

Laboratory Experiment to Record Rate of Movement of Cultured Benthic Foraminifera

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ABSTRACT

Sensitivity of foraminifera towards environmental /climatic changes, makes them a distinct proxy of paleoclimatic conditions. In order to use these micro organisms for paleoclimatic reconstruction, their response in the modern marine environment and in culture under laboratory condition, needs to be well studied. Accordingly, recently a laboratory culturing of benthic foraminifera has been initiated. As a continuation of this program, an experiment on cultured foraminifera to study the speed of movement of benthic foraminifera on glass surface of petridish was performed. The first order result of this study has provided initial estimates for rate of movement which varied from 0.034 to 0.139 millimeter/minute. Such laboratory measurements after much refinement, coupled with the field studies may be of use to model bioturbation and sediment dynamics in coastal regions.

INTRODUCTION

Foraminifera (both infaunal and epifaunal) are quite capable to move through the sediment mainly to feed and reproduce and to escape burial in the sediment by storms, currents or bioturbation (Severin and Erskian, 1981 and Severin, 1987). The

movement of these organisms on or through the sediment is important because the organisms change physical and chemical properties of the substratum (Weinberg, 1991), biogenic structures, pre water chemistry (Yingst and Alter, 1982 and, Aller and Aller, 1986), stratigraphy (Mc Cave, 1985) and transport of sediment (Jumars et al., 1981; Grant et al., 1982 and, Rhoads and Boyer, 1982). Foraminiferal movement in and on the sediment is also one of the fundamental question that needs to be answered in order to understand the ecology of foraminifera (Kitazato, 1988).

In view of this , the locomotion of *Elphidium* sp. was first reported by Dujardin (1841) and followed by subsequent investigators, who observed the movement on the glass surface of the petridishes (Arnold, 1953 and, Banner and Williams, 1973) and through sediments (Severin and Erskian, 1981; Severin et al., 1982; Severin, 1987; Kitazato, 1988 and Weinberg, 1991). Although, the laboratory culturing of foraminifera in India is in infancy stage (Nigam et al, 1996 a and b), nevertheless an attempt is made here to understand the movement of living benthic foraminifera and estimate their rate of movement. This study measures the rate of horizontal movement for *Quinqueloculina* sp. on the glass surface of petridish under laboratory conditions.

METHODS OF STUDY

Sediment Collection : Samples (including bottom sediments and seaweeds) containing living foraminifera were collected from the sub tidal regions of Dias Beach (Dona Paula), which is a protected beach in North Goa and is situated at the confluence of the Mandovi and Zuari Estuaries (Fig. 1) flowing

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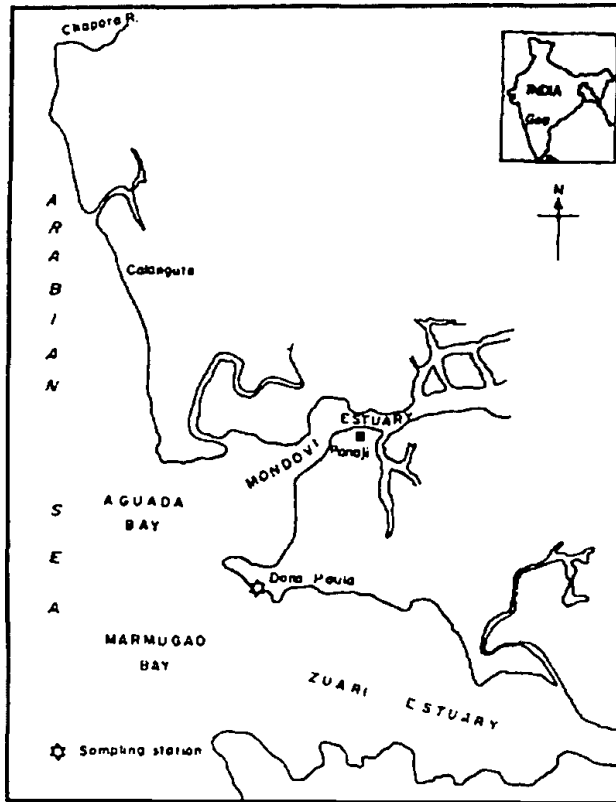


