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Mumbai harbour, India: gateway for introduction of marine organisms

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Abstract Ships have been identified as one of the important vectors in the translocation of organisms from one bioregion to another leading to bioinvasion. In this context, harbours serve as a gateway for the introduction of alien species. Surveys were carried out in the vicinity of ports of Mumbai for macrobenthic fauna, zooplankton and hard substratum community on three different occasions during 2001–2002. The study shows that 14 polychaete species are recently introduced to this area. *Mytilopsis sallei*, a bivalve, which is an invasive species in the Indian context continued to be present but was restricted to enclosed docks, indicating preference for embayed water bodies. The polychaete *Protula tubularia* was abundant in the hard substratum community and is being reported as a possible ship-mediated introduction.

Keywords Bioinvasion · Mumbai harbour · Zooplankton · Fouling · Macrobenthic fauna

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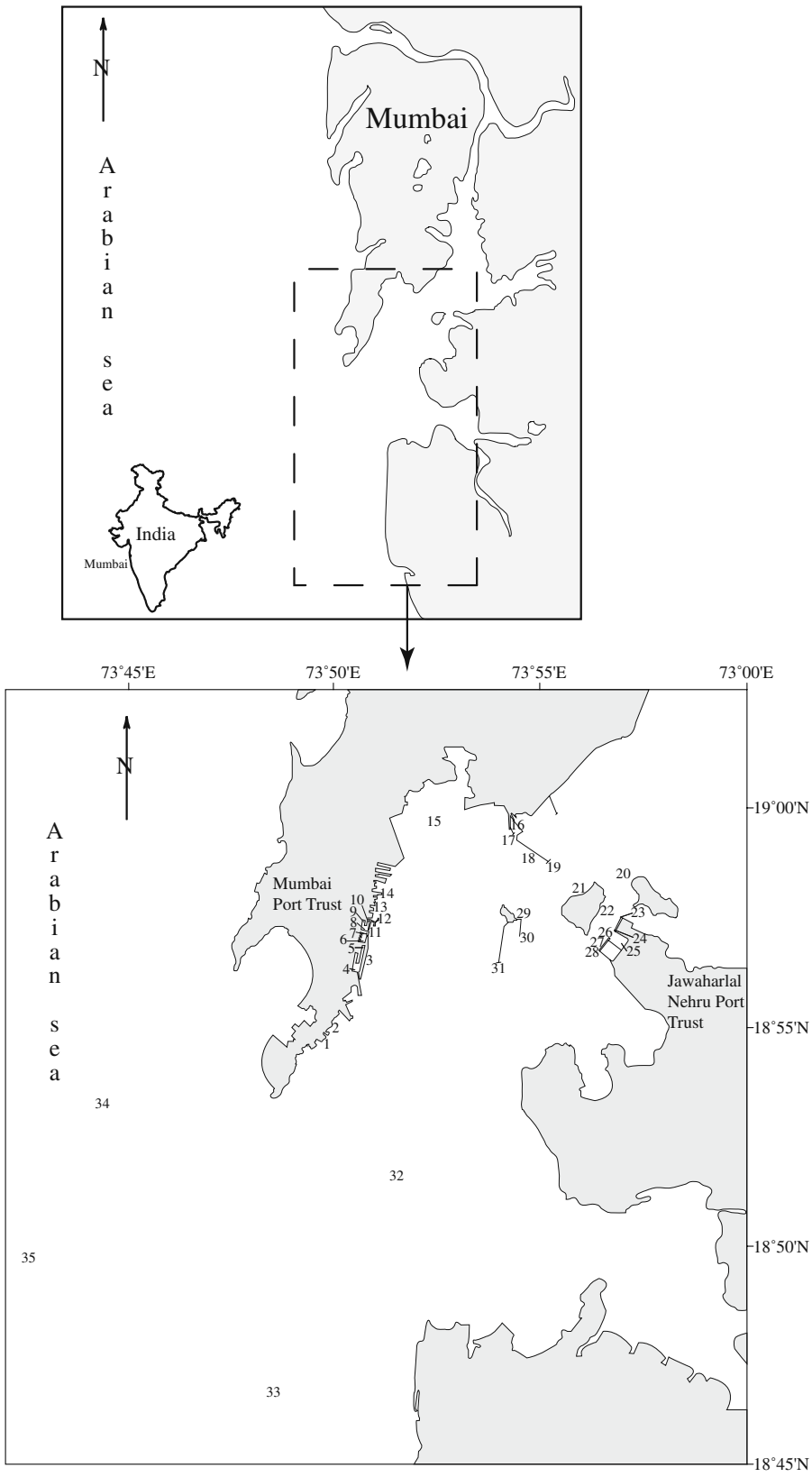
Introduction

