# 42. Recruitment of the Fouling Bivalve, *Mytilopsis sallei* (Recluz), on Metallic and Nonmetallic Surfaces at Visakhapatnam Harbor, India

*G.J.V.J. Raju, K. Satyanarayana Rao, and B. Viswanadham*

*Mytilopsis sallei* (Recluz) has met with astonishing success at Visakhapatnam harbor since its introduction in the 1960s. It completely dominates the fouling communities in the inner harbor and is a source of grave concern. In this paper, data obtained on the recruitment of this important fouling species on different substrata (timber, glass, asbestos, copper, aluminium, mild steel, brass, rubber, asphalt) are presented. A 12-month panel study revealed that recruitment of this bivalve was heaviest on asbestos followed by timber and lightest on copper and brass, with the other substrata falling in the intermediate category.

## INTRODUCTION

In 1967, the dreissinid bivalve, *Mytilopsis sallei* (Recluz), was first noticed in Indian waters at the Southern Lighter Channel of Visakhapatnam harbor, Andhra Pradesh, India. It is believed that this species was introduced into the Indo-Pacific region from Central America via the Panama Canal and Fiji through ship fouling (Ganapati et al. 1971, Morton 1981). While in its home range of Central America, it was never reported as an important fouling organism, At Visakhapatnam, this opportunisitc species met with great success in colonizing, in enormous numbers, all intertidal and sublittoral structures, floating craft, ships, and other vessels. In the process, it gradually altered the fouling picture in the harbor, suppressing the original fouling communities at the infestation sites. In consequence, today, it is the most dominant species in the fouling communities throughout the inner harbor. Forming enormous clusters—several centimeters thick—that must be regularly removed. This highly fecund and fast growing species contributes over 90% of the total fouling biomass at the northern and northwestern arms, turning basin, and part of the entrance channel, adding great weights to submerged structures (figure 1). Morton (1981) considered this species to be currently undergoing a population explosion, removed as it is from the physical and biotic controls that normally hold biological species in check in their home range. Giving due consideration to its fouling potential, Morton warned against its further spread in the Indo-Pacific to the detriment of man's activities and endemic fauna. In fact, the species has already invaded Bombay harbor (Karande and Menon 1975) and Victoria harbor, Hong Kong (Huang and Morton 1983). In view of the importance of this major fouling pest at Visakhapatnam, a number of studies on the biology, ecology, and physiology of this species have been undertaken since 1967. These were reviewed by Morton (1981). Elsewhere in India, at Bombay harbor, Karande and Menon (1975) studied its biology. However, there is a paucity of information regarding quantitative aspects of this bivalve's settlement on different substrata. For this reason, a study was conducted during 1982-1983 in Visakhapatnam harbor using different materials. The results of this investigation are reported in this paper.

## MATERIALS AND METHODS

The materials tested were: timber—*Mangifera indica* (organic substratum); glass, asbestos, rubber, asphalt (inorganic materials); copper, brass, aluminum (nonferrous metals); and mild steel (ferrous material). The sizes of the test panels were 15 × 8 × 2 cm for wood and 15 × 8 × 2 mm for the other materials. The panels, placed in suitably designed wooden frames with grooves, were kept immersed 0.3 m below the low water mark at the naval base jetty, Visakhapatnam. Two series of test-panel exposures were carried out: short term (A series) and long term (B series). The short-term panels were exposed for one month and replaced after every observation. This was carried out using only one material—timber—to obtain information on the seasonality of recruitment. In the B-series, five panels of each material were simultaneously exposed at the commencement of the experiment and one panel removed at intervals of 1, 3, 6, 9, and 12 months. The data on the long-term series provided information on cumulative biofouling accumulation.

*M. sallei* was periodically removed from each of the panels and wet weights taken. The material was then oven dried at 100°C until a constant weight was reached. The dry-weight values (gm/m$^2$/unit time) thus obtained provided a statistical measure of fouling concentration and served as an index of the biofouling productivity of *M. sallei*. In the A-series, organisms on the panels were counted. Sets of copper and glass slides (15 × 8 cm) were also immersed, intermittently, on a short-time scale and closely examined for early recruitment.