Fig. 1. Sample collection site.

into the Arabian Sea. The tidal amplitude of the study area varies from 2-3 meters. It is protected on either sides by rocky cliffs. A few rocks can be seen in the subtidal regions during low tide. Such protected areas are suitable to obtain living specimen of foraminifera.

After collection, the sample (seaweeds + sea water) was poured in a plastic bucket, with additional seawater. The algae were gently shaken by hand for about 10 minutes and allowed to stand for 15 minutes so that the foraminifera can settle to the bottom. The vegetation and water were replaced by fresh sea water. Filtration was done through different sieves of 850 microns and 63 microns respectively.

The material which passed through 850 microns was gathered over a 63 microns sieve, rinsed 2 to 3 times and whatever remained, was subsequently kept in fresh sea water, (which was filtered using Ashless Whatman Filter Paper No. 42).

Culture : Living specimen of benthic foraminifera

were separated from the field samples under Binocular Microscope, having 20 X eye pieces. Recognition of living specimen was possible by their thin wall test and dark grey to brownish coloured protoplasm. Such living specimens, after repeated rinsing in filtered sea water, were kept individually in wells of the autoclaved Costar culture dish and filled with sea water. Such containers have lot of surface area with respect to volume. The advantage of using small culture dish is to be able to study directly under the Inverted Microscope. In this way, the foraminiferal specimen do not have to be disturbed. While viewing these culture dish under the microscope, one must be careful that the microscope light does not overheat the water and the cover should be removed from time to time to allow aeration. The sea water of the dishes was changed daily. While changing the medium (sea water), care was taken to maintain the salinity by adjusting the loss due to evaporation through addition of distilled water. In addition, some individuals of *Quinqueloculina* were cultured separately in a petridish filled with fresh sea water in order to observe their pseudopodial movements. Specimen used for this purpose were thoroughly cleaned with the help of a soft brush under the microscope.

Observation and Measurement of the Movement:

The behaviour of the benthic foraminifera (*Quinqueloculina*) during movement was noticed through the glass surface of the culture petridish (under which a circular scale was attached) which was covered with another bigger petridish to avoid any external disturbance to the sea water of the petridish. This petridish was put under a Wild Binocular Microscope at magnification using 20 X eyepieces. Before starting the observation, the specimen (*Quinqueloculina* sp.) was gently brought to the centre so that petridish is not shaken. The observations for movement were taken at varying interval (depending on the time specimen took to start movement), though the specimen was continuously under observation during this period. This is done in view of the fact that usually the living specimen, once touched, does not start moving immediately. Three different specimen (A, B and C) of same species were used in this experiment. Details

