Indian Journal of Marine Sciences
Vol 39(1) March 2010, pp. 74-84

Changes in the occurrance of hard substratum fauna: A case study from Mumbai harbour, India

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Received 9 September 2008; revised 1 March 2009

Intensive sampling was carried out in the marine environment of Mumbai and Jawaharlal Nehru ports to investigate the composition of benthic sessile population on three different occasions during 2001 to 2002. this study recorded 29 species of hard substratum fauna and 14 associated fauna. The acorn barnacle *Balanus amphitrite* and tube dwelling polychaete *Protula tubularia* were the dominant hard substratum species recorded from the area. *Protula tubularia* with no previous records from Indian waters appears to be an introduction in the region. The bivalve *Mytilopsis sallei*, which has been reported earlier as an invasive species Indian waters, was mostly found restricted to enclosed habitat within the ports. A comparison with historic data, based on the literature available, indicates the presence of 15 taxa which appeared for the first time this locality the present study envisages that the hard substratum faunal composition in Mumbai harbour environment is changing due to ever increasing human perturbation.

[Keywords: hard substratum fauna, ballast water, *Balanus amphitrite*, *Protula tubularia*, *Mytilopsis sallei*, bioinvasion, Mumbai harbor]

Introduction

The extent and nature of hard substratum faunal composition are influened by a wide range of biotic and abiotic factors including geographical location. Abiotic factors can be further grouped in-to environmental factors, which determine the characteristic of the environment and inherent surface property of the substratum[1-8]. On the contrary, biotic factors include breeding, competition for space and predation[9-10]. However, in recent times, a biotic factor which has been recognized as bioinvasion, has been found to influence the local ecosystem in general and faunal composition in particular[11]. The primary method of marine bio-invader introduction is through ballast water and ships hull. Though not much attention is paid to this problem in Indian waters, except for some efforts made by Anil et al.[12] and Subba Rao[13], the incidences of introduction show upward trend in other parts of the world[14] and has been implicated in economics and human health. It is estimated that over 4000 species of invertebrates, algae and fishes are transported in ballast tanks every day[15]. Since the ballasting and deballasting are primarily done in the port areas during loading and unloading of cargo, the port environment serves as gateways for alien species introduction.

Western side of Mumbai, has been investigated for chemical, biological and physical parameters as early as forties[16-21]. Biological parameters include phytoplankton abundance, benthic fauna and zooplankton. Whereas the data on the hard substratum fauna from Mumbai harbour is available since 1967 in parts as components of hard substratum community[22-29], and the same has been compared with the present investigation. The present study reveals the changes in the hard substratum faunal composition in Mumbai harbour.

Materials and Methods

Study area

Mumbai harbour (18° 54'N; 72° 40'E) is located at the mouth of the bay that separates the city from the west coast of the hinterland. This semi enclosed basin opens into the Arabian Sea at its southern end. Jawaharlal Nehru Port (JNPT), (18° 57' N; 72° 57' E) is located within the Mumbai harbour on the eastern side of the bay. Mumbai harbour, in general, is approximately 23 km in length and 10 km in width. The water depth ranges from 1.75 to 10 m[30]. Both, Mumbai and Jawaharlal Nehru harbour channels are maintained to depths of 10.7 to 11 m. below chart datum. The tides in this area are semi diurnal. The circulation in the harbour is influenced by the tide. The movement of water in this area exhibits an elliptical pattern[31]. This pattern of circulation results in low flushing of the bay water, leading to accumulation of pollutants and/or ballast water inoculums[32,33]. The northeast side of the basin is connected by Thana-Creek. It receives wastewater from the heavily industrialized Thane-Belapur belt, along its eastern shore. On the eastern shore of the bay Dharamtar, Nava-Shiva and Panvel Creeks, which are recipients of industrial waste, are discharging within the port limits. The basin is also influenced by 2485 million liters per day of industrial and municipal waste to its western side through several point sources[33]. The basin environment is also subjected to inoculation of non-native waters containing wide range of pollutants and biota through shipping activities. Examination of ships' ballast record (the period Ballast Water Reporting Forms) for 3,581 vessels for 2000 – 2002, suggests that 2.6 million tones of ballast water was received by Mumbai and Jawaharlal Nehru ports through national and international shipping[34] Samples were collected from 17 stations during three different periods (2001 and 2002) to evaluate and elucidate the possible changes in the hard substratum fauna in these harbours (Fig. 1).