Temperature and salinity data were collected at weekly intervals at the



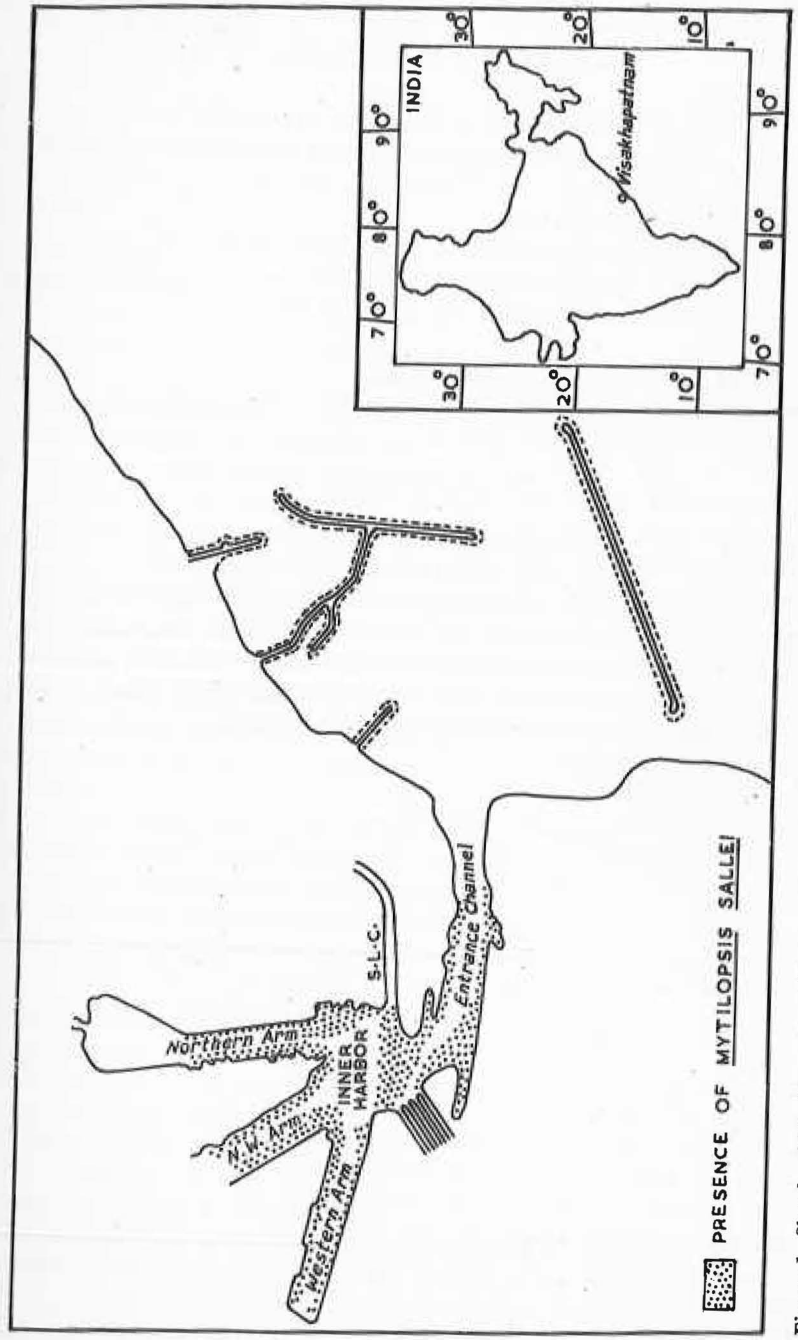


**Figure 1.** Sketch of Visakhapatnam harbor showing the occurrence of *Mytilopsis sallei*.

dock site. The study was conducted from November 1982 to October 1983.

