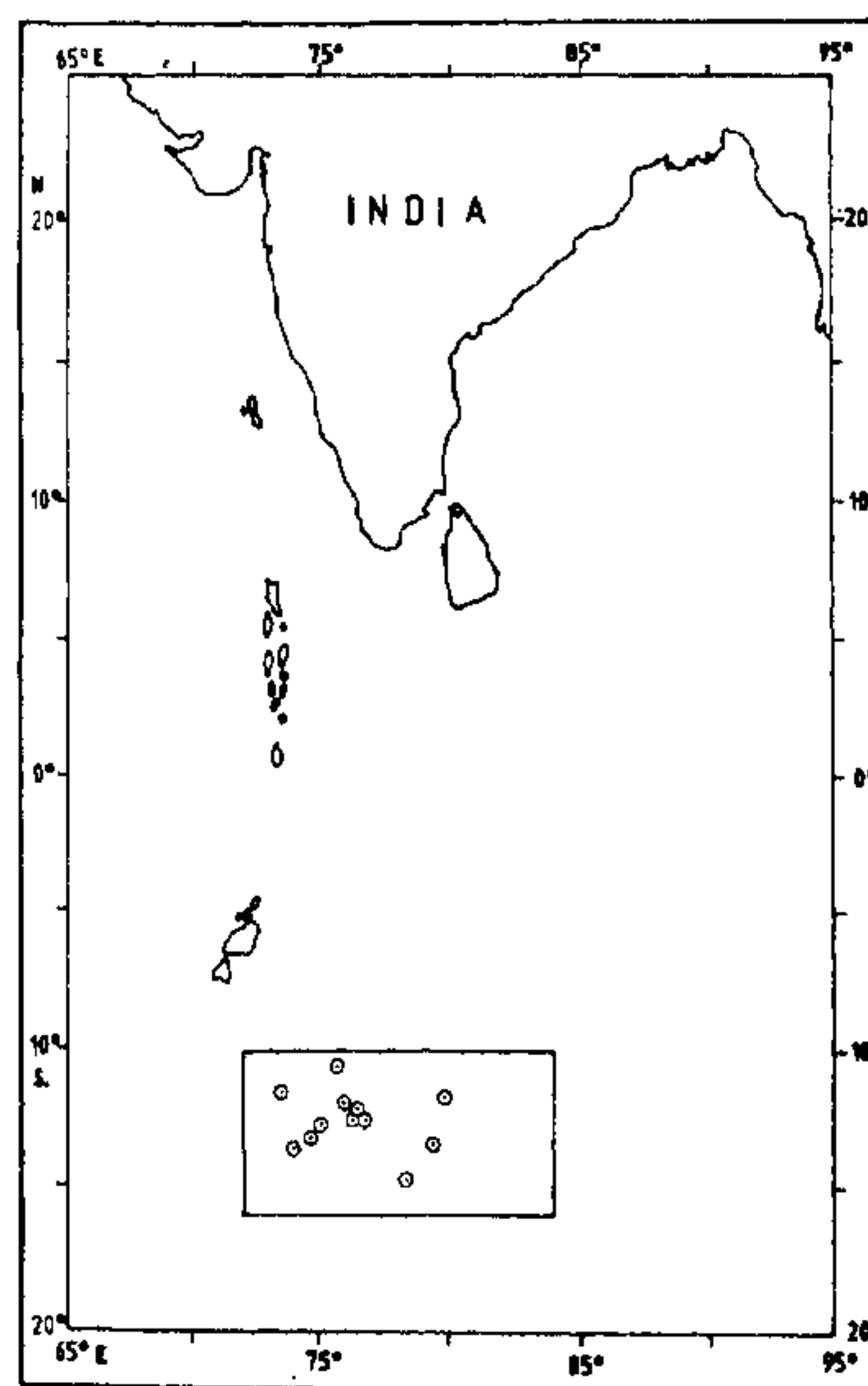


Figure 2. Distribution of brisingids in survey area.

ability to inhabit these locations. Distribution of the organism is fairly uniform over the study area. The sediment in this area was predominantly red clay and siliceous ooze⁹. The nodule coverage ranged from 0 to 17%. The organism was generally associated with faecal tubes of holothurians and acorn worms, and body casts of polychaetes, and with burrows and pellets for which they may themselves be responsible. The specific tracks of these animals could not be deciphered. A few pennatulids were also photographed along with them.

