RESEARCH ARTICLE

Application of benthic foraminifera to determine ecological status of Panvel Creek and adjoining River Estuaries

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ABSTRACT

Foraminifera, the amoeboid protists, occupy a unique place in the coastal marine ecosystems. These single celled, organisms exist as benthic, planktonic and rarely as terrestrial forms. Their ooze persists in the sediments over prolonged periods. The study of fossil foraminifera is an integral part of paleoceonography, paleoclimology, biostratigraphy. The analysis of foraminifera from sediments and/earth's crusts is routinely done for oil prospecting. The use of foraminifera as bioindicators of coastal environment has also become common.

The comprehensive ecological status was carried out over three years from 2008 to 2010 as a part of EIA project for the proposed site of the International Airport. The study was continued over the subsequent years till 2015. Only a part of the data has been used for this report.

The sediment samples collected from 14 stations across Panvel Creek, Gadhi River estuary and Ulwe River estuary were analyzed for physic-chemical parameters and for qualitative as well as quantitative analysis of macrobenthic fauna. Of the modern (living) forams, those belonging to the family Hauerinidae (6 species) and family Rotaliidae were predominant. It was also noticed that the density of foraminifera was maximum in premonsoon, moderate in monsoon and minimum in post-monsoon season. Moreover, the anthropogenic activities have been taking toll on them and the diversity as well as density was found decrease over last 8 years. The construction of the proposed International airport has not started yet and in coming few years as the development intensifies the ecosystem is bound to degrade further. The diversity and density of foraminirerans can be used as bioindicators in following the degradation of the creek ecosystem and the success of the mitigations efforts, if any, undertaken against this degradation.

Key words: foraminirera, sediments, Panvel Creek, Gadhi River estuary, Ulwe river estuary, bioindicator

INTRODUCTION

The pace of development in India has perceivably increased over the past few decades. The key role in the development is played by the infrastruc-

-tural facilities like roads, airports and sea-ports. There had been a proposal by the City and Industrial Development Corporation (CIDCO) to construct a new Navi-Mumbai International airport (NMIA), close to Panvel. The NMIA was proposed to cover more than 1600 ha of land, most of which is in possession of the Government. However, a major part of it lies in CRZ area, considered to be an ecosensitive region, figure 1. CIDCO entrusted the EIA studies of the project to the Centre for Environment Studies and Engineering, IIT Mumbai. The author shouldered the responsibility of evaluating the comprehensive ecological status of the region that included Panvel Creek and the adjoining Gadhi River Estuary and Ulwe River Estuary. The report was prepared and submitted to CIDCO in the later months of 2010. The construction of NMIA was to begin immediately after the clearance from MoEF and it was targeted to be commissioned in 2013. Unfortunately there were controversies over certain aspects causing a delay. It was felt that a monitoring of the Brackish water ecosystems to understand how it would get altered during the construction and commissioning of NMIA, so that the study was continued through the subsequent years.

Panvel Creek is named after the city that is spread along its banks. The creek is about 7 km long and connects to Thane Creek. It passes through Taloja, Panvel and Ulwe before meeting the sea at Belapur as seen in figure 2. The creek once used to support pearl fishery along its sandy beaches and was historically the focal point of trade and commerce with Persia. In the recent decades it has been known for the extensive dredging for the commercially significant black sand. It has come into ecologist's attention because of (i) the location in CRZ area, (ii) the need to cut two hills in the area, (iii) the need to reclaim marshlands, thus destroying mangroves over 161 ha and (iv) the need to alter the course of Gadhi slightly and filling of major portion of Ulwe River. The Rivers, particularly, Gadhi River, support a fair biodiversity, though the creek has already been stressed and loosing considerable extent of its biodiversity. Among the other components of the biodiversity, it was rather easy to access the diversity of foraminifera and accordingly has been the focal area of the current report.