## RESULTS AND DISCUSSION

The temperature and salinity data obtained for the period of investigation are presented in figure 2. The maximum recorded temperature was 32.5°C (May) and the minimum 24.4°C (December). Salinity ranged from 34.0 ppt (April) to 16.2 ppt (October).

Information on the seasonality of recruitment of *M. sallei* gathered from A-series panels is presented in figure 3. The biomass values (wet and dry weights) from B-series panels are given in figure 4.

### Seasonality of recruitment and abundance

It can be seen from figure 3 that *M. sallei* was recruited throughout the year on monthly panels. From this, it was inferred that breeding occurs throughout the year in the species, similar to several other important fouling organisms from this harbor such as *Balanus amphitrite*, *Hydroides norvegica*, *Electra bengalensis*, and *Bugula neritina* (Ganapati et al. 1958, Purushotham and Satyanarayana Rao 1971).

A perusal of the hydrographical conditions (figure 2) indicates that the temperature variations are limited for this harbor (8.1°C range) but that salinity fluctuations were considerable (18 ppt range). In earlier studies, salinity was considered to play a more significant role in determining the seasonality and abundance of fouling organisms of this harbor (Purushotham and Satyanarayana Rao 1971, Satyanarayana Rao and Ganapati 1978). Studies conducted by Ganapati et al. (1971), Kalyanasundaram (1975), Ramachandra Raju et al. (1975), Karande and Menon (1975), and Morton (1981) showed that this bivalve was extremely tolerant to fluctuating salinity conditions (0.083 to 50 ppt). Kalyanasundaram (1975) observed that spawning occurred in salinities up to 35 ppt but further development of fertilized eggs was more predominant in salinities below 25 ppt.