This report acquires significance because:

- (i) It is the first report of genus *Freyella* from the Indian Ocean from depths greater than 3000 m. Since this species was observed even at 5400 m depth, it seems capable of surviving under extreme conditions (3–4°C temperature; 300×10^5 to 500×10^5 pascal pressure.
- (ii) This is probably a new species.
- (iii) The species can survive on sediment substrate as well as in regions of rocky exposures and thick nodule populations.

1. Heezen, B. C. and Hollister, C. D., *The Face of the Deep*, Oxford University Press, New York, 1971, p. 659.
2. Clarke, M. R. and Herring, P. J., in *Deep Oceans* (eds. Herring, P. J. and Clarke, M. R.), Arthur Barker Ltd, London, 1971, p. 164.
3. Lemche, H., Hansen, B., Madsen, F. J., Tendal, O. S. and Wolff, T., *Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening*, 1976, 139, 263.
4. Fechter, H., in *Grzimek's Animal Life Encyclopedia: Vol. 3, Mollusks and Echinoderms* (ed. Grzimek, B.), Van Nostrand Reinhold Company, New York, 1974, p. 361.
5. Koehler, R., *Echinodermata of the Indian Museum (Deep Sea Asteroidea)*, no. 5, Indian Museum, Calcutta, 1909.
6. Moore, R. C. (ed.), *Treatise on Invertebrate Palaeontology*, Part V, *Echinodermata* 3, 1962, p. 695.
7. D'yakonov, A. M., *Seastars (Asteroidea) of the USSR Seas*, Zoological Institute of the Academy of Sciences of the USSR, No. 34, 1968, p. 183.
8. Nichols, David, *Echinoderms*, Hutchinson University Library, London, 1969, p. 191.
9. Udintsev, G. B., *Geological and Geophysical Atlas of the Indian Ocean*, Pergamon Press, Oxford, 1975, p. 130.

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Effect of culture filtrate on growth of *Spirulina platensis*

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There is need for genetic improvement of the biotechnologically important cyanobacterium *Spirulina platensis*.

sis. Repeated unsuccessful efforts to get isolated colonies on agar plates after dilution of the cultures and synchronous growth, in contrast to thick mat-like growth, from bulk inoculum prompted an investigation of the effect of *Spirulina* culture filtrate on growth of fresh inoculum. The results show that sterilized *Spirulina* culture filtrate has extracellular growth-stimulatory factor(s).

DURING efforts to obtain synchronous growth of the cyanobacterium *Spirulina platensis* it was found that very dilute cultures fail to grow and tend to lyse both in liquid and on solid media. It appeared that a certain minimum cell population or inoculum size is necessary to initiate and sustain growth of *Spirulina* cultures. Furthermore, it was observed that when the inoculum size was large enough to initiate growth of the culture the growth rate was proportional to inoculum size. These observations indicated that the inoculum has a factor that is necessary for further growth and sustenance of the culture. If this factor falls below a certain critical level, the organism would not only fail to grow but the cells would also lyse eventually.

The present work was undertaken to ascertain, first of all, if this premise is true, and, if a growth-stimulating factor does exist, whether it is cell associated or is present extracellularly. *S. platensis* CFTRI cultures were raised in Zarrouk's¹ medium for six days under standard autotrophic culture conditions² on a shaker. The culture fluid was filtersterilized using a Millipore membrane filter (0.22 µm). Different volumes of culture filtrate were added to Zarrouk's medium (Figure 1). The total volume of the medium was 10 ml, to which 5 ml *S. platensis* inoculum was added, to give an absorbance at 560 nm of 0.1.

