

## EFFECTS OF TOTAL SOLAR ECLIPSE ON THE BEHAVIOURAL AND METABOLIC ACTIVITIES OF TROPICAL INTERTIDAL ANIMALS

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### ABSTRACT

To study the effects of total solar eclipse of 16th Feb. 1980, on the behaviour and metabolic activities of intertidal invertebrates - nematodes, gastropods and bivalves - having different habitat preference a set of relevant observations, covering the pre-eclipse, eclipse and post-eclipse period, were carried out in the natural environment of Dias beach, Goa (Lat. 15°25'N; Long. 73°45'E).

Nematodes, inhabiting the interstices of sandy beach, were observed for variations in their locomotory rhythm. Similarly, the inhabitants of rocky shore, namely, a sessile organism like the rock oyster (*Saccostrea cucullata* Born.) and a sluggish organism like the periwinkle (*Littorina intermedia* Phil.) were studied for changes in metabolite-water and carbohydrate-composition. Environmental factors considered are tidal amplitude, atmospheric temperature and the sand column temperature.

Results indicate that the stratification of nematodes which usually was maximum (57 to 80%) in the top 1 cm layer of the sand column at all the tide levels, during pre- and post-eclipse period, showed low population density of 11 to 40% on the day of the total solar eclipse. Similarly, the metabolite contents in *S. cucullata* and *L. intermedia*, as assessed from the variations in water and carbohydrate composition, indicated a sudden fall of 10% and 16%, respectively, almost coinciding with the planetary events of 16th Feb. 1980.

An attempt is made to analyze the magnitude of exogenous and endogenous factors in influencing the observed changes, coinciding with the total solar eclipse. On *prima facie*, the observed changes in the behavioural activity of interstitial nematodes and in the metabolite composition of the rock oyster and the periwinkle, appear to be a consequence of the total solar eclipse. However, the possibilities of these observed changes, being an event of the persisting "biological clock" or "circadian rhythm", which reportedly controls the activities of intertidal animals, cannot totally be overruled.

### INTRODUCTION

The activities of the marine invertebrates in the natural habitat fluctuate over a solar cycle and the fluctuations are not random but seem to be correlated with the rhythmic daily changes in the intensity of solar radiations. While one of the most dramatic cyclic activity is the diurnal vertical migration of many planktonic invertebrates, the intertidal animals, similarly display diurnal changes in activity correlated with the natural periodicity of daylight to darkness over a 24 hrs period (Segal, 1970).

The intertidal biotope is a region of severe environmental fluctuations that exhibit a number of different periodicities (Southward, 1965). The inhabitants of this region experience the solar day cycle with its variations in illuminations and temperature, while they are

simultaneously exposed to the lunar and solar periodicities of tidal movements. Among the intertidal invertebrates, the degree of endogeneity of a biological rhythm may be weakest in some of the surface living sessile forms which are structurally well adapted to withstand a wide range of environmental variables (Rodriguez & Naylor, 1972). Some of the most persistent endogenous rhythm in marine organisms occur in burrowing forms (Naylor, 1976). However very little is known about the effects of rather than usual planetary events like solar and lunar eclipse, on the behaviour, metabolism and responses of marine intertidal animals, especially from the tropical environments.

On February 16, 1980, a total solar eclipse - an exceptional event was observed in Goa as elsewhere in India. The eclipse started at 1417 hrs (IST), reached the peak at 1540 hrs (IST) and ended at 1652 hrs (IST). In order to study the effects of total solar eclipse on marine intertidal animals, a set of field experiments, were conducted on the days of pre-eclipse (14th & 15th Feb. 1980), eclipse (16th Feb. 1980) and post-eclipse days (17th & 18th Feb. 1980), for studying the responses in behaviour and metabolism of burrowing (Nematode worms), sessile (Rock oyster) and sluggish or slow moving (Periwinkle) animals, and the results of the study are presented and discussed in the present paper.

#### MATERIAL AND METHODS

Field experiments were carried out at Dias beach, Goa (Lat. 15°27'N; Long. 73°48'E) which harbours a sheltered sandy beach, interspersed with jutting rocks. The Dias beach, situated at the confluence of Mandovi and Zuari river with the Arabian Sea, is about 200 m. in length and the tidal amplitude, here, varies from two to three metres.