Shipping is the backbone of the global economy and facilitates transportation of 90% of commodities. A single bulk cargo ship of 200,000 tonnes can carry up to 60,000 tonnes of ballast water. It is estimated that 2–3 billion tonnes of ballast water are carried around the world each year. Translocation of organisms through ships' ballast water is considered an important bioinvasion vector and threat to naturally evolved biodiversity. Consequences of such invasions are being realised increasingly in recent years (Ahlstedt 1994; Pearce 1995; Ruiz et al. 1997, 2000; Carlton 1999; Marine biological invasions 2001; Anil et al. 2002; Tavares and DeMelo 2004; Diederich et al. 2005; Subba Rao 2005). Taking note of bioinvasion in different parts of the world and identifying the influence of ships' ballast water on such invasions, the International Maritime Organization has adopted a convention, "The International Convention for the Control and Management of Ships Ballast Water and Sediments".

In any bioinvasion-related study, it is important to have a clear picture of the biodiversity. In view of this, we assessed the macrobenthic, zooplankton and hard substratum community of Mumbai and Jawaharlal Nehru ports on three different occasions during 2001–2002. We compared this with earlier studies and reported on the changes in

Fig. 1 Station map



macrobenthos, zooplankton, and hard substratum community in the ports of Mumbai.

Materials and methods

Samples for macrobenthos were collected from 35 sites (Fig. 1) in triplicate with the help of scuba divers and/or Van Veen grab. The samples were sieved through 0.5-mm mesh nylon sieve and preserved in 5% formaldehyde solution containing Rose Bengal stain.

Zooplankton samples were collected from 14 stations using 100-μm mesh Heron-Tranter plankton net with a flow metre, preserved in 5% buffered formaldehyde solution and analysed in the laboratory.

Hard substratum organisms were collected from submerged structures at 17 stations, such as harbour walls, jetty piles and navigational buoys by scraping an area of 0.1 m^2. Samples were collected in triplicate from 0 (inter-tidal), 3 and 6 m (sub-tidal) depths with the help of scuba divers and/or underwater scraper. The organisms were