Extensive surveys, particularly addressing the history of work on foraminifera have been published by Nigam and Khare (1995), Emmanuelle and Scott (2003), Murray (2003) and Bhalla *et al.* (2007). Ecology of estuaries and the role of foraminifera in the coastal communities has been studied world over (Tietjen, 1969; Scott and Medioli, 1980; Kaladhar *et al.*, 1990; Jayarajan and Reddy, 1995 and 1996; Levy *et al.*, 1993 and 1996; Rajeshwar Rao, 1998; Chaturvedi *et al.*, 2000; Khare and Nigam, 2000; Kamleswara Rao and Srinath, 2002; Emmanuel and Scot, 2003; Nigam, 2005; Woodroffe *et al.* 2005; Bhalla *et ai.* 2007; Rajeshwar Rao *et al.,* 2010 and Gandhi *et al.* 2013). The distribution of species of foraminifera (Kumar *et al.*, 1996; Kathal *et al.* 2000; Nigam *et al.* 2000; Sinha *et al.,* 2000; Gandhi *et al.* 2002; Mazumdar *et al.* 2003) and their taxonomy/ phylogeny (Loeblich and Tappan, 1988; Vergara *et al.* 1997; Murray, 2003; Pawlowski *et al.,* 2013) has also been studied extensively. The uses of foraminiferal microfossils in prospecting for oil, (Boardman,*et al.*,1987; Jones, 1996), paleoclimology and paleoceanography (Zachos *et al.*, 2001) and as bioindicators (Naidu *et al.,* 1984; Yanko *et al.,* 1999) have been reported. The current report is exploring the possibility of using the diversity and abundance of modern benthic foraminifera to indicate the ecological status of the coastal wetlands.

MATERIALS AND METHODS

A total of 21collection stations were established along the course of Panvel Creek and the Gadhi as well as Ulwe River Estuaries connected to it. These stations were visited using a mechanized boat on the 8th lunar day, during high tide in the peak pre-monsoon, monsoon and post-monsoon seasons. The parameters like depth, temperature, turbidity, TSS, TDS, DO, concentration of nutrients, etc. were recorded at each station. The sediment samples were collected using Petersen's grab. These samples were immediately divided into two parts, from which one part was stained using Rose Bengal and formalin, (Teitjen, 1969) for the study of meso- and macro-benthos. On pre-weighed glass slides, the sediment samples were smeared and these were weighed again so as to determine the weight of sediments. The slides were eventually examined under the compound light microscope to record the species of foraminifera and also the total number of foraminifera per gram of fresh sediments. The other part was further divided in to two portions, one was air dried in the laboratory for analysis of texture, organic carbon as well as nutrient contents and the remaining was analyzed for determining moisture content, water holding capacity

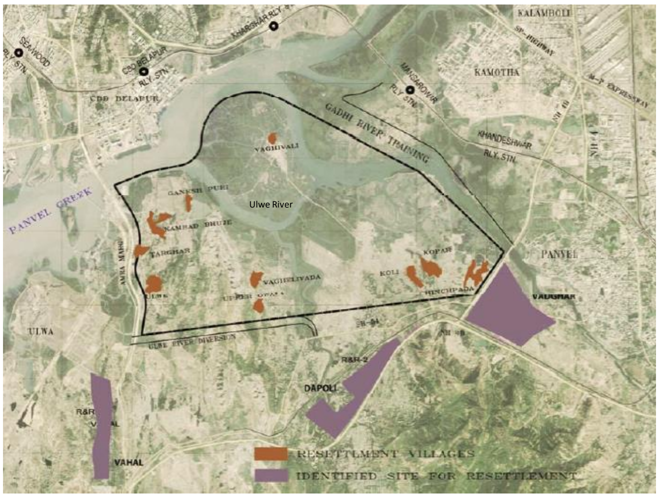

Fig. 1: The proposed site of the Navi Mumbai International Airport (NMIA)

Fig. 2: Satellite image showing Panvel Creek (source- Google maps)

pH, and inorganic nutrients, using standard methods described by APHA (1981) Trivedi and Goel, (1986) and Loring and Rantala (1992). The organic carbon contents were analyzed from the oven dried samples (at 70^{0}C) using Walkley and Black rapid titration method (Trivedi *et al.*, 1987). The texture was studied using The species of benthic, modern, living, foraminifera encountered throughout the seasons were recorded and so was their number per gram of wet, fresh sediments. The records of the successive years from 2008 to 2015 have been considered in the present analysis.