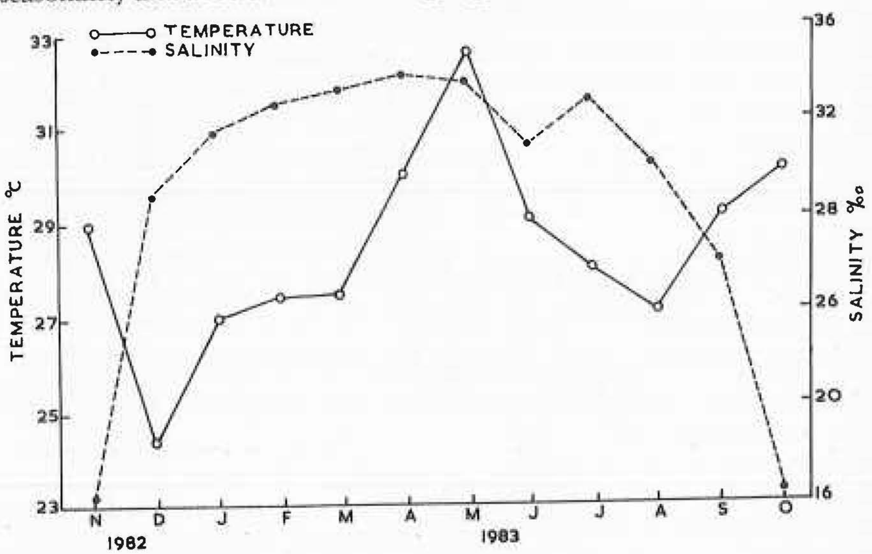


**Figure 2.** Hydrographical parameters at the test site.



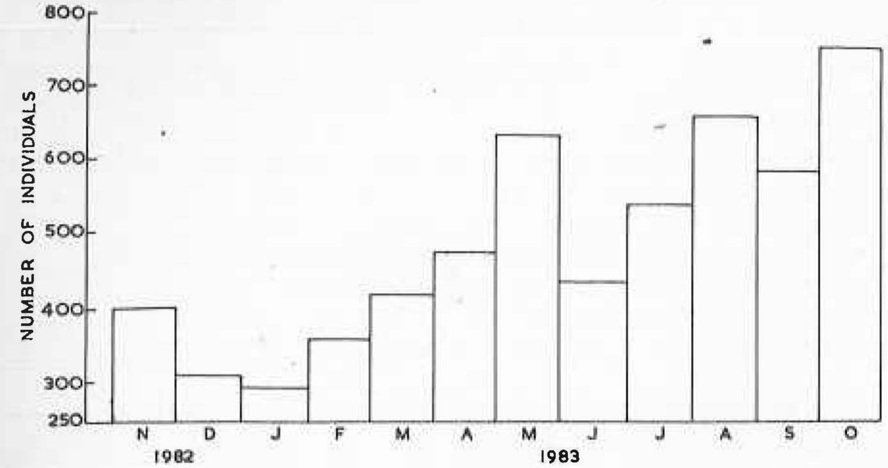


**Figure 3.** Monthly recruitment of *Mytilopsis sallei*.

Our results, in general, lend additional support to these earlier observations, but are different from the pattern of breeding noted at Bombay harbor by Karande and Menon (1975). There they observed that this species had a very short spawning period (October to December). They attributed this to the simultaneous participation of all females in spawning in one single short burst and to the widely occurring consecutive sexuality with a single sex reversal.

### Biomass

Heavy accumulation of *M. sallei* occurred throughout the period of study. The maximum value of 117 kg/m$^2$/year recorded (on asbestos panels) compares favorably to some of the highest figures quoted in the fouling literature. The quantitative data on the fouling biomass from Indian harbors are rather meagre and only in recent years has some attention been given to this. While the available data do not permit accurate comparisons (e.g., differences exist in studies conducted at different harbors in relation to periods of immersion, substrata used, and value placed