Sampling

Hard substratum faunal samples were collected from the submerged structures like harbour wall, jetty pile and marker buoy by scrapping an area of $0.1 m^2$. Samples were collected in triplicate from 0 (inter-tidal), 3 and 6 m (sub-tidal) depth with the help of scuba divers/scrapper on three different occasions (November 01, April 02 and October 02). The organisms were immediately anesthetized after collection using 10% $MgCl_2$ solution and preserved in 5% formaldehyde prepared in seawater. Biomass (wet weight) of each sample was measured using a balance and later the organisms were identified to genus/species level using a stereo zoom microscope. The genus/species, encountered at each station, were noted and expressed in terms of percentage occurrence. A total of 459 samples of hard substratum faunal assemblages were analysed from all the three samplings.

Data analyses

ANOVA was performed on the hard substratum faunal biomass and composition data to evaluate the variations between stations, sampling months and depths[35]. Cluster analysis (Bray Curtis coefficients[36] and Group average method[37]) was carried out based on the presence and absence of the taxa to distinguish the faunal similarities at different depths and also among different stations during 3 different samplings. This analysis was performed using the PRIMER software version 5.

Results and Discussion

In all 29 taxa of hard substratum fauna and 14 taxa of associated fauna were recorded during the period of study (Table 1). Among these, 15 taxa belonging to sponges, corals, hydroids, polychaetes, bivalves and ascidians are reported for the first time from this environment (Table 2). Faunal occurrence varied

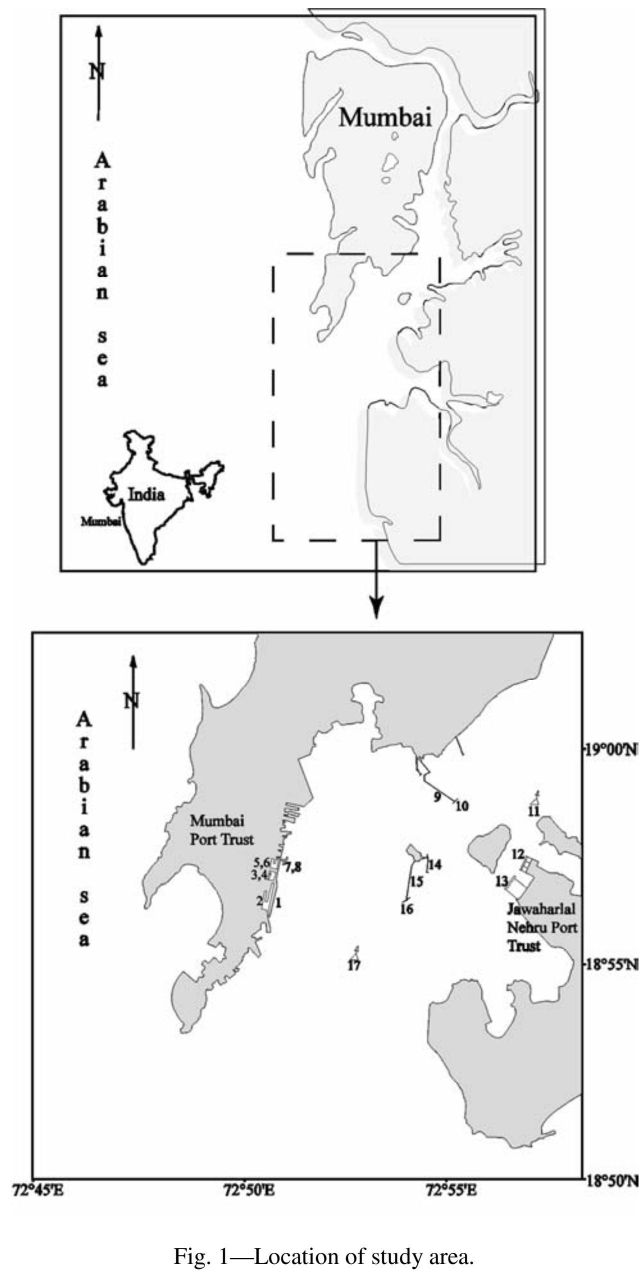

Fig. 1—Location of study area.

