

THE RELATIVE SENSITIVITY OF BENTHONIC FORAMINIFERA IN THE POLLUTED MARINE ENVIRONMENT OF COLA BAY, GOA

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Abstract

Quantitative faunal data when compared with the time integrated data of the most recent top layer of the bottom sediment presents an estimation of the degree of pollution in a region where industrial effluents are discharged. The environmental stress gradient thus caused by the dispersion of the pollutants measures the relative sensitivity of tolerance of the benthonic foraminifera hence they are treated as the best indicator species of pollution. The foraminiferal gradient in the bay indicates high foraminiferal productivity with large sized, mostly megalospheric, robust, many-chambered *Ammonia*, with *Elphidium* sp., *Florilus boeum*, *F. scaphus* followed by miliolids in the littoral zone, and smaller sized *Nonionella* sp., *Fursenkoina pontoni*, *Bulimina marginata* and *Brizalina striatula* and others being dominant in the distal zones. This property of certain species restricting themselves to the least affected zone is suggestive of their response to the effect of effluents and thus being absent near the outfall area.

The total foraminiferal number (TFN) and the total species number (TSN) represent the abundance and the index of diversity besides spatial heterogeneity. The organic carbon content in the sediment is inversely proportional to the abundance of the benthonic populations. Living foraminifera are very useful in establishing zones of effects of pollutants in a region.

Correlation coefficient between TFN and TSN on the one hand and between TFN with the nature of the substrate in relation to the radial distance from the mouth of the discharge point on the other, appears to be very erratic. The relative sensitivity of the benthonics nearer the outfall area is more positive than could have been expected otherwise.

Introduction

In an earlier publication, Setty and Narayanan (1976, in Press) recorded the distribution pattern (in terms of abundance) of the various benthonic foraminifera in the modified marine environment of Cola Bay, Goa, where the industrial effluents of a fertiliser factory are discharged. The present paper, while noting the dispersal of waste discharge, its dispersion and dilution in the surrounding

waters defines the environmental stress gradients that caused, and distributed the foraminiferal populations into different zones from the intertidal to offshore areas. These gradients are used to measure the relative sensitivity of tolerance of the foraminiferal populations of the affected region. So, a comparison of the quantitative faunal data with the time-integrated data of the most recent top layer of the bottom sediments of the area therefore permits, to a very great extent, a clear estimation of the degree of pollution.

The foraminiferal density in the nearshore zone usually reflects the shallow depths of the area and also its local population variation which is again controlled by productivity, local biomass quality and other physical and chemical parameters like the temperature, salinity, Eh, pH nutrients and of late, the influence of man as a source of pollution of the environment. Sometimes, this pollution factor creates an abiotic zone at the site of pollutant discharge and its immediate vicinity as in Chaleur Bay (Schaefer, 1974) but on the other hand, it has not been so in Cola Bay. The benthonic foraminifera, among other organisms of the substrate are sensitive to the environmental stresses and hence become the best indicator species of pollution. Thus they are important in the final assessment of the effects of population.

Physical Setting of the (Polluted) Substrate

The effluents are discharged by M/s. Zuari Agro-Chemicals Ltd., (a fertiliser factory) directly into the Cola Bay through a pipeline just at the junction of low water mark on the beach. The pollutants are mostly composed of fertiliser byproducts like ammonia and arsenic, besides sewage and other wastes of the surrounding. It is learnt that arsenic was used in the manufacture of urea. At a certain time, this industrial discharge was considered to be the cause of a large scale mortality of the fish and therefore, the dispersal of the dead fish on the shore aggravated into a widespread agitation by the local people. In order to prevent this as a recurring phenomenon and to shift the discharge point away from the shore so that the natural dispersal and dilution process is enhanced, by the longshore currents or pipeline survey was undertaken in 1975 by the National Institute of Oceanography (CSIR).

The substrate of the Cola Bay region is carpeted by a sandy apron all around the shore which is followed by clay with a patch of silt at a depth of 9.5 km (Siddiquie *et al.* 1975) (Fig. 2). Grab samples were collected for this study from stations close to the effluent pipeline and also from other stations of the bay (Fig. 1). The top 1 cm layer was separated from the samples and dyed with rose bengal to get the living/dead ratio of foraminifera following a technique by Walton (1952).