From 14th to 18th Feb. 1980, interstitial sampling, along a transect extending from the high tide mark to low tide level was carried out. Sampling was done during the low tide phase, and in the afternoon and the evening hours. At high tide level (HTL), mid tide level (MTL) and the low tide level (LTL), the sand column upto 5 cms, was sampled by using a hand operated plexiglass core tube, of 2 cm diameter. Replicate of five samples were collected at each sampling site and on each of the days of sampling. The sand core was sliced at 1 cm thickness and each of the subsample, separately preserved in 5% neutralized seawater formalin and 1% Rose Bengal solution. The nematode worms, were sorted and enumerated under the binocular microscope and the values represent the mean of five replicates. At each of the sampling point, data on sediment temperature (upto 5 cms) and atmospheric temperature were recorded.

Simultaneously, the samples of periwinkle (*Littorina intermedia* Phil.) and rock oyster (*Saccostrea cucullata* Born.), from the intertidal rocks, were collected. The periwinkles and rock oysters were transferred live to main laboratories, where the meat and the body fluids were removed for biochemical analysis. And analyses were done in triplicate and as per the standard procedures (AOAC, 1950).

#### RESULTS AND DISCUSSION

##### Tidal cycle :

The study area comes under the regime of semidiurnal mixed type of tides (Fig. 1) and accordingly all the sampling programme was conducted during the low tide phase. The minimum low tide of 0.15 m was encountered on the day of the total solar

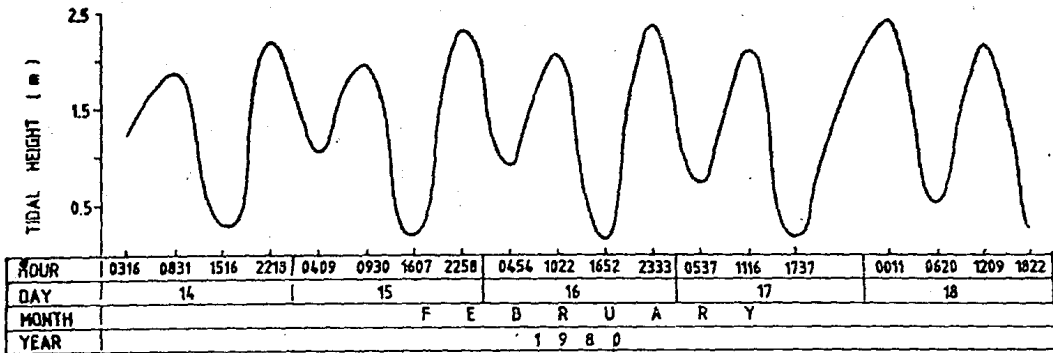


Fig. 1: Tidal variations during the pre-eclipse (14th & 15th Feb. 1980), total solar eclipse (16th Feb. 1980) and post-eclipse (17th & 18th Feb. 1980) days

eclipse i.e., 16th Feb. 1980. Though the time of the low tide varied from 1516 hrs. of 14th Feb. 1980 to 1822 hrs. of 18th Feb. 1980, the sampling was uniformly conducted between 1400 hrs and 1915 hrs. for assessing the direct effect, if any, of tidal amplitude on the related rhythm (Naylor, *opp. cit.*) of the animals studied.

#### Atmospheric temperature :

The air temperatures over the study area, varied from  $27.2 \pm 0.4^\circ\text{C}$  on 15th Feb. 1980 to  $29.4 \pm 0.2^\circ\text{C}$  on 19th Feb. 1980 (Fig. 2). On the day of the total solar eclipse i.e., 16th Feb, 1980, wide fluctuations, ranging from  $27.6^\circ\text{C}$  at 1445 hrs. to  $26^\circ\text{C}$  at 1545 hrs. were observed. While comparable data recorded on pre-eclipse and post-eclipse days, did not show significant variations in the air temperature, the air temperature recorded at every 5 minute interval on the day of the total solar eclipse, showed peak values at the start and again at the end, with a conspicuous low, at the time of totality of the eclipse.