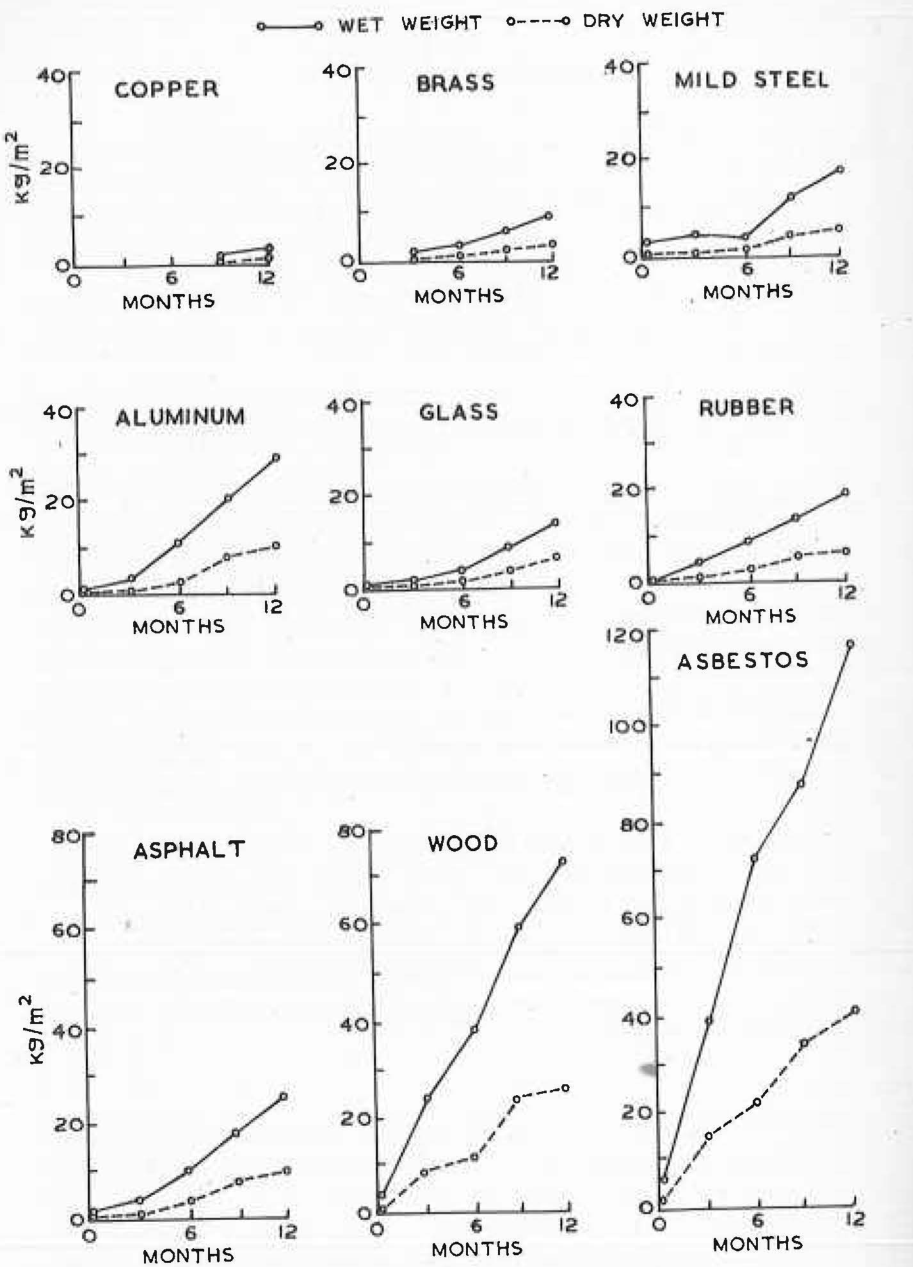


**Figure 4.** Biomass (wet weight •————•, dry weight o............o) of *Mytilopsis sallei* on different materials.



on dry/wet weights) they, nevertheless, serve as indicators of fouling biomass at the various harbors. For example, Santhakumaran et al. (1983) gave the maximum fouling recorded at Madras as 50 $kg/m^2/yr$ and at Bombay as 38 $kg/m^2/6$ months. Renganathan et al. (1982) mentioned a figure of 17–18 $kg/m^2/yr$ at Tuticorin. Hameed and Balasubramanyam (1977) recorded a maximum of 0.29 $kg/m^2$ month (dry weight) at Cochin. It is clear from the above that the biomass development achieved by *M. sallei* at Visakhapatnam (117 $kg/m^2/yr$ wet weight or 40 $kg/m^2/yr$ dry weight) has rarely been matched elsewhere in India.

In other locations, however, extensive mussel fouling of the type witnessed at Visakhapatnam has been reported in the literature. Zvyagintse et al. (1982) mentioned that the bivalve, *Mytilus viridis*, created an enormous biomass on all anthropogenic substrata in the Far East Marine Basin, USSR. They observed that during 18 months of operation along the coast, ships in this area were completely covered with a "fur coat" of large mussels, contributing biomass values of up to 56 $kg/m^2$. It was estimated that an average of 8 million kilograms of these mussels had to be removed annually from ships entering and leaving Peta Bay alone. They further reported that these mussels developed heavily not only on low-speed ships but also on those sailing at a speed of 1.3 knots.

Figures of fouling biomass comparable to these have seldom been reported. One of the highest values we found in the literature was the report of Riggio (1979) who observed an accumulation of 14 kg of wet weight or 2 kg of dry weight per panel (20×30×0.4 cm) of the ascidian, *Ciona intestinalis*, at Palermo harbor, Sicily. This is equivalent to 112.9 $kg/m^2$ wet weight and 17 $kg/m^2$ dry weight, respectively, in two months. Santhakumaran et al. (1983) also mentioned that the same species achieved a biomass development of 76 $kg/m^2/yr$ at Trondheim, Norway.

It is interesting to note that many workers, including Depalma and Ross (1970), consider a figure of 5 $kg/m^2/yr$ (dry weight) as very severe fouling (on a severity scale of 1–6). The figures obtained at Visakhapatnam clearly reveal the potential of *M. sallei* as a problematic fouling species in Indian harbors.