A bathymetric profile of the bay indicates that a small channel is present near the effluent discharge point, which gradually widens towards the open sea. The

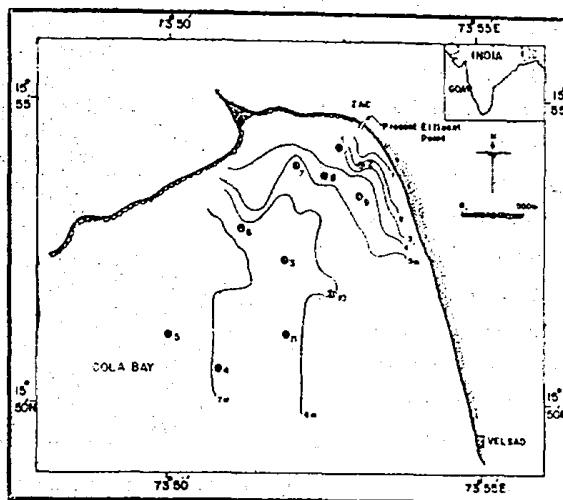


Fig. 1—Bathymetry and sample locations (1-11).

tidal waters comprising of heavier open sea saline waters move much rapidly through this channel towards the shore (Fig. 3). As a result, it creates a local

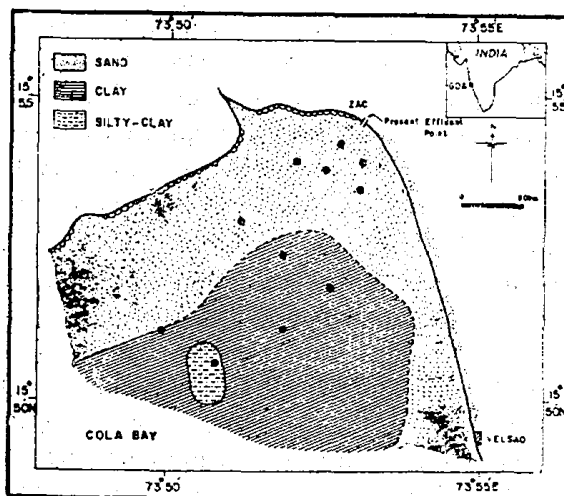


Fig. 2—Sediment distribution pattern in Cola Bay (after Siddiquie *et al.*, 1975).

mixing with the effluent discharge at its mouth and thus accelerates the dilution process creating a sort of 'upwelling' in the region. The current pattern studied indicates that the velocity of the currents is higher and oscillatory at the subsurface level in the channel region and at the head of the bay while it is directed away from the bay at a distance from the shore (Kurup, 1976, in Press). This is near stn. no. 4. This helps in the better dispersal material and rapid transport of the pollutants in the direction of the open sea. Therefore, the discharge point is proposed to be located near stn. no. 4 (a distance of 2 km from the shore).

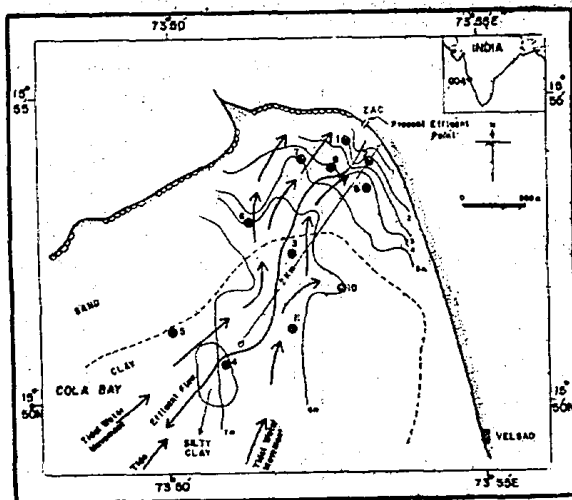


Fig: 3—Transport mechanism of effluents in the channel and tidal effects.