Table 1—Species occurrence during different sampling months at all the stations. Different notations indicates occurrence of species during different sampling months. (● =November 01, ▲=April 02, ■ =October 02)

Species/Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	% occurrence
Sponges																		
Suberites carnosus *	●	▲■	●▲	●▲■	●▲■	●▲■			●■	●			●	●	●▲■			43
Prostylyssa foetida *		■	●▲■	●			●▲■	●▲■								▲		24
*Haliclona sp.**												●					●	4
Bryozoans																		
Nellia tenella	●											●		●▲	●■	●		14
Scrupocellaria scruposa													●	●▲	●■	▲		12
Membranipora tenuis																	●	2
Bugula stolonifera																	●	2
Bugula neritina		■												▲				4
Acanthodesia sp.																	■	2
Corals																		
Astrangia cavatus *	●■													●	●■	●		12
*Astrangia sp.**							●											2
Gorgonians *												●		●	●■			8
Hydroids																		
Obelia dichotoma *												●						2
Laomedia bistriata *	●								●▲				●					8
Aqlaophenia pluma *														●	●▲	●▲		10
Bougainvillia ramosa *									●▲	●								6
Zoothamnium sp. *	●																	2
Sea anemones									●				●		●	●		8
Polychaetes																		
Hydroides norvegica			●	■	■	■			●■									12
Protula tubularia *	●	▲	●■	●■	●	●	●▲■	●▲■	●▲■	●	●■	●	●	●▲	●■	●▲	●	57
Barnacles																		
Balanus amphitrite	●▲■	●■	●■	●▲■	●■	●■	●▲■	●▲	●▲■	●▲■	●▲■	●▲■	●▲■	●▲■	●▲■	●■	●	84
Balanus tintinabulum									▲■	■					▲	▲	■	12
Chthamalus sp.		■							●	●■		■						10
Bivalves																		
*Modiolus sp.**			●					●	●	●			●		●	●		14
Mytilopsis sallei		■																2
Saccostrea cucculata																▲		2
Crassostrea gryphoides																▲		2
Ascidians																		
Botrylloides leachi *						▲												2
Ectenascidia bombayensis *						▲												2
Associated fauna																		
Crabs																		
Leptodius exaratus			●						●			●	●			●▲	●	14
Medaeops granulosus				●						●	●			●	●	●▲		14
Pilumnus longicornis							■		●									4
Leptodius euglyptus															●			2
Charybdis callianassa									■									2
Epixanthus frontalis									▲									2
Shrimps																		
Alpheus sp.	■		▲		▲		■	■	■									12
Gastropods																		
Gyrenium natator			▲	▲						●				●▲	●			12
Littrorina littora										●		●						4
Mitra scutulata												●						2

Contd—

Table 1—Species occurrence during different sampling months at all the stations. Different notations indicates occurrence of species during different sampling months. (● =November 01, ▲=April 02, ■ =October 02) —*Contd*

Species/Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	% occurrence
Thais lacera			●	▲			●	●	●						▲	●▲		16
Thais rugosa						▲												2
Thais sp.					■		■		■	■								8
Trocus sp.														●▲	●			6

* - first report from the area

Table 2—Decadal occurrence of fouling/hard substratum communities from Mumbai port area since 1967

Fouling groups	60's	70's	80's	90's	After 2000
Sponges					
Suberites carnosus					*
Prostylyssa foetida					*
Haliclona sp.					*
Leucosolenia sp.				*	
Sycone sp.				*	
Bryozoans					
Bugula stolonifera				*	*
Bugula bengalensis			*	*	
Bugula neritina	*		*	*	*
Bugula sp.	*				
Electra bengalensis		*	*	*	
Electra crustulenta				*	
Electra tenella				*	
Electra bellula				*	
Electra sp.	*				
Membranipora perfragilis				*	
Membranipora savartii				*	
Membranipora annae			*	*	
Membranipora tenuis			*	*	*
Membranipora hugliensis				*	
Membranipora sp.	*			*	
Acanthodesis savartii		*			
Acanthodesia sp.	*		*	*	*
Zoobotryon verticellatum				*	
Zoobotryon sp.	*				
Amathia convoluta			*	*	
Amathia sp.	*				
Bowerbankia sp.	*				
Scrupocellaria scrupusa	*		*	*	*
Scrupocellaria sp.	*				
Caulibugula sp.	*				
Nolella paupensis	*			*	
Nolella sp.	*				
Victorella pavida				*	
Victorella sp.	*			*	
Mammillopora sp.	*				
Schizoporella unicornis		*			
Schizoporella sp.	*				
Conopeum eriphorum		*			
Conopeum sp.	*				
Alserina smitti	*				