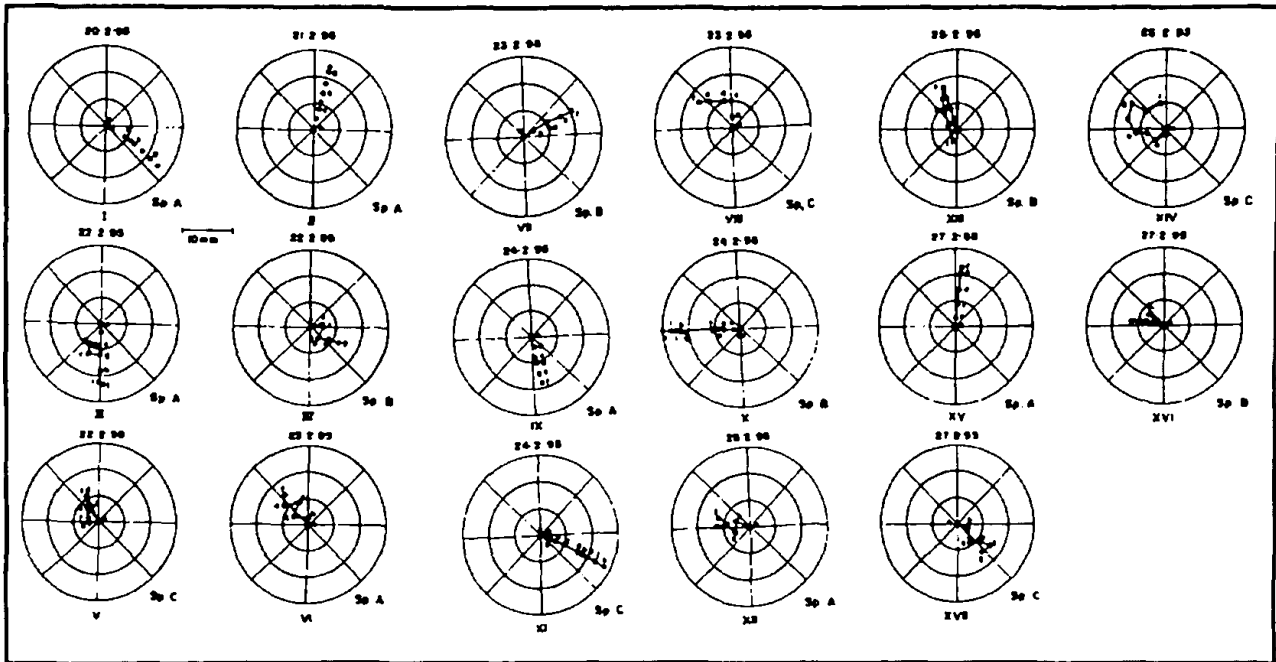


Fig. 2. Path of movement of *Quinqueloculina* measured under microscope using circular scale attached underneath the glass petridish.

are given in Table 1. The moving path of the specimen is recorded and plotted on the same scales [(Fig. 2 (I-XVII))] to know the position of the specimen and also the displacement from the previous position. This step was necessary to calculate total displacement, as foraminifera may move either straight towards the periphery of the culture dish or follow a zig-zag path. The direction of movement is directly related to the apertural position and orientation of the foraminiferal test (Kitazato, 1988). A total of one hundred thirty two observations were made on seventeen specimens. The speed (S) of movement of *Quinqueloculina*- in a given time interval T is calculated using the following formula:

$$S = \frac{\Delta D}{\Delta T} = \frac{P_N - P_{N-1}}{t_N - t_{N-1}}$$

where,

- PN = Position at the time of reading
- PN₋₁ = Position at the time of previous reading
- tN = Time of the reading

tN-1 = Time of previous reading

The average of all such readings is also calculated and plotted graphically (Fig. 3).

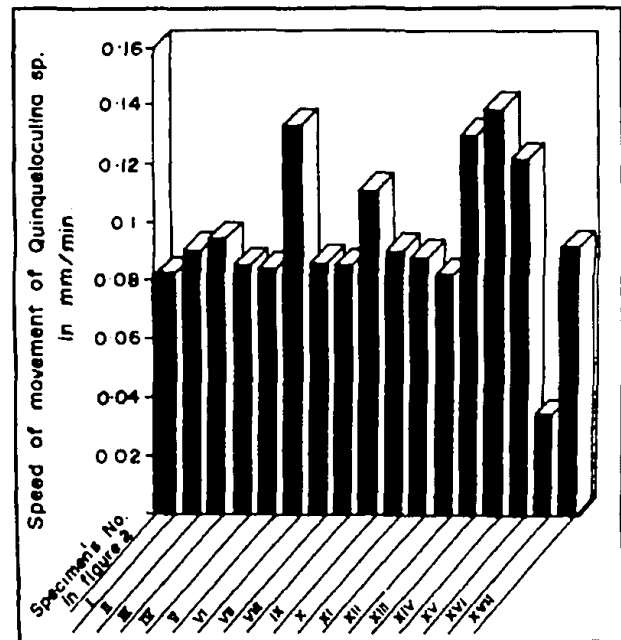


Fig. 3. Bar diagram showing the average rate of movement of *Quinqueloculina*.

