

Comparative Account of Macrofouling Ecology at Vijaydurg Harbor and Musakazi-Jaitapur Bay, Central Western Coast of India

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The extent and the nature of fouling were studied on mild steel, aluminum, and stainless steel panels at the Vijaydurg harbor and Musakazi-Jaitapur Bay on the central western coast of India. In addition, cathodically protected and unprotected panels of copper and brass were investigated. Fouling activity continues throughout the year at both stations. Protected brass had the maximum fouling assemblage followed by copper and then by mild steel. Unprotected copper and brass were free from fouling.

INTRODUCTION

Biofouling is a site-specific phenomenon. Its intensity varies with the type of surface available for settlement. Texture and surface roughness are two factors that play significant roles in influencing the recruitment of fouling organisms (Pomeroy and Weiss 1946). In relation to this, materials for marine applications can be broadly classified into three types: toxic-film forming, highly corrodible, and passive metals (Raju et al. 1988). The data collected by using any one type of these materials will not provide a true picture of the fouling dynamics at a given site. With this in mind, the choice of the materials used in this study allowed for a broader understanding of the development of a fouling community.

Two stations seven kilometers apart were selected on the central western coast of India (figure 1). These stations were at Vijaydurg harbor (16°33'26.6; 73°20'17.3) and Musakazi-Jaitapur Bay (16°37'11.6; 73°20'23.9). Both are important fishing harbors (about 300-350 fishing trawlers operate in the area) along the Konkan coast. They are influenced by freshwater brought by the Vaghotan and Rajapur Rivers, respectively, during the

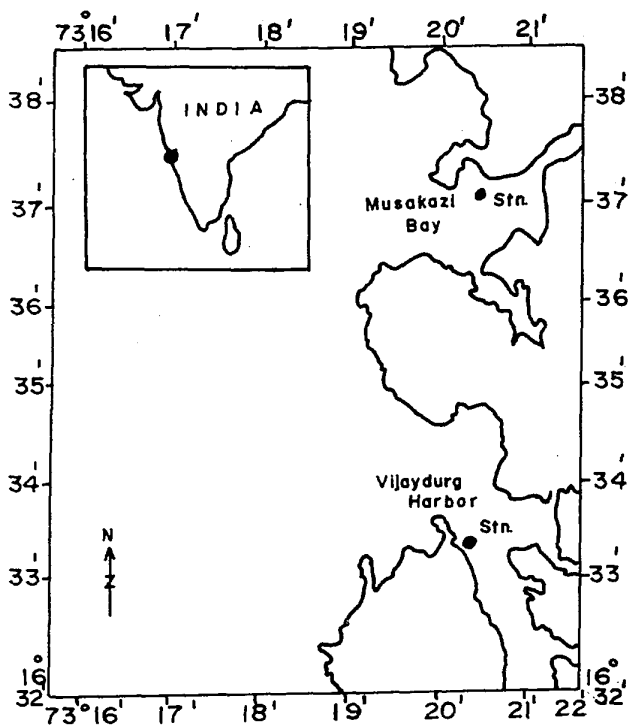


Figure 1. Test stations at the Vijaydurg harbor and Musakazi-Jaitapur Bay.

monsoon from June to September. The water column during high tide was six meters at both stations.

METHODS

Panels (10 × 15 cm) of unprotected mild steel, stainless steel, aluminum, copper, and brass were used. In addition, sets of cathodically protected panels of copper and brass served for comparison of data; cathodic protection was achieved using mild steel anodes. Panels were exposed at the subsurface (0.5 m below low tide) and near bottom (5 m) to allow for generalization of data for the entire water column. Data were collected for monthly and cumulative periods (2, 4, 6, and 12 months). Only unprotected panels were used for the monthly collections. The fouled panels were assessed for fouling biomass, abundance, and community structure. The

fouling community was classified according to the following composition: algae, hydroids, bryozoans, barnacles, oysters, and mussels. The abundance of each group was expressed in terms of the percentage of total area covered by the group. Salinity was monitored fortnightly. The studies were conducted from June 1989 to May 1990. However, data could not be collected from June to September at the Musakazi Station due to difficulties in obtaining access to the raft.