Contd—

Fouling groups	60's	70's	80's	90's	After 2000
Nellia tenella				*	*
Nellia sp.		*			
Crisia elongate				*	
Crisia holdswortrii		*			
Hippoporina indica			*	*	
Hippoporina feegeensis			*	*	
Hippoporina americana				*	
Celleporaria pilaefera			*		
Thalamoporella stapifera				*	
Rimulostoma signatum				*	
Alderina arabiansis				*	
Microporella sp.				*	
Clothrudim sp.				*	
Savignyella sibogae				*	
Corals					
Astrangia cavatus					*
Astrangia sp.					*
Gorgonians					*
Hydroids					
Pennaria sp.	*				
Plumularia sp.	*			*	
Sertularia sp.	*			*	
Tubularia sp.				*	
Hydractinia sp.	*				
Alcyonaria sp.	*				
Actinaria sp.	*				
Telesto sp.	*				
Obelia dichotoma					*
Obelia sp.			*	*	
Laomedia bistriata					*
Aglaophenia pluma					*
Bougainvillia ramosa					*
Zoothamnium sp.					*
Companularia sp.			*	*	
Clytia sp.			*	*	
Sea anemone					*
Polycheates					
Hydroides norvegica			*		*
Hydroides elegans				*	
Hydroides operculatus				*	
Hydroides sp.	*				
Sabellid sp.	*				
Nereis sp.	*				
Desycone cingulata					

Contd—

Table 2—Decadal occurrence of fouling/hard substratum communities from Mumbai port area since 1967—*Contd*

Fouling groups	60's	70's	80's	90's	After 2000
Dasychone sp.	*				
Pomatoceros sp.	*				
Polynoe sp.	*				
Spirorbis sp.	*			*	
Protula tubularia					*
Apomatus sp.				*	
Pomatoleus sp.				*	
Ficopomatus uschakovi				*	
Chaetopterus variopedatus				*	
Pseudobranchiomma orientalis				*	
Branchiomma cingulatum				*	
Jasmineria sp.				*	
Demonax leucaspis				*	
Barnacles					
Balanus amphitrite		*	*		*
Balanus amphitrite variegatus	*	*			
Balanus amphitrite denticulata		*			
Balanus amphitrite venustus		*			
B. a. communis	*				
B. amarylliseuamaryllis	*				
B. tintinnabulum tintinnabulum	*				*
B. tintinabulum zebra	*				
B. a. euamaryllis	*				
B. a. insignis	*				
B. a. venustus	*				
B. a. denticulate	*				
B. a. hawaiiensis	*				
B. a. cochinensis	*				
Balanus amaryllis		*			
B. amaryllus euamaryllis	*			*	
B. amaryllus nivea	*				
Balanus calidus	*				
Balanus reticulates				*	
Chthamalus malayensis	*				
Cthamalus sp.					*
C. withersi	*				
Tetraclita purpurascens	*				
Megabalanus tintinnabulum				*	
Bivalves					
Mytilus sp.	*				
Scapharca sp.	*				
Modiolus sp.					*
Mytilopsis sallei				*	*
Oysters	*				
Saccostrea cuculata				*	*
Crassostrea gryphoides				*	*
Crassostrea sp.					
Ascidians					
Ascidiella sp.					
Symplegma reptans					
S. brakenbielmi					
S. viride					
Diplosoma macdonaldi					
Botrylloides magnicoecum				*	
B. chevalense				*	
B. leachi					*
Styela bicolor				*	
Ascidia indica				*	
Ascidia sydneiensis				*	
Ascidia molgula					
Ectenascidia bombayensis					*
Ectenascidia sp.				*	

60's (Karande, 1967; Karande, 1968): 70's (Swami & Karande, 1987): 80's (Swami & Karande, 1988; Karande & Swami, 1988): 90's (Karande & Udhayakumar, 1992): After 2000 (Swami & Chhapgar, 2002; Swami, 2003).

significantly among the stations ($p<0.05$) and different sampling months ($p<0.001$), being maximum at station 15 (Jawahar dweep) during Nov. 01 sampling. Similarly, biomass varied significantly between different sampling months and depths ($p<0.05$), but not among the stations. A maximum biomass of 1440 $g.m^{-2}$ (wet wt.) was recorded at station 7 (Ferry wharf) during Apr. 02 sampling at 3m depth. Among the hard substratum fauna recorded, the barnacle *Balanus amphitrite* showed maximum percentage of occurrence (84%), indicating higher magnitude of distribution at all the stations and sampling months (Table 1). Such dominance of the barnacle *B. amphitrite* was also observed by earlier workers in Mumbai harbour [23,25,26]. The next species, in decreasing order of occurrence, included a polychaete, *Protula tubularia* (57%), followed by 2 species of sponges, *Suberites carnosus* (43%) and *Prostylyssa foetida* (24%). The segregation of different hard substratum fauna is also clear from the cluster analysis. A few stations separated from the main groups due to the occurrence of a particular species Also a combination of clusters differed for each sampling month, showing the changes in faunal composition during different sampling period (Fig. 2). Depth related changes were also evident in faunal composition (Fig. 3). The intertidal zone (0 m) was dominated by barnacles, whereas, submerged zones at 3 and 6 m were mostly dominated by soft bodied organisms like sponges, polychaetes, hydroids and bryozoans (Fig. 4).