Foraminiferal Gradient

Table I lists the several foraminiferal species that are encountered in the study area. Out of the 25 species identified from the topmost surface of the substrate, only 12 of them are known to be living at the time of collection. It is interesting to note that out of five species of *Ammonia* recorded only two (i.e., *Ammonia beccarii* var. *dentata* and *A. beccarii* var. *tepida*) are the sole living representatives. Most of these *ammonia* are megalospheric, somewhat high spired; some showing a large number of chambers in each whorl but more particularly so in the last whorl; some of the last whorls either bent, crooked or curved and some others being dotted with several drill cavities. In this way, they appear to be sensitive to the abnormal environment. Most of these populations are very hardy, robust, and thick-walled and submit a quantitative evaluation of changes. Next in dominance are *Elphidium* sp. which is followed by *Florilus boeum*, *F. scaphus* and the miliolids.

Large, robust and thick-shelled *ammonias* are very common in the intertidal beach areas whereas smaller specimens and particularly *Ammonia tepida* and *A. parkinsoniana* are common in the offshore; *Elphidium crispum* is more common in the beach sediment while *E. poyeanum* is in the offshore. Next in abundance is *Florilus boueum* which is present both in the beach and the offshore while *F. scaphus* is generally found in the

offshore only. Similarly, *Eponides repandus*, *Brizalina striatula*, *B. pseudoplicata*, *B. vaghani*, *Bulimina marginata*, *Nonionella* sp., *Cibicides pseudoungarianus*, *Fursenkoina pontoni*, *Gavelinopsis complanata*, *Rosalina* sp. and *Neoconorbina* sp. are mostly distal areas from the shore. Next in abundance are the Miliolids of which the characteristic ones, in their order of abundance are *Spiroloculina excavata*, *S. exima*, *Triloculina trigonula*, *T. tricarinata*, *Quinqueloculina bicostata*, and *Q. seminulum*. All these are found both in the intertidal and offshore environment. Robust and adult specimens of *Calcarina calcar* are common in the beach sediments whereas its juveniles are common in the offshore regions.

This clearly indicates spatial heterogeneity of foraminifera. Further, the low / high incidence of foraminifera in the littoral / nearshore shallow areas represents the basic environmental conditions that are responsible for the impoverishment of certain species in one region and the enrichment of others in an other region. The total foraminiferal number (TFN) is highest at stn. nos. 2 and 9 followed by 8 and 3; and 1 and 7 (Fig. 4). However, the total species number (TSN) is somewhat different though it is expected to have a similar distribution pattern. TSN is highest at stn. no. 10 which is followed by stn. nos. 1 and 7, 8, 3, 6, 11 and 4 (fig. 5). Thus TSN appears to be higher than the TFN. This shows that the quantitative evaluation of changes in abundance is not in agreement with the changes in species diversity. The high diversity of species nearer to the outfall area indicates that some components of the effluents encourage the growth of a larger number of species. It is well known that ammonia (NH_3), after discharge into the marine

TABLE I
Foraminiferal species in the Cola Bay

LIVING	FORAMINIFERAL SPECIES
—	<i>Ammonio parkinsoniana</i>
—	<i>A. tepida</i>
—	<i>A. dentata</i>
—	<i>A. Sp. 'A'</i>
—	<i>A. Sp. B</i>
—	<i>Bulimina marginata</i>
—	<i>Brizalina striatula</i>
—	<i>Cancris oblonga</i>
—	<i>Calcarina calcar</i>
—	<i>Elphidium crispum</i>
—	<i>Eggerella advena</i>
—	<i>Florilus grateloupi</i>
—	<i>F. boeunam</i>
—	<i>F. scaphus</i>
—	<i>Fursenkoina pontoni</i>
—	<i>Haplophragmoides</i> sp.
—	<i>Lagena</i> sp.
—	<i>Miliolina circularis</i>
—	<i>Nonion tuberculatum</i>
—	<i>Nonionella</i> sp.
—	<i>Pararotalia</i> sp.
—	<i>Quinqueloculina seminulum</i>
—	<i>Q. venusta</i>
—	<i>Spiroloculina exima</i>
—	<i>Trochammina</i> sp.

environment breaks down into nitrates and nitrites, which, as nutrients, accelerate the growth of phytoplankton in the surface waters, which, in turn, encourages the productivity. Thus a foraminiferal abundance is resulted.