#### Interstitial temperature :

The sand column temperature, upto 5 cms. depth, displayed varying pattern of distribution at different tidal levels (Fig. 2). Accordingly, at HTL, a relatively high range of value from  $33.8^\circ\text{C}$  during pre-eclipse to  $31^\circ\text{C}$  on the day of eclipse to  $32.4^\circ\text{C}$  in the post-eclipse time, was observed. Similarly, at MTL, the value was highest ( $32^\circ\text{C}$ ) during pre-eclipse, lowest ( $29.2^\circ\text{C}$ ) on the day of eclipse, followed by a recovery in the post-eclipse period. In contrast, at LTL, the sand column temperature, which was maximum ( $31.2^\circ\text{C}$ ) during the pre-eclipse days, gradually declined during eclipse and post-eclipse phase. Apparently, this may be due to the shift in the timings of the low tide (Fig. 1), from 1516 hrs. on 14th Feb. 1980 to 1822 hrs. on 18th Feb. 1980, though the magnitude remained almost unchanged.

#### Behaviour of nematodes :

The distribution and abundance of the nematode worms, in the stratified sand column, varied at different tide levels and also during pre-eclipse, eclipse and post-eclipse phase. Rodrigues (1984) who reported most of the meiofauna to be concentrated

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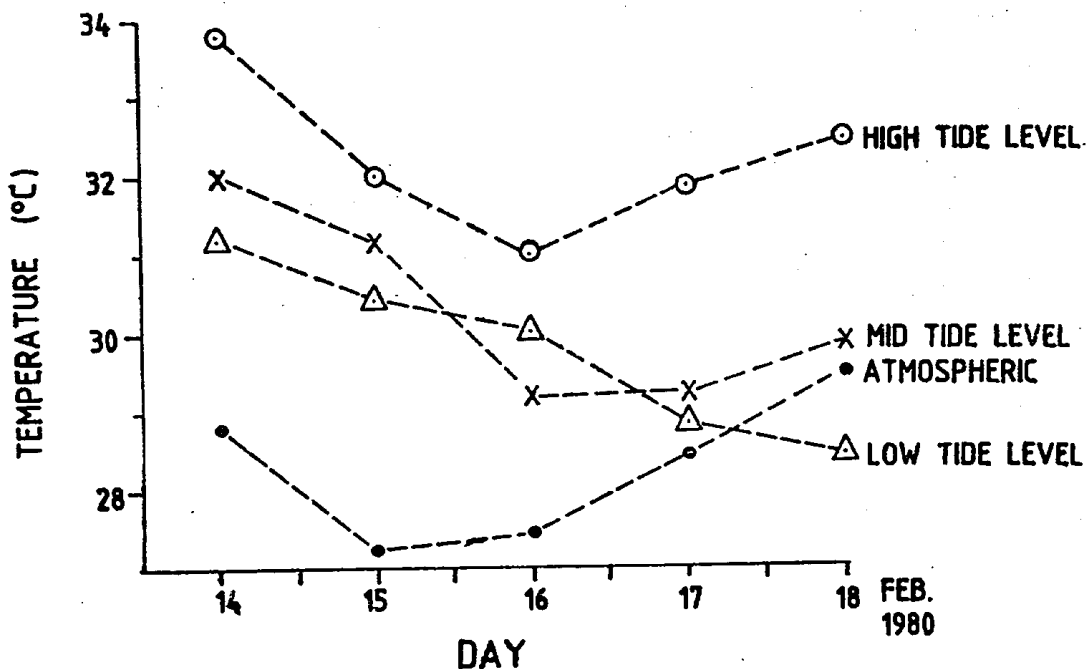


Fig. 2 : Atmospheric and sand column temperature, upto 5 cms. depth at different tidal levels, during pre-eclipse, total solar eclipse and post-eclipse days.

in the upper 5 cm. layer of the sand column at Dias beach (Dona Paula) of Goa, did not come across the pattern of aggregation of nematodes, as observed in the present study (Fig. 3).

The stratification of nematode worms, which was maximum, upto 80%, in the top 1 cm. layer and also at all the tidal levels, during pre-eclipse and post-eclipse period, erratically dropped to 11% at the time of the total solar eclipse. High aggregation of nematodes, almost amounting to 60% or more, was observed to be stratified just below the top 1 cm. layer and more localized at 2cm. and 3 cm. layer of the sand column, on the day of the total solar eclipse Dahl (1952) has elaborated on the stratification of interstitial nematodes and has reported a positive correlation with the photoperiod, tidal amplitude and availability of organic matter.