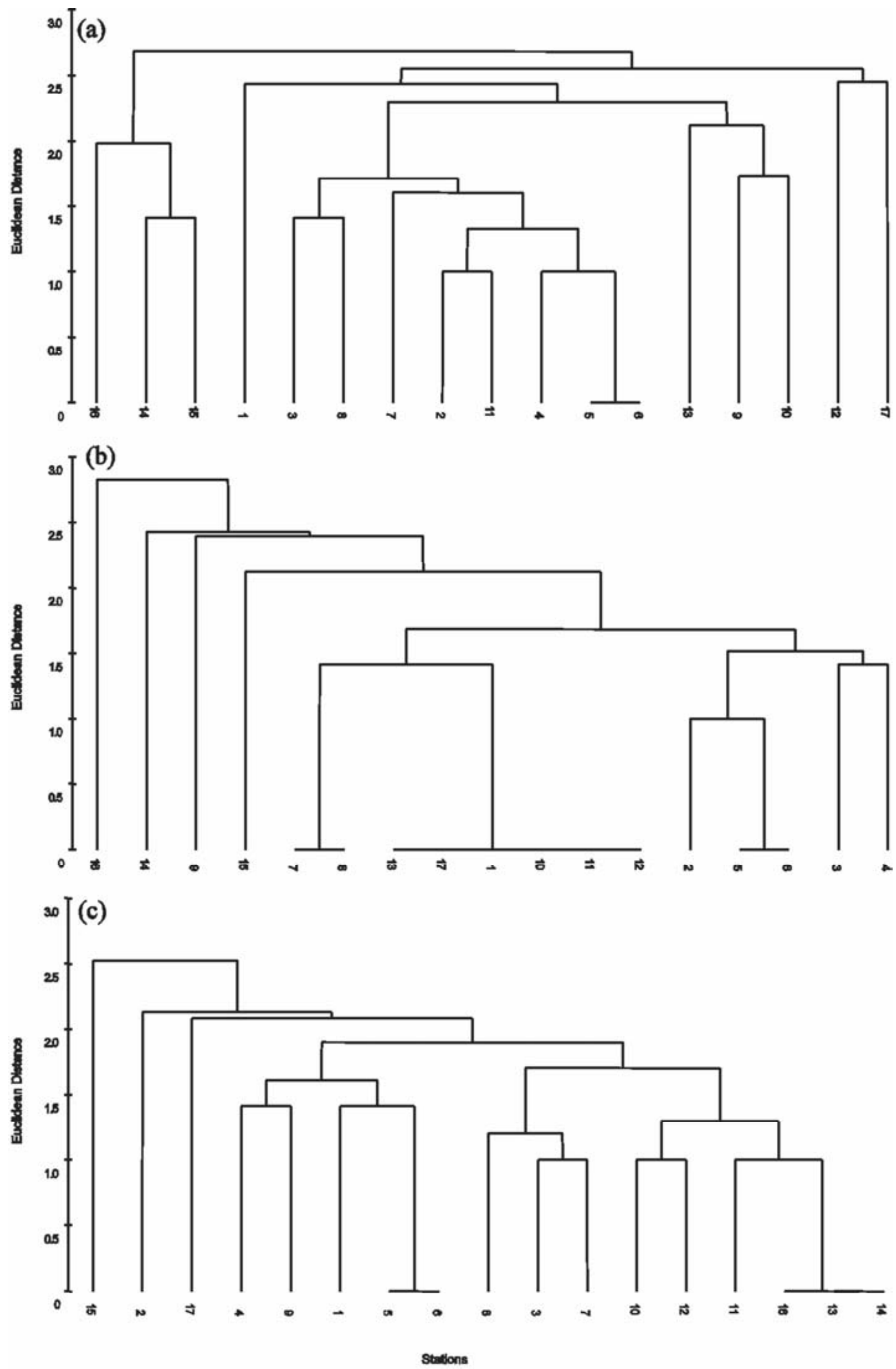

Fig. 2—Cluster dendrograms of the hard substratum fauna sampled at different stations during 3 different occasions, (a) Nov-01; (b) Apr-02; (c) Oct-02.