RESULTS AND DISCUSSION

Salinity: The salinity values at Vijaydurg Station ranged between 16.2 and 38.0 ppt at the subsurface and 23.5 and 38.0 ppt at near bottom. At Musakazi the values were between 11.2 and 37.5 ppt at subsurface and 12.2 and 37.5 ppt at near bottom. Salinity values were low during the monsoon at both stations.

Variations in the Abundance of Fouling Organisms: Tables 1 and 2 show the abundances of major fouling organisms on different surfaces at both stations.

Algae: Algal growth was confined to the subsurface and contributed to the increased biomass assemblage during certain months. Its incidence was higher on the monthly panels than on the cumulative ones. Of the nine species encountered, the most dominant were *Enteromorpha intestinalis*, *E. tubulosa*, and *Ectocarpus siliculosus*. Those species that were rare to moderately common were *Ectocarpus linza*, *C. fascicularis*, *Lyngbya majescula*, *Ulva rigida*, *U. fasciata*, and *Giffordia sandriana*. Algal settlement was conspicuous during October, February, and April at Musakazi, and abundant during October, July, and May at Vijaydurg.

Hydroides: This group of the fouling community is considered one of the initial macrofoulers (Karande 1968, Boero 1984). Hydroides were found to settle throughout the year with variations in intensity. They were abundant during August, November and from February to May at Vijaydurg, and peaked at Musakazi from October to December and March to May.

Bryozoa: This group was mainly represented by encrusting forms at both stations. Of the eight species, *Membranipora* sp. and *Hippoporina* sp. were important and were present on all the monthly panels. Similar observations were made at the port at Kakinada (Satyanarayana Rao and Balaji 1988). On cumulative panels, *Electra* sp. was abundant at both stations following the monsoon. The other species, which were rarely found, included *Bugula*

Table 1. Abundance of fouling groups on different metal surfaces in Vijaydurg harbor.

Month	Metal	Algae	Hydroids	Bryozoans	Barnacles	Oysters	Mussels
June	MS	-	+	-	+	-	-
	AL	-	++	-	++	-	-
	SS	++	+	-	++	-	-
July	MS	+	-	-	++	-	+
	AL	+++	++	-	+++	-	++
	SS	+++	+	-	++++	-	++
August	MS	+	++	-	++	-	-
	AL	-	++++	+	+++	-	+
	SS	+++	++	-	++++	+	+
September	MS	-	++	-	+	-	++
	AL	+++	-	-	+	-	+
	SS	+	+	-	+	-	+
October	MS	+	-	-	+	+	+
	AL	+++	++	++	+	++	+++
	SS	++	+++	+	+	+++	+++
November	MS	-	-	-	-	-	-
	AL	+	++++	++++	+	+	++
	SS	++	++++	++	+	++	+
December	MS	-	-	-	-	-	-
	AL	-	++	+++	++	-	+
	SS	+	+++	+	++	+	-
January	MS	-	-	+	+	-	-
	AL	-	+	++	+	-	-
	SS	-	++	+++	+	+	-
February	MS	-	+++	-	++	+	-
	AL	++	+	+	++++	++	+
	SS	-	++++	+++	+++	++	+
March	MS	-	++++	+	++	+	-
	AL	+	++	+	+++	++	+
	SS	+	++	+	+++	+	-
April	MS	-	++++	++	++	-	+
	AL	+	++	++	++++	-	-
	SS	-	+++	+++	+++	-	-
May	MS	+	++	-	+++	-	+
	AL	+++	+++	-	++++	-	+
	SS	+++	+++	-	++++	-	-

MS = mild steel; AL = aluminum, SS = stainless steel.

+ = 1-25%; ++ = 25-50%; +++ = 50-75%; ++++ = 75-100%.

Table 2. Abundance of fouling groups on different metal surfaces in Musakazi-Jaitapur Bay.