RESULTS AND DISCUSSION

The results pertaining to the studies as described above have been displayed in tables numbered 1 and 2 while the figures 3 and 4 have been given as the support to classification of foraminiferal specimens. The orders Hauerinidae and Rotaliidae are equally represented by the species. Though the data on abundance of individual species has not been presented here, the *Ammonia beccarii* and *Ammonia tepida* of Rotaliidae have been most abundant. Also, it is worth to mention that the total number of foraminiferal species has been maximum in pre-monsoon, moderate in monsoon and minimum in post-monsoon season in all subsequent years.

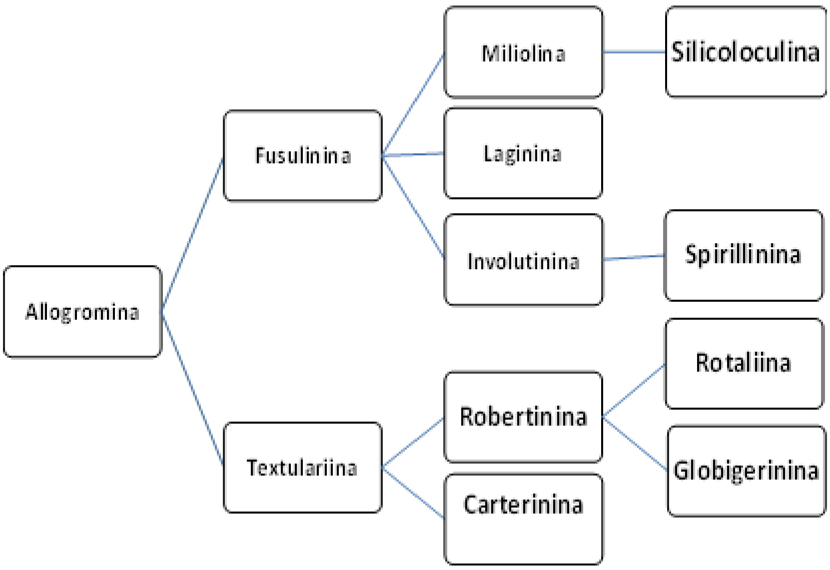

Fig. 3: Foraminiferal Suborders as described by Loeblich and Tappans, 1988. Of these suborders, only Fusulinina are extinct.