Comparison of the hard substratum fauna between different sampling months showed that there was a marked difference in the components of the two post-monsoon samplings (Nov. 01 and Oct. 02). During Nov. 01 sampling, at the intertidal zone (0m), there was an-occurrence-of-12 different species belonging to bivalves, polychaetes, sponges, sea anemone, bryozoans, hydroids and barnacles, whereas Oct. 02 was represented by only 4 species belonging to hydroids, bryozoans and barnacles. Similarly, there was a difference in occurrence between the two post-monsoons at subtidal zone (3m) (Fig. 3). The

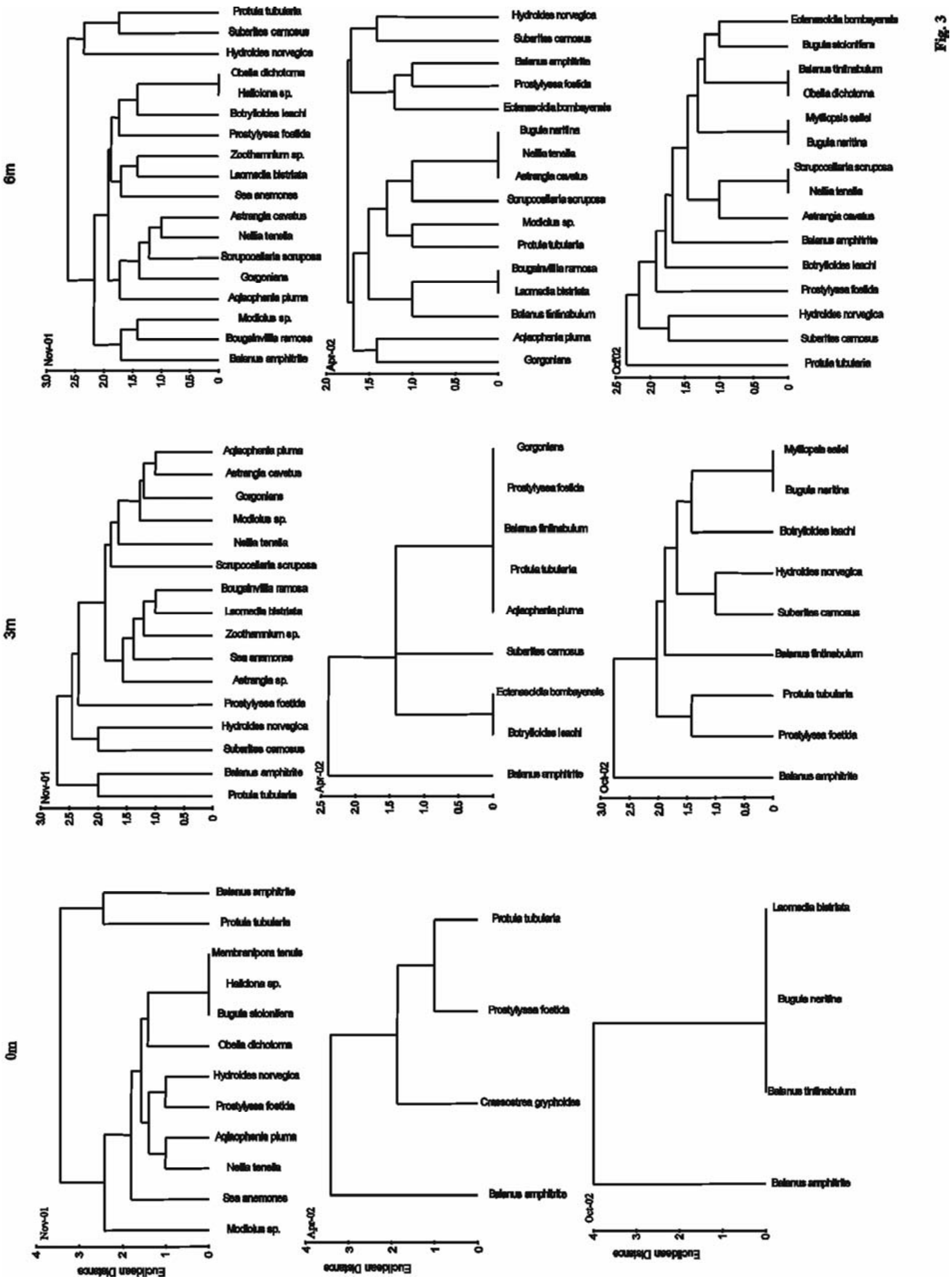

Fig. 3—Cluster dendrograms of the hard substratum fauna sampled at different depths (0m, 3m and 6m), during 3 different occasions (Nov-01, Apr-02 and Oct-02).