Month	Metal	Algae	Hydroids	Bryozoans	Barnacles	Oysters	Mussels
October	MS	+++	+	+	++	+	++
	AL	+++	++	++	++++	++	+
	SS	+++	++++	+	+++	++	+++
November	MS	+	+	-	+	-	-
	AL	++	+++	+	+++	+++	+
	SS	+++	++++	++	+++	++	+
December	MS	-	+	++	+	-	+
	AL	++	++	++	++++	+	-
	SS	+	+++	++++	++	-	-
January	MS	+	-	+	-	-	-
	AL	+	-	++++	+	-	-
	SS	-	+	++++	+	+	-
February	MS	-	+	+	+	-	-
	AL	+++	+	+++	++	-	-
	SS	+++	++	+++	+	+	-
March	MS	-	++	+	++	+	-
	AL	++	++++	+++	+++	++	-
	SS	++	+++	+	+++	+	++
April	MS	++	++	++	++	+	++
	AL	+++	+++	++++	++++	++	+
	SS	++	+++	++	+++	+	-
May	MS	+	++	-	++	+	+
	AL	++	++++	-	+++	+	+
	SS	++	+++	-	+++	+	-

MS = mild steel; AL = aluminum, SS = stainless steel.

+ = 1-25%; ++ = 25-50%; +++ = 50-75%; ++++ = 75-100%.

neritima, *Bugula* sp., *Scrupocellaria* sp., and *Parasmittina* sp. *Hippoporina* sp. grew in a wide salinity range, which indicates that they can tolerate wide fluctuations in salinity.

Sessile Barnacles: This group formed the major component of the fouling assemblage and was found almost throughout the year at both stations. *Balanus amphitrite* was the most dominant. The other species occasionally found were *Megabalanus tintinnabulum* and *Balanus amaryllis*. Two clear peaks were observed at both stations. At Musakazi, maximum settlement was from October to December and from March to May. At Vijaydurg, dense settlement was seen during July and August and from February to

May. This shows that at Vijaydurg, the first peak of barnacles was during the monsoon, whereas at Musakazi it was postmonsoon. It is not surprising to obtain peak barnacle settlement during low saline waters at Vijaydurg as Anil and Wagh (1988) also reported a similar observation at the Marmugao harbor in Goa. They observed barnacle settlement in saline water as low as 9.1 ppt. It is well known that barnacles breed throughout the year, however, the period of dense settlement varies from one location to another (Ganapati et al. 1958; Nair 1967 a, b; Karande 1968). All these authors attributed the differences in peak settlements to changes in salinity. However, in scrutinizing the results from various places, it is probable that barnacle settlement is controlled not only by salinity but also by other factors that collectively control this phenomenon.

Mollusca: A lone species of oyster, *Crassostrea gryphoides*, was found to settle at both stations. The overall settlement of oysters was negligible compared to other fouling organisms. Oysters were in moderate quantity from March to May at Musakazi and during November, February, and March at Vijaydurg. Their intensity increased in October at Vijaydurg and from October to November at Musakazi. Although settlement was rare to moderate on monthly panels, massive growth was observed on cumulative panels at near bottom at Vijaydurg. At Musakazi, they grew heavily over barnacles settled on panels (figure 2).

In general, mussel fouling at both stations was moderate. The *Modiolus* sp., though meagre, were found most of the year, except during June and January at Vijaydurg and January, February, and March at Musakazi. Conspicuous increases in spats of *Perna viridis* were noted in July and September to November at Vijaydurg and during October at Musakazi. The growth of *P. viridis* was restricted to the lower depths only at Vijaydurg on all types of panels, whereas they were rarely found there at Musakazi.

Other Foulers: The other organisms whose contributions were not significant were isopods, amphipods, decapods, and polychaetes. The settlement of serpulids was restricted to lower depths.

Fouling Biomass: From our data (figures 3, 4), it is evident that fouling activity continues throughout the year at both stations. This could be due to the continuous breeding activities of fouling organisms (WHOI 1952).

The data on the monthly fouling biomass showed one prominent peak during May at Vijaydurg and two peaks at Musakazi during October and May. Dense settlements of barnacles and hydroids were mainly responsible for the increased biomass in May. The major foulers in October at Musakazi were sessile barnacles, mussels, algae, and hydroids.