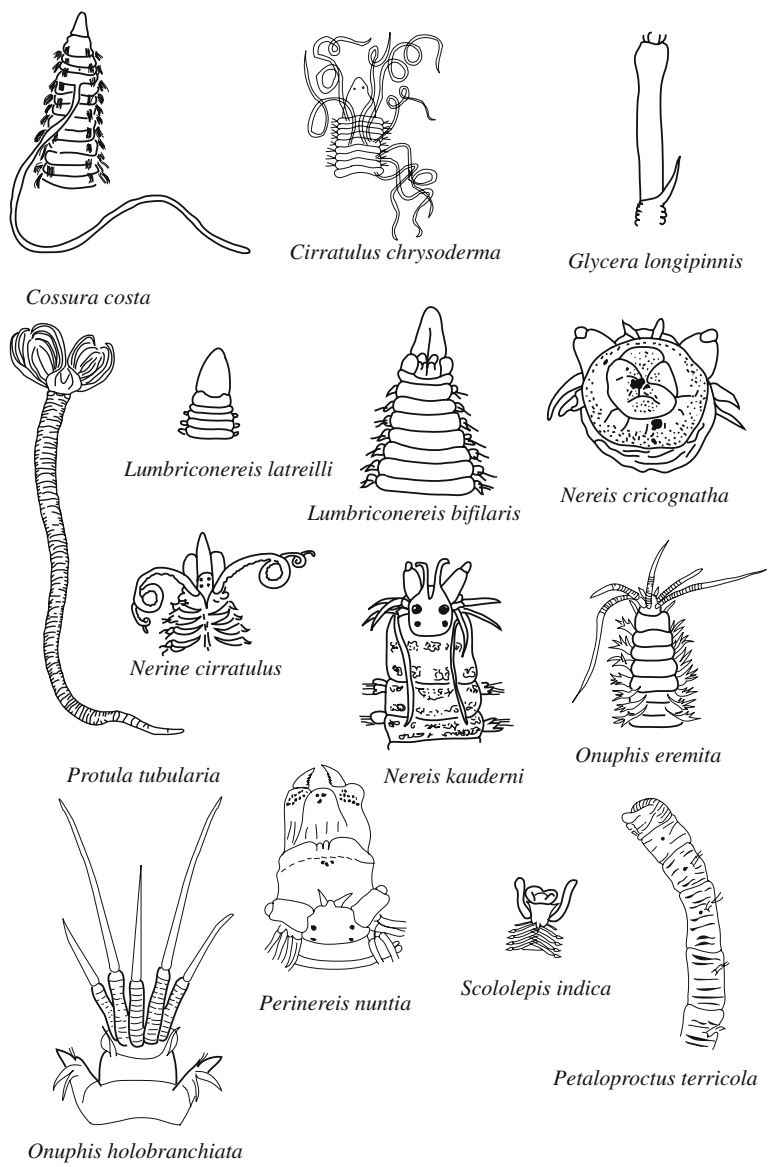


Fig. 2 Introduced polychaete species in Mumbai port area (sketch—anterior part)

immediately anaesthetised after collection using 10% $MgCl_2$ solution and preserved in 5% formaldehyde prepared in seawater. Subsequently, these organisms were identified in the laboratory through microscopy.

In order to identify instances of introduction, the data from the present investigation is compared with the data collated from published literature relevant to Mumbai harbour area and Indian waters (Bal and Pradhan 1952; Karande 1967, 1968; Pillai 1968; Gajbhiye et al. 1984, 1991; Swami and Karande 1987, 1988; Karande and Swami 1988; Karande and Udhayakumar 1992; Tiwari and Nair 1993; Lodh 1990; Swami and Chhapgar 2002; Swami 2003). Species were designated as non-indigenous species based on the non-native species criteria described by Chapman (1988) and Chapman and Carlton (1991).

Results and discussions

Macrobenthos

Analysis of the macrobenthic population and collation of data indicates 14 polychaete species (Fig. 2) that can be categorised as introduced to Mumbai and Jawaharlal Nehru ports in recent years. Among these, *Cossura costa* was found at 20% of the sites sampled.

Zooplankton

Compilation of information with reference to zooplankton diversity suggests changes in species composition (Bal and Pradhan 1952; Pillai 1968; Gajbhiye et al. 1984, 1991; Lodh 1990; Tiwari and Nair 1993). Table 1 provides information on the introduction of copepod species in the vicinity of Mumbai and Jawaharlal Nehru ports and their percentage contribution to the zooplankton community. The *Paracalanus* species (Fig. 3) encountered in this study does not match entirely with the description of the genus *Paracalanus*, as it has conflicting/overlapping taxonomic status with the genus *Parvocalanus*. A detailed study of this species is underway to elucidate its taxonomic status.

Table 1 Introduced copepod species in Mumbai harbour area

Copepods	Percentages
Nanocalanus minor	6.99
Cosmocalanus sp.	4.99
Euterpina acutifrons	4.78
Tortanus sp.	2.09
Paracalanus sp.?	12.47

Hard substratum community

Hard substratum community forms encountered in this study were compared with published reports with reference to distribution of fouling organisms (Karande 1967, 1968; Karande and Menon 1975; Swami and Karande 1987, 1988; Karande and Swami 1988; Karande and Udhayakumar 1992; Swami and Chhapgar 2002). Such a collation of data indicates the continued existence of a bivalve, *Mytilopsis sallei*, reported as an invasive species in the Indian context.