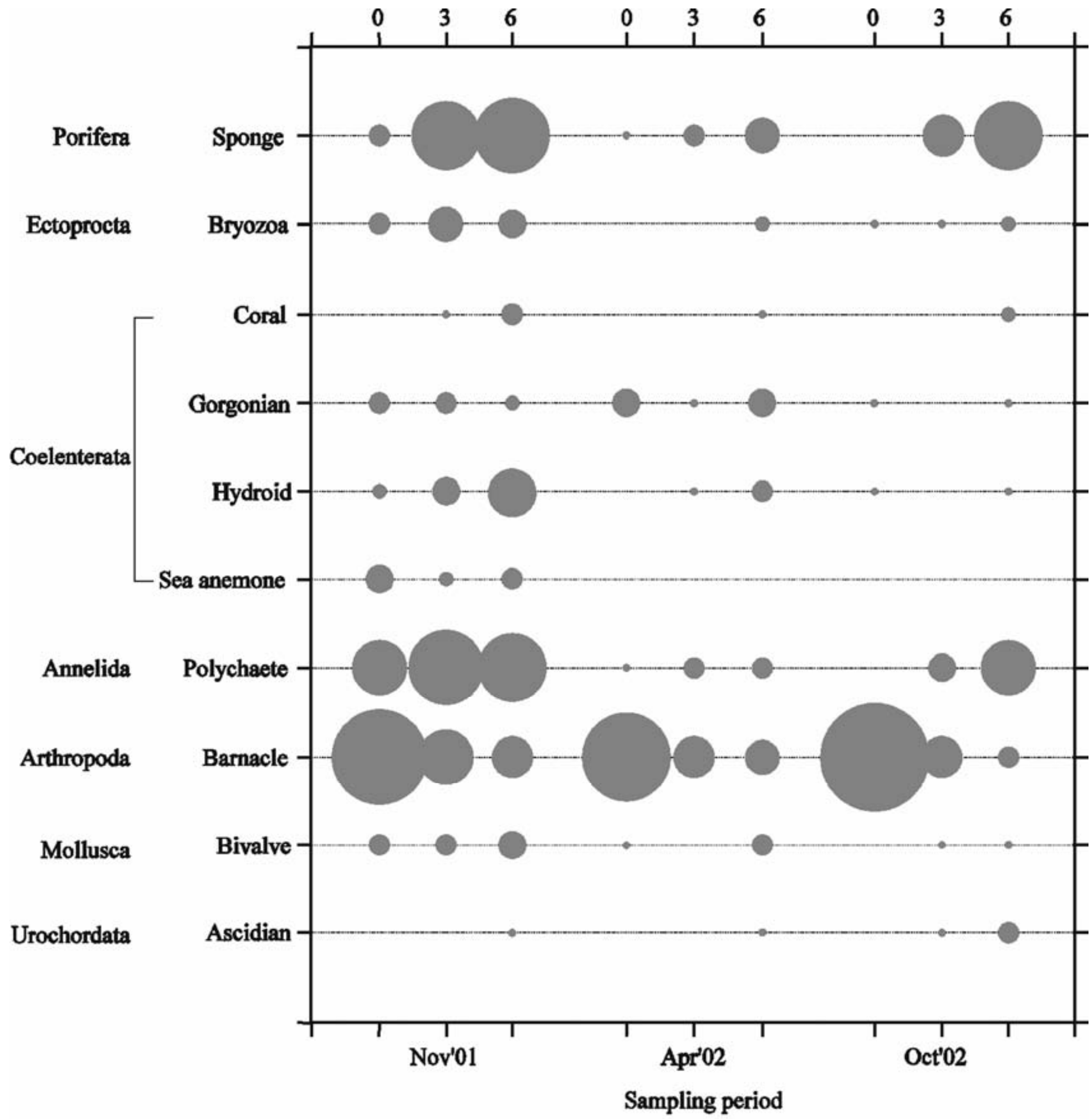

Fig. 4—Bubble plot of the hard substratum fauna to show the depth wise occurrences (0m, 3m and 6m), during 3 different samplings (Nov-01, Apr-02 and Oct 02). The maximum symbol height corresponds to 100% occurrence.

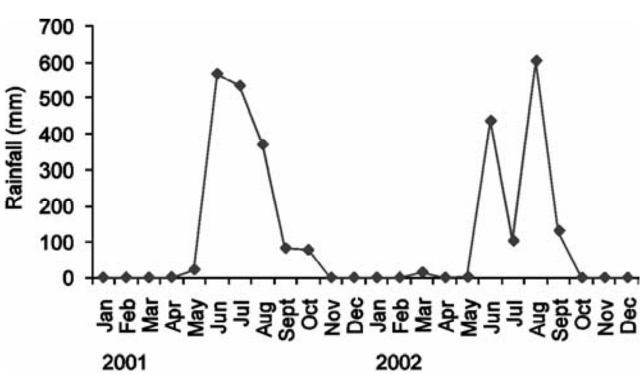

Fig. 5—South-west monsoon pattern in Mumbai and Jawaharlal Nehru harbour.

probable causes for such variations could be the pattern of rainfall during these two years of sampling. The area under study is a tropical environment influenced by the south-west monsoon. The two post-monsoon seasons differed with respect to the length and intensity of the preceding monsoons. In 2001, the monsoon was prolonged and unimodal. It peaked between June-August and ended in October. In 2002, however, the monsoon was erratic and ended earlier in September (Fig. 5). Though the differences were not reflected in the physico-chemical variables, certain changes were noticed in the dinoflagellate and copepod communities from the area[39].