The cultures were allowed to grow and absorbance was read periodically for 9 days. Figure 1 shows that addition

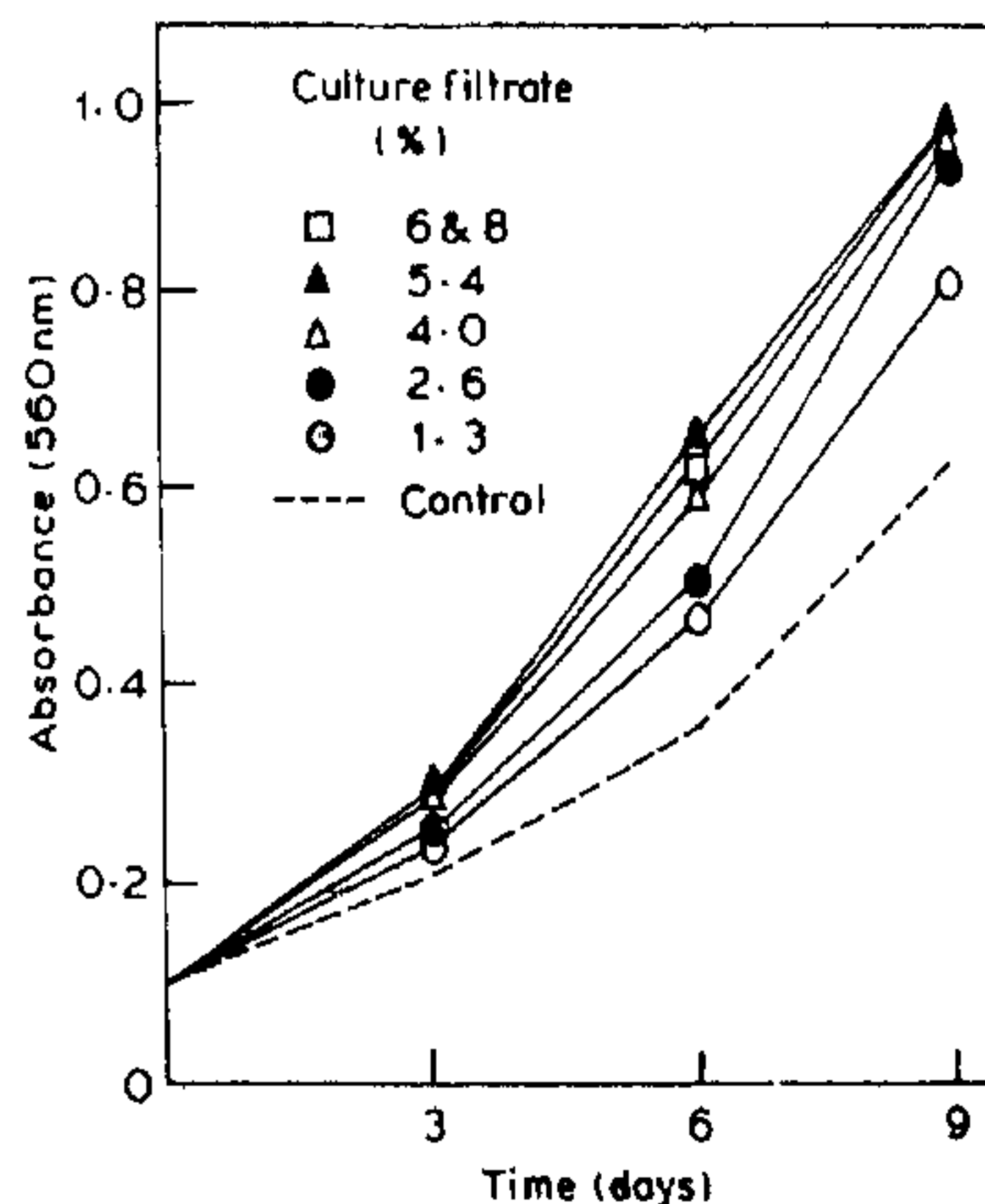


Figure 1. Growth of *Spirulina platensis* CFTRI with/without added sterilized culture filtrate.