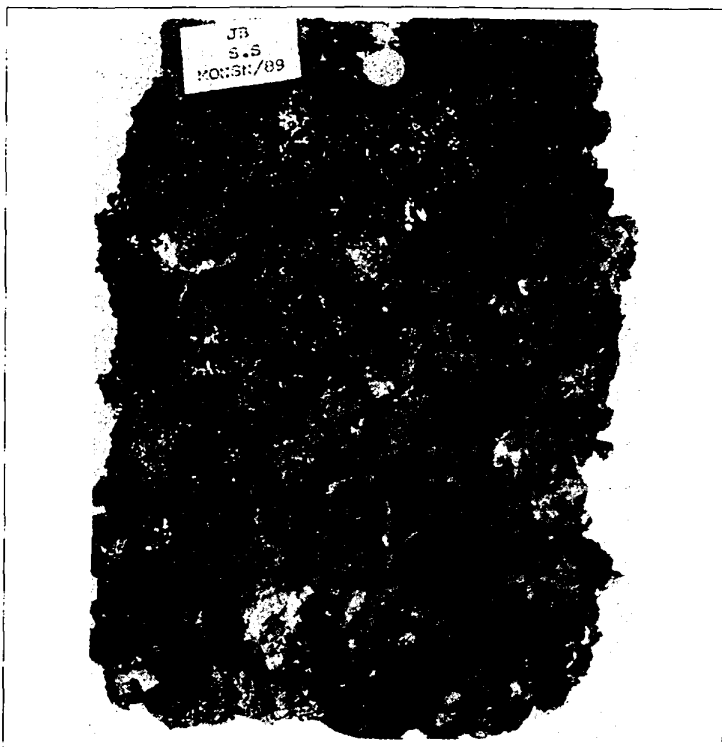


Figure 2. Panel showing heavy settlement of oysters growing over barnacles.

A depth-dependent pattern in the fouling biomass was observed only at Musakazi. There, the fouling biomass on monthly and cumulative panels was comparatively higher at the subsurfaces versus the near bottom.

Generally, the extent of fouling varies with the type, nature, surface texture, color, and degree of reactivity of materials (Raju et al. 1988). Of the materials used in the present study, the mild steel collected very little (negligible - 0.75 and negligible - 0.52 kg/m² at Vijaydurg and Musakazi, respectively) compared to aluminum (0.05 - 1.25 and 0.05 - 2.7 kg/m² at Vijaydurg and Musakazi, respectively) and stainless steel (0.05 - 1.85 and 0.05 - 0.96 kg/m² at Vijaydurg and Musakazi, respectively). No settlement was seen on the monthly panels of copper and brass. These differences were obviously due to the differences in the materials. The severe corrosion of the mild steel might have caused exfoliation of the settled organisms