Table 1. Showing details of the Experiment for the Rate of Movement of *Quinqueloculina* sp.

Date	Position in Figure	Time	Distance between Nth & N-1 position covered	Speed in time ΔT [tN-(tN-1)] (in mm per min)	Average speed per min) in mm)	Remarks
20.2.95 (Sp.A) Figure I	1.10*					
	a	1.15	0	0.00	0.082	Movement of spec- imen in one dir- ection
	b	1.45	1	0.03		
	c	2.15	3	0.10		
	d	2.30	1	0.067		
	e	2.45	1	0.067		
	f	3.00	2	0.13		
	g	3.15	2	0.13		
h	3.30	2	0.13			
Total No. of observations = 8						
21.2.95 (Sp.A) Figure II	1.10*					
	a	1.30	0	0.00	0.090	Specimen moved straight
	b	2.00	2	0.67		
	c	2.15	2	0.13		
	d	2.30	1	0.067		
	e	2.45	2	0.13		
	f	3.00	2	0.13		
	g	3.15	2	0.13		
h	3.30	1	0.067			
Total No. of observations = 8						
22.2.95 (Sp.A) Figure III	1.15*					
	a	1.20	0	0.00	0.094	Specimen moved initially straight then zig zag.
	b	1.50	1.5	0.05		
	c	2.15	2.5	0.10		
	d	2.30	1	0.067		
	e	2.45	1	0.067		
	f	3.00	2	0.13		
	g	3.15	2	0.13		
	h	3.30	3	0.20		
	i	3.45	2	0.13		
	j	4.00	1	0.067		
Total No. of observations = 10						
22.2.95 (Sp.B) Figure IV	2.55*					
	a	3.00	0	0.00	0.085	Specimen moved in zig zag path.
	b	3.30	2	0.067		
	c	3.45	0.5	0.033		
	d	4.00	2.5	0.167		
	e	4.15	0	0.00		
	f	4.30	2	0.13		
g	4.40	2	0.20			
Total No. of observations = 7						
22.2.95 (Sp.C) Figure V	2.55*					
	a	3.00	0	0.00	0.084	Specimen moved initially straight then reverted
	b	3.30	3	0.10		
	c	3.45	2	0.13		
	d	4.00	0	0.00		
	e	4.15	2	0.13		
	f	4.30	2	0.13		
g	4.40	1	0.10			
Total No. of observations = 7						