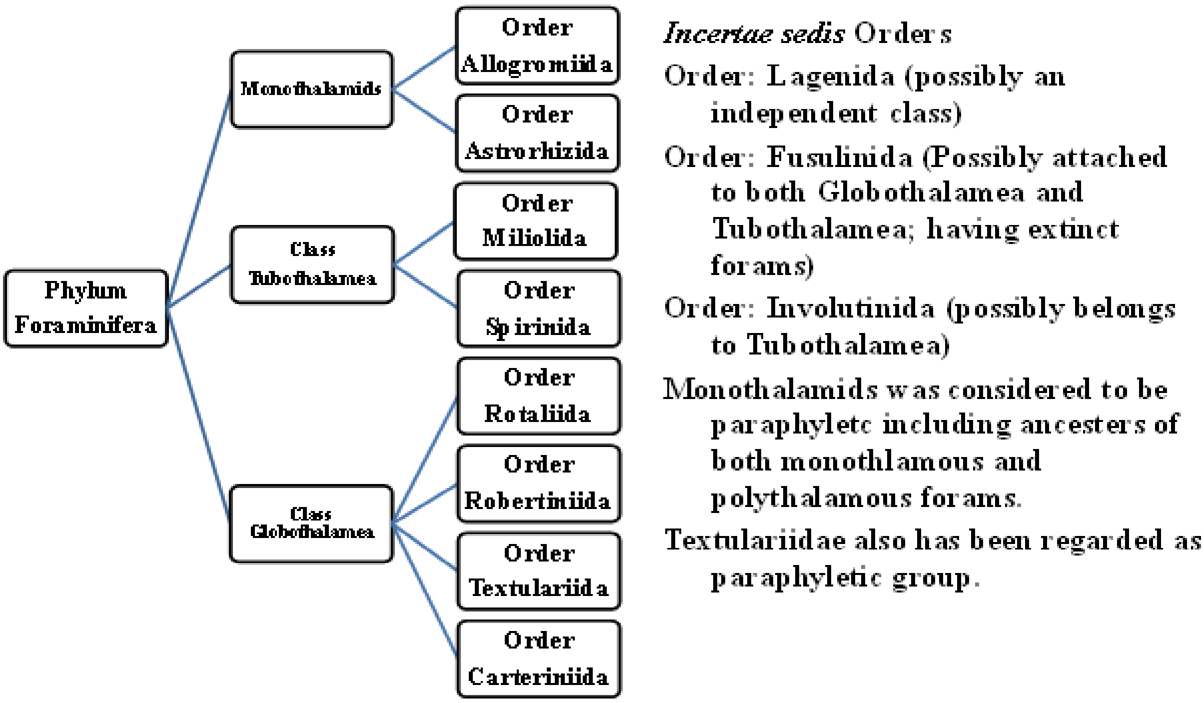

Fig. 4: Most Recent Classification of Forams based on Molecular Phylogeny by Pawlowski et al., (2013)

Table 1: Living Foraminifera in the sediments of Panvel Creek between 2008 1nd 2015

S. N.	Foraminirera Species	Scientist	Order
1	Textularia conica	d'Orbigny, 1839	Textulariida
2	Spiroloculina communis	Cushman & Todd, 1944	Hauerinidae
3	S. Orbis	Cushman, 1921	Hauerinidae
4	S. antillarum aeua	Cushman, 1932	Hauerinidae
5	Quiniqeloculina vulgaris	d'Orbigny, 1826	Hauerinidae
6	Q. lamarkiana	d'Orbigny, 1839	Hauerinidae
7	Q. Seminulum	Linnaeus, 1758	Hauerinidae
8	Triloculina insignis	Brady, 1881	Hauerinidae
9	T. trigonula	Lamarck, 1804	Hauerinidae
10	Eponides repandus	Fichtel & Moll, 1798	Eponididae
11	Cibecides refulgens	de Montfort, 1808	Cibicidae
12	Hanzwaia nitidula	Hanzwa, 1944	Gavelinellidae
13	H. asterizans	Hanzwa, 1944	Gavelinellidae
14	Ammonia beccarii	Linnaeus, 1758	Rotaliidae
15	A. tepida	Cushman, 1926	Rotaliidae
16	A. dentata	Parker and Jones, 1866	Rotaliidae
17	Pararotalia minuta	Takayanagi, 1955	Rotaliidae
18	P. nipponica	Asano, 1936	Rotaliidae
19	P. calcar	d'Orbigny, 1839	Rotaliidae
20	Bulimina costata	d'Orbigny, 1852	Rotaliidae
21	Asterorotalia dentata	Parker and Jones, 1866	Rotaliidae
22	Elphidium crispum	Linnaeus, 1758	Elphididae
23	E. discodale	d'Orbigny, 1839	Elphididae

Table 2: Foraminiferan species encountered in sediments of Panvel Creek between 2008 and 2015