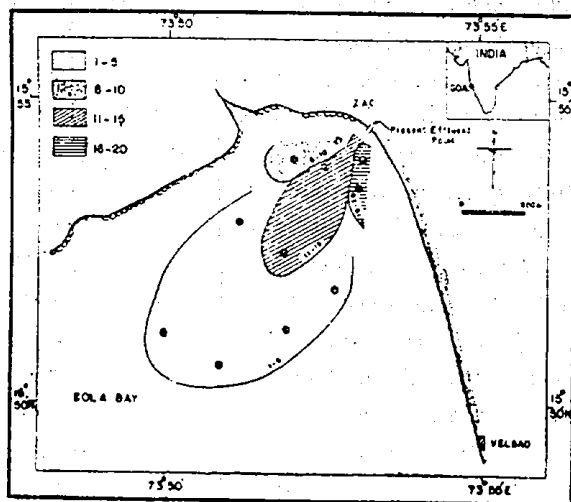


Fig. 4—Distribution pattern of total foraminiferal number (TFN).

Correlation Coefficient

(1) The TFN and TSN show an increase towards the inshore direction with respect to the discharge point, which points out to a local increase in the rate of production. This is suggested by the high TFN values at stn. nos. 2, 9, 3, 8 and 1; and

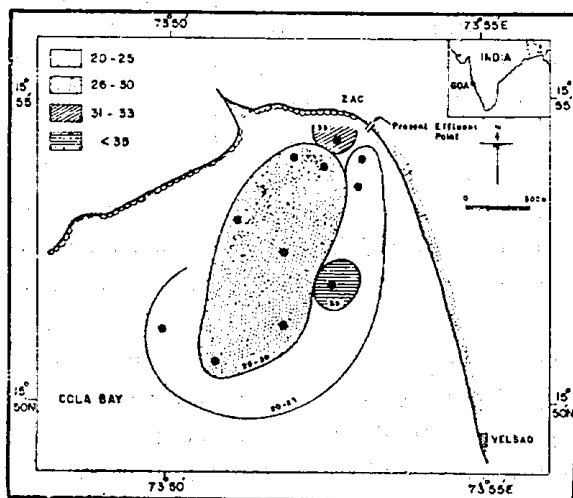


Fig. 5—Distribution pattern of total species number (TSN).

also high TSN values at stn. nos. 1, 2, 9, 7, 8, 3, 6, 11 and 4 (Fig. 6). Though TFN and TSN are correlatable, the TFN is not in full agreement with TSN as could be expected in stn. nos. 1, 2, 9 and 11.

(2) Contrary to the high frequency of TFN and TSN values in the near-shore bay and close to the effluent pipeline location, the organic carbon values are very low at stn. nos. 1, 9 and 11. It is high to very high in regions away from the outfall area as in stn. nos. 6, 3, 10 and 5 (Fig. 7). With an increase in organic carbon values the TFN decreases, but it is highest in the adjoining transition zone. This suggests that organic carbon in a sediment is directly proportional with the diversity and abundance of the foraminiferal populations.

(3) Correlation between TFN and TSN with the substrate (sand, silt, and clay) and pH, and water depth is not quite meaningful since the changes are not parallel in all directions and also do not correspond well with one another. This implies that the environmental variable in distal areas are scattered resulting in low population densities.

(4) In some regions like the Restigouche estuary, Canada, (Schaefer, 1975), as in Cola Bay, Goa, the foraminifera do inhabit the substrate nearer to the outfall point, but it is an abiotic zone at a similar location in the Chaleur Bay (Schaefer, 1973). Therefore, if the population density is not controlled in terms of effluents, substrate,

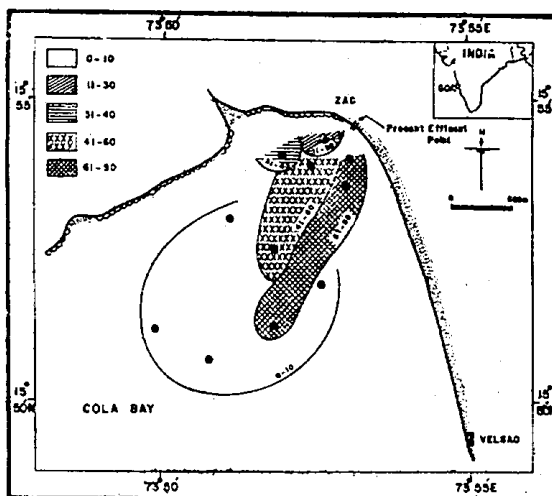


Fig. 6—TFN and TSN pattern to show the effects of effluents on the surrounding substrate.