Date	Position in Figure	Time	Distance between Nth & N-1 position covered	Speed in time ΔT [tN-(tN-1)] (in mm per min)	Average speed per min in mm)	Remarks
12.05*						
23.2.95 (Sp.A) Figure VI	a	12.10	0	0.00	0.133	Specimen moved in zig zag path.
	b	12.25	1	0.067		
	c	12.40	3	0.2		
	d	12.55	3	0.2		
	e	1.10	3	0.2		
	f	1.25	2	0.133		
Total No. of observations = 6						
..						
1.15*						
23.2.95 (Sp.B) Figure VII	a	1.20	0	0.00	0.086	Specimen moved straight
	b	1.50	2	0.067		
	c	2.15	3	0.12		
	d	2.30	0	0.00		
	e	2.45	3	0.20		
	f	3.00	2	0.13		
Total No. of observations = 6						
1.15*						
23.2.95 (Sp.C) Figure VIII	a	1.20	0	0.00	0.085	Specimen moved vertically and then horizontally.
	b	1.50	2	0.067		
	c	2.15	1	0.04		
	d	2.30	1	0.067		
	e	2.45	2	0.133		
	f	3.00	3	0.2		
Total No. of observations = 6						
9.45*						
24.2.95 (Sp.A) Figure IX	a	9.50	0	0.00	0.111	Specimen moved straight
	b	10.00	2	0.2		
	c	10.15	2	0.133		
	d	10.30	1	0.097		
	e	10.45	2	0.133		
	f	11.00	2	0.133		
Total No. of observations = 6						
9.45*						
24.2.95 (Sp.B) Figure X	a	9.50	0	0.00	0.090	Specimen moved horizontally.
	b	10.00	0	0.00		
	c	10.15	1	0.067		
	d	10.30	2	0.13		
	e	10.45	1	0.067		
	f	11.00	1	0.067		
	g	11.15	5	0.33		
	h	11.30	1	0.067		
	i	11.45	1	0.067		
	j	12.00	1	0.067		
	k	12.15	2	0.13		
Total No. of observations = 11						

Date	Position in Figure	Time	Distance between Nth & N-1 position covered	Speed in time ΔT [tN-(tN-1)] (in mm per min)	Average speed per min (in mm)	Remarks
24.2.95 (Sp.C) Figure XI	9.45*					
	a	9.50	0	0.00	0.088	Specimen moved in straight line.
	b	10.00	1	0.10		
	c	10.15	0	0.00		
	d	10.30	1	0.067		
	e	10.45	1	0.067		
	f	11.00	2	0.133		
	g	11.15	3	0.20		
	h	11.30	1	0.067		
	i	11.45	1	0.067		
	j	12.00	2	0.13		
k	12.15	2	0.13			
Total No. of observations - 11						
25.2.95 (Sp.A) Figure XII	1.25*				0.082	Specimen moved in zig zag path.
	a	1.30	0	0.00		
	b	2.0	3	0.10		
	c	2.15	2	0.13		
	d	2.30	2	0.13		
	e	2.45	0	0.00		
f	3.00	2	0.13			
Total No. of observations = 6						
25.2.95 (Sp.B) Figure XIII	9.25*				0.13	Specimen moved in straight line and then reverted
	a	9.30	0	0.00		
	b	9.45	2	0.13		
	c	10.00	2	0.13		
	d	10.15	2	0.13		
	e	10.30	2	0.13		
	f	10.45	2	0.13		
	g	11.00	2	0.13		
	h	11.15	3	0.20		
i	11.30	3	0.20			
Total No. of observations = 9						
25.2.95 (Sp.C) Figure XIV	9.25*				0.139	Specimen moved in zig zag path
	a	9.30	0	0.00		
	b	9.45	1	0.067		
	c	10.00	2	0.13		
	d	10.15	2	0.13		
	e	10.30	2	0.13		
	f	10.45	3	0.20		
	g	11.00	3	0.20		
	h	11.15	3	0.20		
i	11.30	3	0.20			
Total No. of observations = 9						
27.2.95 (Sp. A) Figure XV	9.40*				0.122	Specimen moved in straight line.
	a	9.45	0	0.00		
	b	10.00	1.5	0.10		
	c	10.15	2.5	0.167		
	d	10.30	3	0.2		
	e	10.45	3	0.2		
f	11.00	1	0.067			
Total No. of observations = 6						