Comparison of the present data with the earlier reporting's based on the hard substratum community assemblages, from as early as sixties, also indicates some degree of changes in faunal composition[22-29] (Table 2). The differences included both non occurrences of previously reported species and vice versa. Non occurrence of certain organisms in the present investigation can be due to variations in the sampling scheme and/or methodology. Earlier reporting's were mostly based on monthly/seasonal observations from a limited area (1 to 3 stations) using experimental coupons. Such a sampling approach would provide information on seasonal succession in communities. Reporting of new species through this sampling is mostly due to the intensiveness in observations. The details of the species reported are given in table 2. Among all these species, the polychaete *Protula tubularia* is reported for the first time from the Indian coast.

P. tubularia is a soft, tube dwelling, fouling polychaete. Its distribution is limited to Red Sea, England, Atlantic, Mediterranean, Japan and Sri Lanka[40-41]. The occurrence of this polychaete in Mumbai harbour could be assumed as an introduction to the area, which might have been facilitated by ships. Examination of data on ships' ballast water discharge, collected through ballast water reporting forms, for 3,581 vessel visits and 4,934 associated Ballast Water tank discharges, for the period from 2000 - 2002 for Mumbai and Jawaharlal Nehru ports, indicates that Sri Lanka contributes immensely in terms of percent ballast discharge frequency (10.1%, being the 3rd highest of the 82 source ports) and the volume of ballast water received at Mumbai port (1.7% of the total ballast[34]). These figures are suggestive of a strong trade link between Sri Lanka and Mumbai and hence can be implicated in the introduction of the polychaete *P. tubularia*, which has been reported from Sri Lanka[41]. This species is a prolific breeder and voracious filter feeder. It occurs in dense mats on hard surfaces, and may out compete other resident species[40]. In the present investigation also these tube dwellers were found in thick mat on jetty piers at station 7 (Ferry wharf). With regard to the bivalve *Mytilopsis sallei*, it was found to grow on the walls at Station 2 (Indira dock), which is an enclosed area. In Visakhapatnam, this species was reported from the inner harbour environment which is again an enclosed and polluted system[42]. This species is a native of tropical and sub-tropical Atlantic waters and is reported to have invaded Visakhapatnam during 1960's[43]. Subsequently, it was found in the Naval dock at Mumbai harbour during 1975[44] and it was opined that naval ships might have played an important role in facilitating the transportation of this species.

A thorough knowledge on the composition of the hard substratum fauna at a given locality, the intensity of their occurrence, vertical distribution and response to different anthropogenic pressures is an essential prerequisite to understand their ecology. Constant monitoring of the arrival of new entrants to the fauna is also very important, particularly in the wake of the successful colonization by *M. sallei* in Mumbai and Visakhapatnam waters and its reported spreading southwards. Since the remedial measures hinges on a comprehensive collection of these baseline data to pinpoint the ways of actual control, these aspects should receive due attention. It is evident from the present investigation that there are changes in the hard substratum faunal composition in Mumbai harbour environment, probably due to the ever increasing human activities such as shipping. Mumbai port, being a shipping hub, handles a large amount of traffic. The traffic record for 2005-2006 alone shows a multiple fold increase of cargo (44.19 million tones) over a period of five decades (10.47 million tones in 1955-1956; www.mumbai porttrust.com/performance/index7). This sort of trend of traffic in Mumbai harbour would enhance the chances of introduction of organisms in the future via hull fouling and/or ballast water, if no proper management strategies are put in place for their control.

Acknowledgements

The authors are grateful to Dr. S R Shetye, Director, National Institute of Occanography for his support and constant encourangement. Thanks are also due to Mr S. Chakraborthy and Mr A Chatterjee former country focal points, for Global Ballast Water Management program in India. Authors are thankful to Dr. P.A. Thomas, Dr. R. Jeyabaskaran, Mr. Y. Vishwakiran and Ms. Janhavi Kolwalkar for the identification of some hard substratum species.This is NIO contribution 4702.

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