### Recruitment on different substrata

No surface tested was free from *M. sallei* fouling at this harbor, but considerable differences were found in the quantities accumulated on different substrata. Maximum fouling occurred on asbestos and wood and minimum on copper and brass. It is well known that a number of factors (physical, chemical, and biological) influence the development of fouling communities. While temperature and salinity are credited with broadly influencing the geographical distributions of individual species, their seasonality, and abundance, much emphasis is placed on the chemical composition and toxicity, corrosion state, and roughness of the substrata itself as factors exerting marked influence on the affixation of sedentary organisms. In view of the importance attached to these factors, the observations made in this study are considered in detail in relation to them. It should be noted that because there is enormous variation between panels on the same rack, more replications are needed to say, positively, that the treatments are really different for reasons other than chance.

**Metallic surfaces**

Several researchers working on marine fouling and corrosion of exposed metals (Clapp 1948; Efird 1975; Laque 1945, 1972; Srinivasa Rao 1977b) recognized, in general, three main categories of metals and metal alloys during the course of their investigations on marine fouling and corrosion: toxic film-forming metals, highly corrodable metals, and passive metals. In our study, toxic film-forming metals are represented by copper and brass, highly corrodable metals by mild steel, and passive metals by aluminum. The differences noted in the behavior of these metals, in respect to fouling by *M. sallei*, present some interesting aspects, which are presented below.

*Copper and Brass:* Of the different metals tested, copper and brass had minimal fouling, with the least being on copper. This is probably due to the well known toxic effect of copper. A great deal of work in the past was done on the mechanisms involved in the antifouling action of copper-based alloys. The classical concept of action, as cited in the works of Ketchem (1948), Ferry and Riley (1946), and Ferry and Caritt (1946) postulates that toxic (copper) ions are slowly released in seawater from the metal surface as a result of corrosion and that they poison the free-swimming or settling stages of the foulers (a controlled rate of release of the toxic ion at 10 $\mu m/cm^2$/day from antifouling compositions was considered to be the critical minimum level required for preventing barnacle settlements). This view was held by the field for several years. Later, studies by Efird (1975), Crisp and Austin (1960), and Dewolf (1946), however, showed that the fouling resistance of copper-based alloys need not be attributable to the leaching factor alone and that it is the adherent cuprous-oxide corrosion product that is toxic to the settled organisms. This view was strengthened by the fact that barnacle cyprids, on which most of the work was done, required 6-13 mg/l of copper concentration to be killed, which is much greater than the maximum solubility of copper ions in seawater (0.3-0.7 mg/l). This indicated that mechanisms other than leaching were involved in the antifouling action of copper (Srinivasa Rao 1977a). This theory on the mode of antifouling action by contact poisoning and not by leaching of copper is increasingly gaining acceptance.



It is interesting to note that in our study, on numerous occasions, large numbers of settling stages of *M. sallei* (straight-hinged larva) were found on copper slides within two to three weeks immersion. However, the community failed to develop further, as indicated by the meager development of biomass noted on the three- and six-month panels.

Examination of the young stages further revealed the feeble development of byssal threads in the specimens found on the two- and three-week panels; these young forms were easily lifted off the surfaces when subjected to even the slightest disturbances. The absence and meager recruitment of *M. sallei* observed on the three- and six-month panels may be due either to the death of the organisms themselves or their failure to develop a full byssal-thread complex in the initial recruitment period. It is of interest to note in this context that considerable work has been conducted on the effects of metal toxicants on byssal-thread production in another bivalve, *Mytilus edulis,* (Martin et al. 1980). These studies clearly revealed that toxic metals interferred with the development of the adhesive mechanisms.

In the absence of experimental data on the effects of copper on survival or byssal-thread production in the juvenile *M. sallei,* it is not possible to arrive at any immediate conclusions regarding the exact mechanisms involved in the elimination of young *M. sallei* from these surfaces. In view of the known sensitivities of molluscs to copper, it is possible that the antifouling action of copper may be due to its action as a contact poison (for the larvae). Much further work, obviously, is needed in this direction.