The aggregation of meiofauna, which also includes nematodes, in the interstitial niche, is regulated by the pore size distribution which is related to tidal phase and temperature regime directly affecting the rate of evaporation (Crisp & Williams, 1971). However, it is evident (Fig. 3) that the sudden decrease in nematode population from the top 1 cm layer cannot be attributed to any conventional environmental and biotic factor but to the extraordinary planetary event of the total solar eclipse. In a preliminary account, Parulekar *et al.* (1981) have reported major changes in the behavioural and metabolite activities of some intertidal marine animals as a consequence of the total solar eclipse.

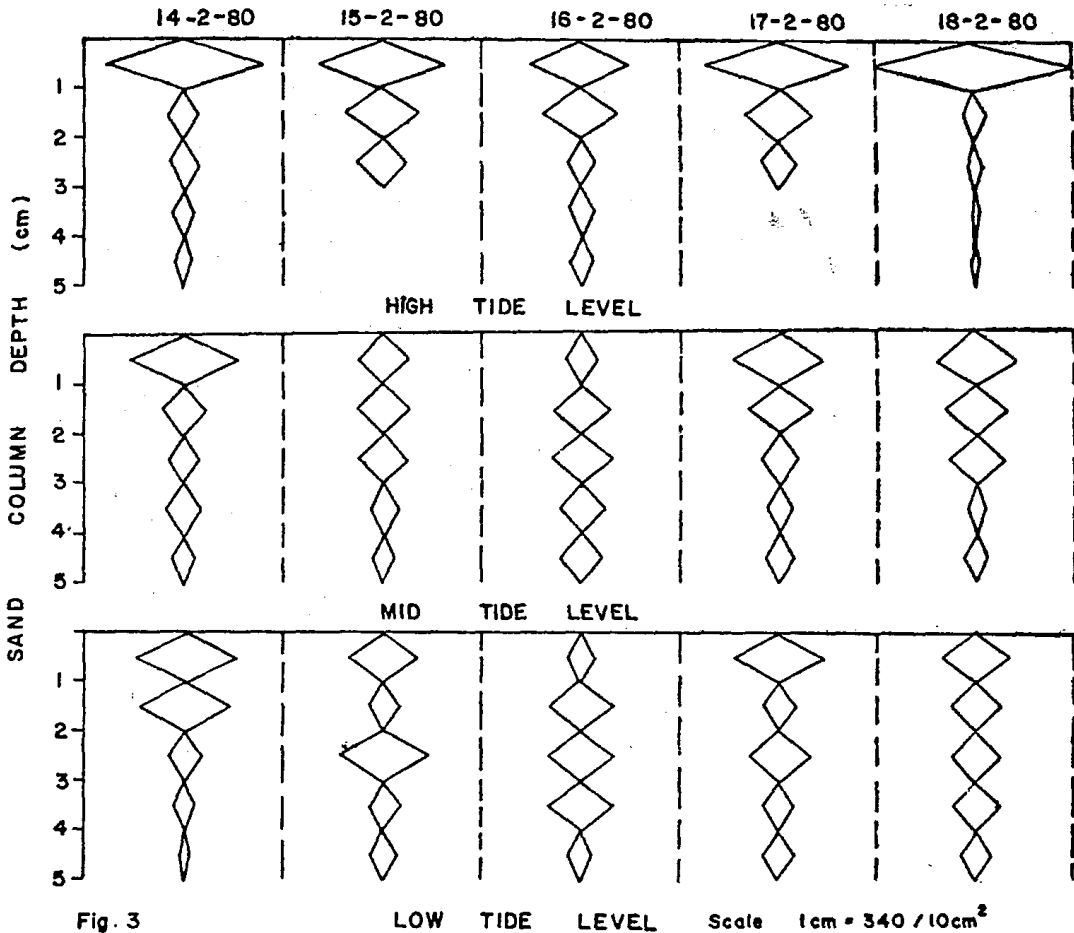


Fig. 3

Fig. 3: Distribution of nematode worms within the sand column at different tide levels and on pre-eclipse, total solar eclipse and post-eclipse days.

#### Changes in the metabolites :

As seen from Fig. 4, the changes in the water content of the body tissues of both the periwinkles and the rock oysters, exhibited a sudden decrease on 16th Feb. 1980 coinciding with the total solar eclipse. The decrease was relatively more pronounced in the periwinkles than in the rock oysters.

Similarly, the carbohydrate content (Fig. 4) in both the species, attained the lowest value on the day of the total solar eclipse. In the rock oyster, the carbohydrate content showed a decrease from the previous day of the eclipse and attained the lowest value on the day of the total eclipse followed by sudden increase on the day after the eclipse. In contrast, the observed changes in the periwinkle, were regular and more or less cyclic, a rise followed by a fall, and hence, in a strict sense may not be a direct consequence of the total solar eclipse.