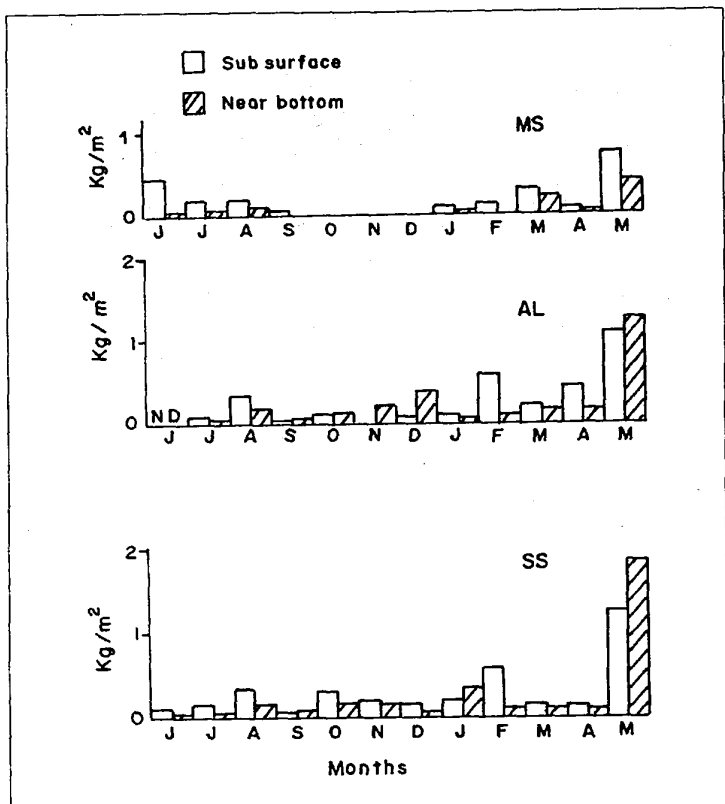


Figure 3. Fouling activity at Vijaydurg harbor on mild steel (MS), aluminum (AL), and stainless steel (SS) panels.

along with the corrosion product. Similar observations of the sloughing of biological materials from highly corrodible metals have been reported in the literature (Efird 1975, Raju et al. 1988). Aluminum and stainless steel, being passive metals, offered firm and stable surfaces for attachment. The lack of settlement on the monthly panels of copper and brass suggests the toxic effect of copper ions on the settling larvae.

Cumulative Panels: The cumulative panels were used to obtain an indication of the potential of fouling biomass build up in a locality for extended exposure periods of two to twelve months (figure 5). The fouling biomass

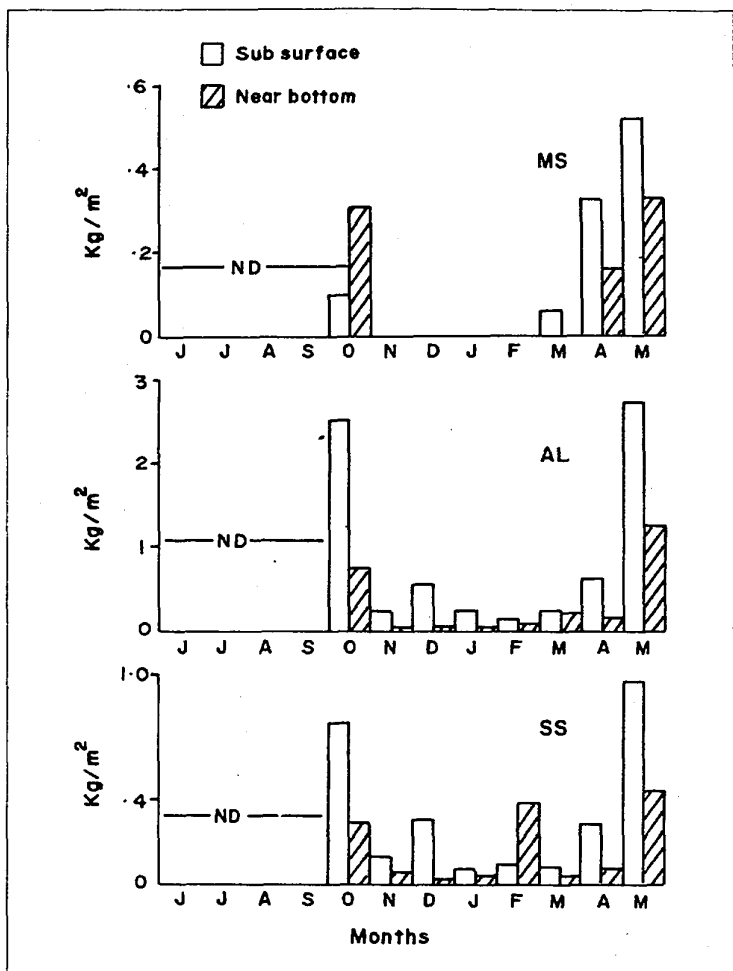


Figure 4. Fouling activity at Musakazi-Jaitapur Bay on mild steel (MS), aluminum (AL), and stainless steel (SS) panels.

values tended to increase with increasing exposures for all metals except aluminum exposed for 12 months at near bottom in Vijaydurg. Anil and Wagh (1988) and De Palma (1976) reported decreases of biomass on different substrata, whereas, Satyanarayana Rao and Balaji (1988) and Raju