S. N.	Foraminirera Species	2008	2009	2010	2011	2012	2013	2014	2015
1	Textularia conica	√	√	√	√	√	√	√	√
2	Spiroloculina communis	√	√	-	-	-	-	-	-
3	S. Orbis	√	√	√	√	√	√	√	√
4	S. antillarum aeua	-	√	-	√	√	-	-	-
5	Quiniqeloculina vulgaris	√	√	√	√	√	√	√	√
6	Q. lamarkiana	√	√	√	-	√	√	√	-
7	Q. Seminulum	√	√	√	√	√	√	√	√
8	Triloculina insignis	√	√	-	-	-	-	-	-
9	T. trigonula	√	√	√	√	√	√	√	√
10	Eponides repandus	√	-	√	√	√	√	√	-
11	Cibecides refulgens	-	√	-	-	-	-	-	-
12	Hanzwaia nitidula	√	√	√	-	√	√	√	√
13	H. asterizans	√	√	√	√	√	-	-	-
14	Ammonia beccarii	√	√	√	√	√	√	√	√
15	A. tepida	√	√	√	√	-	-	√	-
16	A. dentata	√	√	√	-	-	-	-	-
17	Pararotalia minuta	√	√	√	√	√	√	√	√
18	P. nipponica	√	√	√	√	-	-	-	-
19	P. calcar	√	-	-	-	-	-	√	-
20	Bulimina costata	√	√	√	√	√	√	√	√
21	Asterorotalia dentata	√	√	√	√	-	-	-	-
22	Elphidium crispum	√	√	√	√	√	√	√	√
23	E. discodale	√	-	-	√	√	-	-	-
Total number of species		**21**	**20**	**17**	**16**	**15**	**12**	**14**	**10**

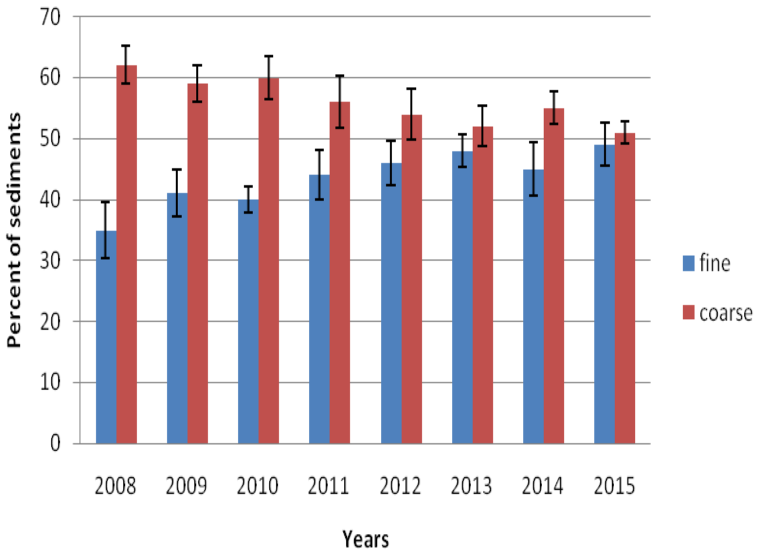

Fig. 5: Change in the texture of Sediemnts

The data on change in the sediment texture has been depicted in figure 5. As is evident from the figure, the sediment texture has become finer in the subsequent years. The figures 6 and 7 indicate the change in the number of species and the change in the total number of foraminiferal species per gram of the fresh sediments respectively. As is evident from these figures, there has been a steady decrease in both, the number of species or diversity of foraminifera and their abundance or total number per gram of sediments. Yanko *et al.* (1999) have reported that reduction in diversity as well as abundance of foraminifera is indicative of the pollution stress. Saraswat *et al.* (2004) have also found a similar shift in response to pollution.

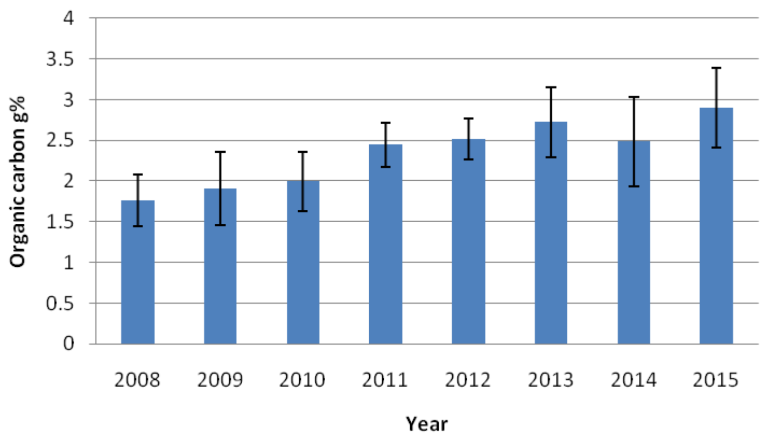

Fig. 6: Change in the organic carbon in the sediments of Panvel Creek during the period of study