During the present study, it is interesting to note that on the three- and six-month panels, the only organisms recruited in any significant numbers were bryozoans—a group known to be extremely tolerant to copper toxicity. Thin films of bryozoan colonies were seen spreading over the surfaces with small bivalves on them. The gradual accumulation of fouling and deposits of corrosion products apparently retarded the corrosion, and the bivalves were able to establish on the old panels.

*Brass:* The brass panels exhibited a similar trend, but recruitment was relatively higher on this metal.

*Mild Steel:* The pattern of development of *M. sallei* on mild steel is interesting. All panels had good growths in three months, but in six months, most had only meagre recruitment. This is because settled organisms are sloughed off periodically, together with corrosion products, which are formed at a fast rate in this metal during the initial exposure periods. De et al. (1977) studied the corrosion rate of selected metals at Visakhapatnam and showed that mild steel corroded at a rate of 49.32 m.d.d. or 9.0 mpy/6 months, which is considered quite fast. Similar observations of the sloughing of biological material from highly corrodable metals were reported in the literature (Efird 1975, Srinivasa Rao 1977b). In the older panels, however, corrosion appears to have been retarded or obscured by gradual accumulation of fouling as well as deposits of products.

*Aluminum:* Aluminum is a passive nontoxic metal. Retention of fouling was better on this metal than on mild steel and the fouling exhibited a gradual increase.

**Nonmetallic surfaces**

Fouling was generally heavy on nonmetallic panels. The inert and rough asbestos panels had maximum growths throughout, followed by wood. Least fouling occurred on smooth glass plates; asphalt and rubber occupied an intermediate position. It is widely believed that texture and surface roughness play a significant role in influencing the recruitment of fouling organisms, especially on nontoxic, nonmetallic surfaces. Development of fouling communities is generally believed to be poor on smooth surfaces (Corlett 1949, Pomerat and Weiss 1946, Barnes and Powell 1950) although individual species are known to exhibit varying preferences in relation to texture during settling stages (Crisp and Ryland 1960). In a study conducted at Miami, Florida using panels of asbestos, wood, plastics, and smooth glass, Pomerat and Weiss (1946) found that the development of fouling was heaviest on asbestos and least on smooth glass. Our results exhibit a similar trend. Coe and Allen (1937), Riggio (1979), and Kawahara (1962) considered hard, porous, and fibrous surfaces, such as concrete or cement blocks, as highly conducive to fouling developments and used these panels in their studies. Wood is also considered a favorable substratum for settlement. However, in the literature, instances of differences in the settlement of fouling organisms between different timber species were noted and were generally attributed to surface contour (whether closely set) and chemical composition. Daniel (1953), for instance, found barnacle cyprid settlement to be less severe on timber panels such as teak, which has a close grained surface and possesses certain alkaloid and resinous substances, than on mango panels. No conclusions can be drawn from our study on this as only one timber species, *M. indica* (mango), was used. Rubber and asphalt—soft, flexible materials—had accumulations intermediate between the dense settlements observed on asbestos and wood and the poor settlements on glass. Between the two, asphalt had more fouling, probably attributable to its having more ridges, depressions, and undulations than rubber. Interruptions in surface contour might act as centers for aggregation of sessile organisms. Smooth glass appeared to have the least amount of fouling, and was especially poor, initially, on the B-series panels (up to six months). However, glass



slides immersed for shorter periods revealed the presence of young *M. sallei* in fairly good numbers even after two or three weeks of immersion, indicating that the smooth surface was not altogether unfavorable for their recruitment. In view of this, the reasons for the poor retention and meagre development of the *M. sallei* community on the B-series panels up to six months are not clear. An interesting observation that should, nevertheless, be noted in this context, is that the attachment of young *Mytilopsis* on these smooth surfaces was extremely loose, unlike on harder surfaces (asbestos or wood). It is possible that the newly settled stages are more easily washed away and dropped off from these smooth surfaces. On the older panels, the surviving bivalves appeared to provide a favorable substratum for further recruitment, as reflected in the increased biomass weights on the panels.

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