M. sallei (Fig. 4) is a native of tropical and subtropical Atlantic waters and is reported to have invaded Visakhapatnam harbour, India during 1960s (Ganapati et al. 1971). Subsequently, this

Fig. 3 *Paracalanus* sp. ?

Fig. 4 *Mytilopsis sallei*

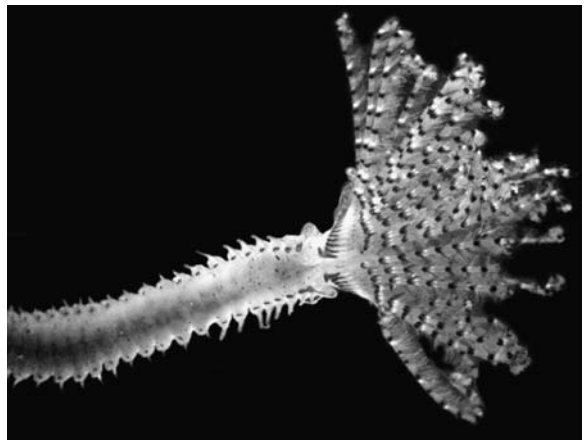


Fig. 5 *Protula tubularia*

species was observed in the Naval dock at Mumbai harbour during 1975 (Karande and Menon 1975). In this study, *M. sallei* was recorded from Indira dock, which is an enclosed water body with limited access to open waters. The observations in Visakhapatnam and Mumbai reflect the preference of this species for embayed water bodies. It has also been reported that indigenous mangrove flora and fauna form an impressive component of life in tidal monsoon drains in Singapore, but *M. sallei* is now by far the dominant fouling species of the upper reaches of such man-made habitats (Tan and Morton 2006). It has also been reported that *M. sallei* is a colonial surface dweller of sheltered waters (Hewitt et al. 2002). This preference of *M. sallei* to settle in embayed/sheltered water bodies indicates that their successful colonisation is limited to such habitat characteristics.

The polychaete, *Protula tubularia* (Fig. 5), was abundant in Mumbai harbour (observed in 17 stations) and recorded during all the three sampling occasions. At some stations, the dominance of this species in the fouling assemblage ranged between 80% and 90%. Its natural range of distribution suggests that it is a native of England, Atlantic Ocean, Indian Ocean, Japan, Mediterranean Sea, Morocco and Senegal (Fauvel 1953). It has also been recorded from Ceylon (Wiley 1902). The chances of this species being transported to Mumbai harbour via ships, appear to be quite high, the nearest being Sri Lanka (earlier known as Ceylon). The data analyses of ship visits to Mumbai harbour, collected for the period 2000–2002 through ballast water reporting forms, indicated that Sri Lanka contributed immensely in terms of percent proportion of all ballast discharges (10.1%), with 1.7% of the proportion of total discharge volume received at Mumbai port. It ranked third among the 82 source ports in the relative overall risk (Anil et al. 2003). These figures, indicative of a strong trade link between Sri Lanka and Mumbai, implicate ships as a vector in the introduction of *P. tubularia*. This species is a prolific breeder and voracious filter feeder. It occurs in dense mats on hard surfaces and may outcompete other resident species (Wiley 1902). In the present investigation, these tube dwellers were also found in dense mats on jetty piers at station 7 (Ferry wharf).

Mumbai port, being a shipping hub, handles a large amount of traffic. The traffic record for 2005–2006 shows a multiple fold increase of cargo (44.19 million tonnes) over a period of five decades (10.47 million tonnes in 1955–1956; http://www.mumbaiporttrust.com/performance/index7). Such an increase in traffic increases the risk of introductions and calls for appropriate management strategies. The degrading environmental conditions, in Mumbai harbour as described by Sawant et al. (2007), can compound problems further by altering the community and facilitating the growth of tolerant invasive species.

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