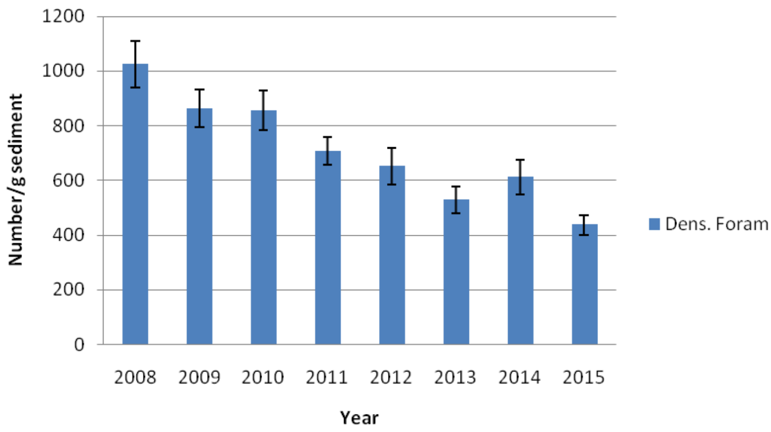

Fig. 7: Change in the number of foraminifera per gram of fresh sediments

Though the extensive construction activity of NMIA is yet to begin, the blasting and stone quarrying in the hills being cut has been going on even before the study was undertaken. It has resulted in dust pollution and the fine airborne particles eventually find their way into the Gadhi and Ulwe River Estuaries, Creeklets as wekll as Panvel Creek, which explains the increase in finer particles in the sediments. The increasing urbanization along the banks of the waterways is responsible in release of sewage, domestic waste as well as untreated silage which is causing an increase, not only in the finer sediments but also in organic carbon contents of the sediments, besides reducing the dissolved oxygen contents of the bottom waters. The adverse effects of siltation have been reported by Ghose (1989), Ghimre and Uprety (1990) and Yanko *et al.* (1999). The Creek has been well known for its good quality black sand that is in increasing demand to satisfy the exploding construction activities in suburbs of Navi Mumbai and Panvel. The sand dredging has been going on extensively and has already made the waters turbulent and black.

The continuous disturbance in the sediments has taken its toll on foraminiferal populations that have thinned out and some species are disappearing from the sediments altogether. The effect of dissolved oxygen on foraminifera has been studied by Mazumdar *et al.* (2003) and Pancho *et al.* (2005 and 2006), are in support of the assumption that reduction in dissolved oxygen is a factor in decline in variety as well as abundance of benthic foraminifera in the Creek as well as Estuaries under study. The increase in temperature of waters is yet another outcome of the anthropogenic activities. Nigam and Caron (2000) have studied the effect of increase in temperature on the reproduction and thus perpetuation of foraminifera. They have reported an inverse proportion between temperature and reproductive potential of foraminifera, thus providing yet another cause for the decline in diversity as well as density of foraminiferal fauna in the study area. Acidification of waters reduces the precipitation of calcium carbonate and may therefore reduce the variety and abundance of foraminifera (Manivannan *et al.,* 1996). Increase in the volume of domestic sewage reduces the pH of water and sediments and reduces the salinity so that the reduction in diversity and density of forams can be explained (Nigam *et al.,* 2006).

CONCLUSION

The quality and quantity of foraminifera in the sediments, of not only Panvel Creek and adjoining Estuaries but all coastal water bodies can certainly be used as a reliable bioindicator of the ecological status. As suggested by NIO (2008), continuous monitoring of water bodies for diversity and abundance of foraminifera can yield valuable information on ecological state of water bodies so that the restoration measures or their efficacy can be easily determined.

Conflicts of interest: The authors stated that no conflicts of interest.

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