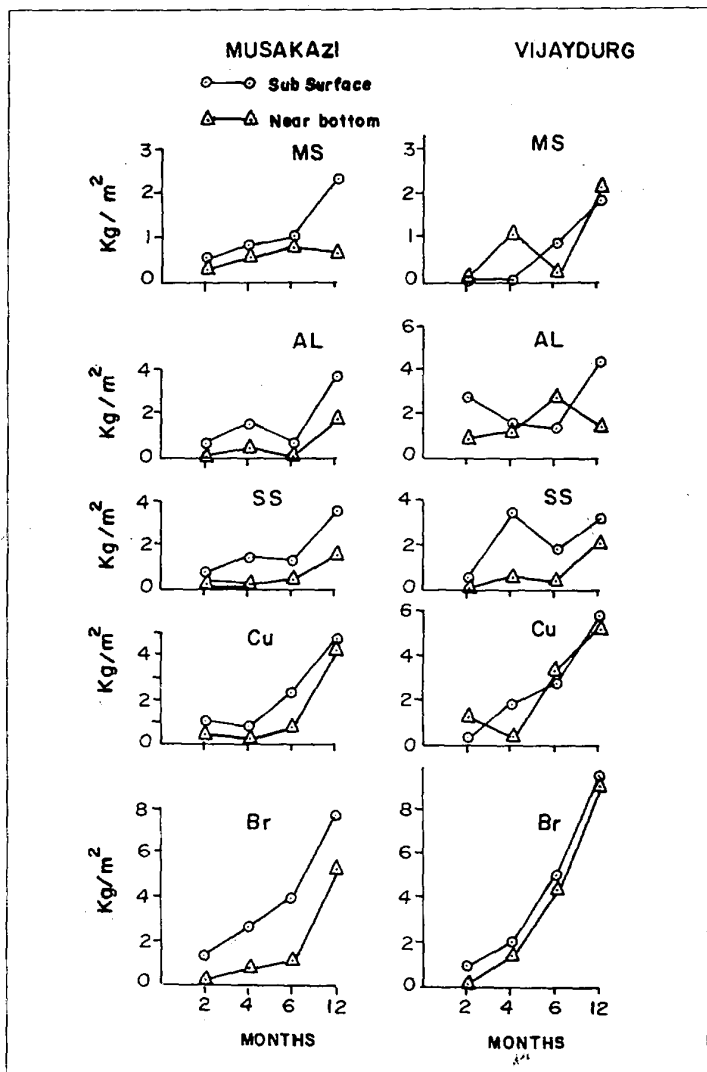


Figure 5. Fouling activity on cumulative panels on mild steel (MS), aluminum (AL), stainless steel (SS), copper (Cu), and brass (Br) at Musakazi and Vijaydurg.

et al. (1988) reported increases of biomass with increased exposure periods. Variations in the extent of fouling assemblages with the types of metals were noted. Mild steel had the minimum biomass (0.2 - 2.3 kg/m²) whereas brass the maximum (0.2 - 9.9 kg/m²). Higher biomass values were observed at the subsurfaces of both stations.

Fouling of Toxic-film Forming Metals: Unprotected copper and brass panels were free of any type of macrofoulers. This was probably due to the toxic effect of copper ions. Earlier reports showed that corrosion of copper greater than 10 µg/cm²/day can deter settlement of macrofoulers (WHOI 1952). Views vary on the action of copper ions on settling larvae. Some researchers noted that toxic ions are slowly released in seawater from the metal surface as a result of corrosion and poison the free swimming or settling stages of foulers (Ketchum 1948, Ferry and Riley 1946). Others (Efrid 1975, Crisp and Austin 1960, Dewolf 1946) showed that the fouling resistance of copper is not because of leaching alone but is due to a cuprous-oxide corrosion product that is toxic to the settled organisms. In our study, the cumulative panels of unprotected copper and brass were found to remain unfouled after twelve-month exposures to seawater. However, the cumulative panels of protected copper and brass were fouled more heavily than other metals. This indicates that because the metals were protected against corrosion, metal dissolution was checked and settlement was facilitated. Therefore, before using these metals for a specific application, it must be decided whether the protection of the metals against corrosion is important for antifouling.

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