Earlier studies on the effect of solar eclipse—both partial and total—on marine organisms, in field and under the laboratory conditions, mostly pertain to zooplankton and

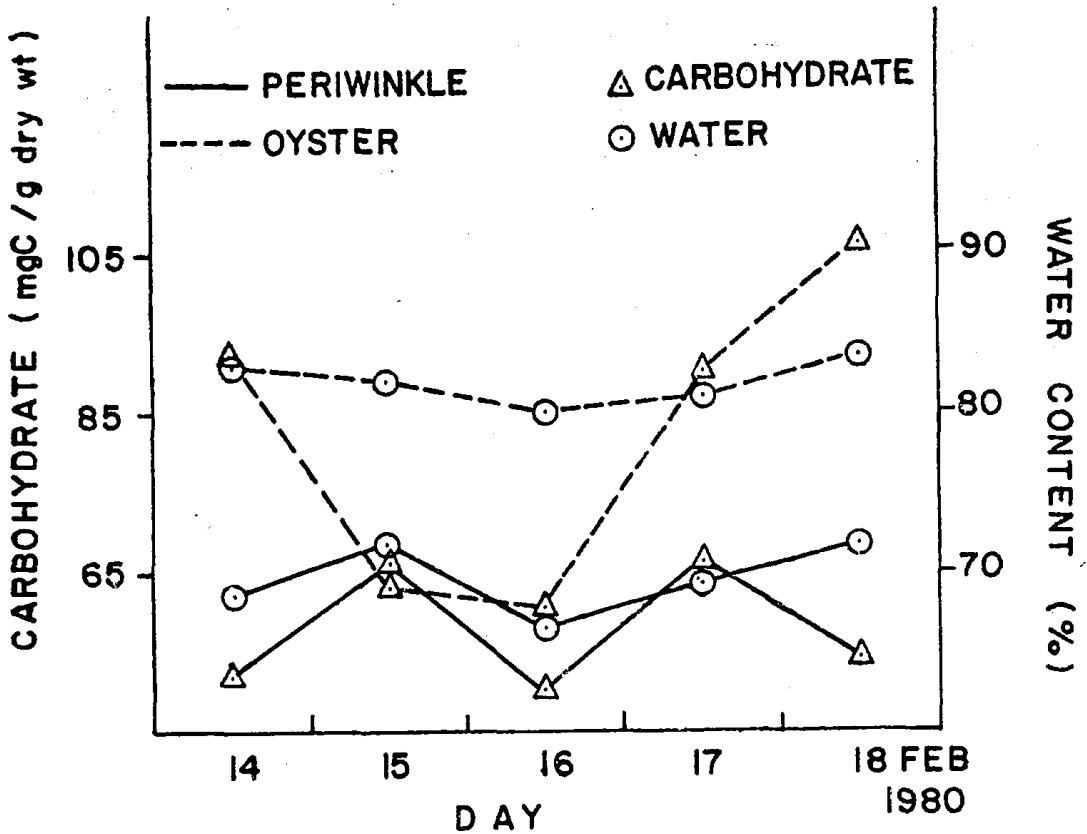


Fig. 4 : Variations in the water content and carbohydrate composition in Periwinkle (*L. intermedia* Phil.) and Rock Oyster (*S. cucullata* Born.) at Dias Beach, Goa, during pre-eclipse, total solar eclipse and post-eclipse days.

nektonic organisms (Wheeler *et al.*, 1935; Mori, 1939; Peptida, 1955; Backus *et al.*, 1965; Skud, 1968; Sherman & Honey, 1970; Goswami & Goswami, 1982). No work on burrowing, sessile and sluggish intertidal benthic animals, is on record.

Skud (1968) made an attempt to compare the results on responses of marine organisms to solar eclipse. However, the validity of such a comparison is far from realistic, because of the wide variations in the duration of totality of eclipse, variations in light and temperature regimes and the fluctuations in the tidal amplitude.

In spite of certain limitations of data, the results obtained in the present study, more than conclusively indicate the magnitude of responses of the intertidal marine animals to the total solar eclipse. However, it is preposterous to infer, whether a response or lack thereof is indicative of an endogenous and/or exogenous rhythm.

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