Date	Position in Figure	Time	Distance between Nth & N-1 position covered	Speed in time ΔT [tN-(tN-I)] (in mm per min)	Average speed per min in mm)	Remarks
27.2.95 (Sp.B) Figure XVI	12.25*					
	a	12.30	0	0.00	0.034	Specimen moved in straight direction- but movement was slow sea water was completely changed.
	b	12.45	1	0.067		
	c	1.00	1	0.067		
	d	1.15	1	0.067		
	e	1.30	0	0.00		
	f	1.45	0	0.00		
	g	1.50	1	0.067		
h	2.00	0	0.00			
Total No. of observations = 8						
27.2.95 (Sp.C) Figure XVII	12.25*					
	a	12.30	0	0.00	0.092	Specimen moved in zig-zag path.
	b	12.45	2	0.13		
	c	1.00	2	0.13		
	d	1.15	1	0.067		
	e	1.30	2	0.13		
	f	1.45	2	0.13		
	g	1.50	2	0.13		
h	2.00	0	0.00			
Total No. of observations = 8						
* Starting Time (In A.M. and P.M); Total Specimen used = 17 ; Total observations made = 132						

RESULTS

In the experiment to study the rate of movement of benthic foraminifera, different stages in locomotion were noted. It was observed that for a few minutes, the specimen was horizontally lying on the petridish and after sometimes single strand of pseudopodia came out through aperture elongated and branched out then the specimen lifted up its test and assumed a vertical position.

Usually, they moved in straight line but, occasionally deviated from their path. Initially, the movement was relatively slower, but after stabilization, the movement started faster. The minimum speed was recorded 0.034 mm/min whereas, the maximum speed was 0.139mm/min (Table 1).

The horizontal movement of *Quinqueloculina* sp. is exhibited in Fig. 2 (I-XVII).

DISCUSSION

Boltovskoy and Wright (1976; table 1) provided the velocity for various species with which foraminifera can transport themselves.

Similarly, Kitazato (1988) measured the velocity of twenty two benthic foraminifera species from coastal (5-100m) Japan, Wetmore (1988) measured rates in twenty four species from coastal (0-10m) Florida at around 14-24 C. Based on earlier work on the locomotion of foraminifera, it is clear that the velocity of foraminiferal movement is distinct in different species but the variations are not extreme. This study demonstrates that certain foraminifera from the shallow coastal regions can be studied in the laboratory with minimal care for studying their speed. Such laboratory studies of living individual and their movement might provide more accurate information on position and activities of foraminifera in the sediment. Often several factors were held

responsible to affect subsurface foraminiferal distribution in the field. To replicate in situ environmental pressure conditions (Mac Donald and Gilchrist, 1980) in the laboratory, sophisticated equipments are needed.

Although, from the available first order data of the speed of *Quinqueloculina*, it is difficult to determine the extent to which rate of velocity here were affected by potential laboratory effects such as, reduced pressure, use of only sea water and maintaining room temperature. In addition to these, the organism may have been stressed in the laboratory. Nevertheless, these speeds which ranged from 0.034 to 0.139 mm/min (average = 0.096 mm/min) look interesting in view of the results obtained by Kitazato (1988) and Wetmore (1988) who reported that for average species, specific rate of locomotion per individual ranged from 11 to 118 mm/day and from 12 to 188 mm/day respectively, although the methods and the interval of observations were different. However, since, these studies were carried out in sediments, the average velocity of benthic foraminifera in/on sediment is slower than the average speed on the glass surface of the petridish, calculated in the present study.

This could be attributed to the fact that glass and surrounding water offer less resistance to movement than sediment. It is also possible that species in the petridish move fast to avoid such a strange environment, as the glass surface (Kitazato, 1988). The present findings are supported by the results of earlier experiments carried out on *Cassidulina nabeaensis*, *Fissurina* sp. and *Q. lamarckiana*, which moved slower on coarse sand-silt at the average velocity of 62.3 μ m/min (on glass surface 255 μ m/min), 47.0 μ m/min (on glass surface 88 μ m/min) and 42.8 μ m/min (on glass surface 235.5 μ m/min) respectively (Kitazato, 1988, table 2).

CONCLUSION

The present study highlights the feasibility of such attempts and provides initial estimates for

rate of movement. Such laboratory measurements coupled with field studies may be of use to model bioturbation and sediment dynamics in coastal regions.

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