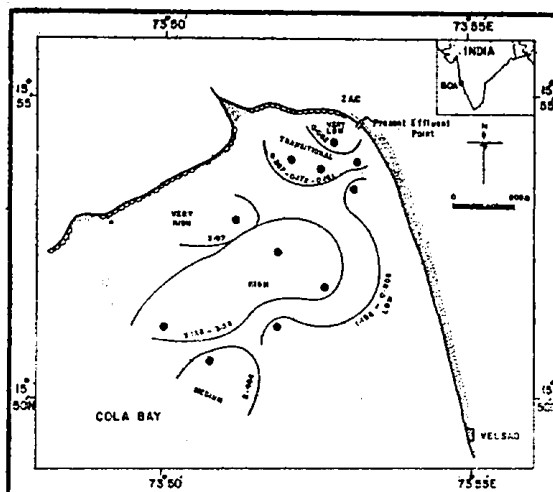


Fig. 7—Distribution pattern of organic carbon content in the sediments of Cola Bay.

tidal turbulence, and organic matter, it can not be correlated. However, it must be noted that the population distribution in such shallow areas as Cola Bay seems to be controlled partially by displacement or reworking of the fauna.

(5) Among the living foraminifera it is possible to establish zones that show effects of effluents on the substrate using the living foraminiferal number (LFN) and living species number (LSN).

Relative Sensitivity

Schaefer (1973) reported that in Chaleur Bay, certain species tend to dominate the biota near an effluent source regardless of the nature of the effluents being discharged. In Cola Bay, at the proximal zone of the outfall point, larger sized specimens of *Ammonia dentata*, *A. tepida*, *Elphidium poeyanum*, *Florilus scaphus*, *Quinqueloculina seminulum*, and *Spiroloculina excavata* dominate the substrate.

Ammonia sp. and its variants decrease in relative abundance, form, size, number of chambers etc. with distance from the mouth of the effluent point. This variation is indicative of a direct effect of the waste discharge in creating a hypertrophic condition which boosts the growth and development of this species (Bock, personal communication, 1976). This observation is applicable to the associated fauna also. However, Sieglie (1974) from his studies in the Caribbean, reports that *Ammonia* populations are negatively affected by pollution, and he further points out that larger foraminiferal populations are related to the dilution of pollutants.

A few other foraminifera like *Fursenkoina pontoni*, *Bulimina marginata*, *Brizalina striatula*, *Gavelinopsis complanata*, *Rosalina* sp., and *Nonionella* sp., are dispersed in the distal region which suggests that they show inhibitions in growth, and represent a very low tolerance level in being absent near the outfall region. This is indicative of a qualitative reliability of certain species representing an ecological shift in the given environment. Does this mean an adverse impact of the environment on the species? However, it may be said, that these species are indicative of environmental stress by way of pollution in the region. Sieglie (1974) considers that an abundance of *Fursenkoina pontoni* is related to pollution.

The sensitivity of foraminifera to pollution is viewed from the abundance trend of the populations, distribution pattern of species present, and the living/dead ratio of species in the substrate.

Planktonic foraminifera are unusually absent in this study area. However, Bandy (1964) had suggested that these tend to be abundant in the waters surrounding the outfall area.

Nonionella sp. particularly decreases towards the outfall area but found only in the central and distal areas as seen in the Orange county outfall region (Bandy, *et al.* 1965).

The species diversity index or TSN which is expected to diminish near the discharge area here shows a greater diversity as also seen in Port Mahon, Isla de Manorca (Mateu, 1974).

While the TSN is higher near the outfall area with the decrease in organic carbon, the TFN is lower with the increase in organic carbon content of the sediment. This indicates that instead of creating abiotic conditions near the discharge point, biological productivity has increased.

Thus, some indicator species assist in mapping the biotopes, gross parameters of the foraminiferal populations, their density and diversity.

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