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Colonization of marine foulants at a power plant site

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Abstract. Observations were made on the colonization of test panels (8 × 5 cm) by fouling organisms in the coastal waters and the cooling circuit (forebay) of Madras Atomic Power Station for a year. In coastal waters, hydroids settled as a pioneer species followed by barnacles and ascidians, whereas at the forebay, sea anemones were the important settlers. Species abundance, diversity indices and fouling biomass showed relatively low values at the forebay as compared to coastal waters. Species richness however was more in forebay than in coastal waters. Low species diversity with high species richness indices observed at the forebay could be attributed to species selection under altered environmental factors (chlorine levels, high flow rates and lack of predators).

Keywords. Power plant; fouling; succession.

1. Introduction

The settlement and growth of fouling organisms on surfaces associated with the power plant cooling water systems can interfere with the efficient operation of the plant (Hillman 1977). An evaluation of the type and abundance of such fouling communities from the cooling circuit of power stations provide information not only regarding efficiency of antifouling treatment adopted in such systems but also about the impacts of such antifoulants on the local ecosystem (Markowski 1959). Moreover, most of these organisms are sedentary or semisessile and thus are best indicators to assess any stress to the ecosystem.

Several studies from Indian coastal waters (Karande 1983; Satyanarayana Rao and Balaji 1987; Nair *et al* 1988; Sasikumar *et al* 1989) have reported very heavy fouling biomass build-up. Reports in the literature also indicate possibility of fouling biomass levels being different even in adjacent habitats. Most of the reports of the Indian authors have so far been on the development of fouling communities in natural habitats, there being very little data available on the fouling communities in impacted habitats. In the present paper, observations on the colonization of fouling organisms in a natural habitat (coastal waters) and inside the cooling circuit (forebay) of Madras Atomic Power Station (MAPS) are reported.

MAPS is located approximately 65 km south of Madras city, on the east coast of India. The power station uses seawater for cooling the condensers. Seawater is drawn through a 468 m long sub-seabed tunnel (figure 1) and is discharged through an outfall structure. Seawater enters the tunnel through subsurface intake gates (1 m depth) and reaches the forebay. From the forebay seawater is pumped at a rate of 35 m^3/s for cooling the condensers. Chlorine is used as a biocide to reduce settlement of foulants in the cooling circuit. Chlorine dosing levels are maintained in such a way as to obtain a chlorine residual of 0·5 to 1 ppm at the forebay. The

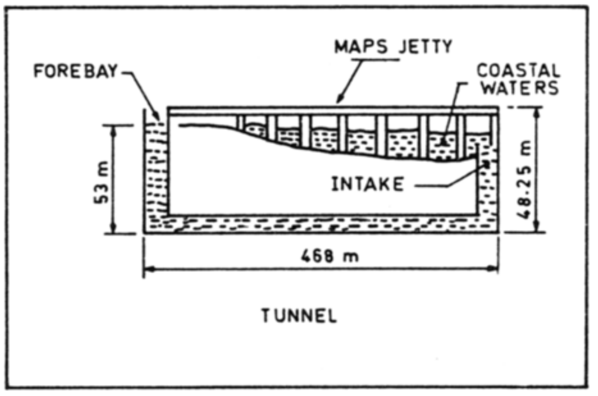


Figure 1. A schematic view of MAPS seawater tunnel.

forebay environment is characterized by the presence of chlorine residuals, high flow rates and absence of predators of common fouling life such as crabs, molluscs, echinoderms etc. and is thus quite different from coastal waters.

2. Materials and Methods

Twentyfour teak wood panels (each 8×5 cm) were suspended on mild steel frames from MAPS jetty as well as forebay at a depth of 1 m below the lowest low water of spring tides. One panel from each location was withdrawn every 15 days and macrofoulants were analysed quantitatively and qualitatively during 1986–87. A few panels from this series were lost after 250 days of immersion at the forebay. In addition, short-term panels were exposed for every 15 days at the same stations. Shannon Weaver diversity index (H) (Stirn 1981) and Menhinick's species richness index (d) (Odum 1969) were used to calculate the species diversity and richness respectively from the panel data. Following formulae were used to calculate indices.

$$\text{Diversity index } (H) = -\Sigma\,(ni/N \log ni/N), \tag{1}$$

where ni = importance value of the species and N = the total number of species.

$$\text{Richness index } (d) = S/(N)^{\frac{1}{2}}, \tag{2}$$

where S = importance value of the species and N = total importance.

3. Results

The data on seasonal variations in settlement of principal fouling organisms observed in the coastal waters and forebay are given in figure 2. In coastal waters (MAPS jetty), barnacles settled throughout the year, whereas at forebay, they were found only during February and August. At the forebay, hydroids settled from February to April with peak growth (50% coverage) in February. However, during other periods, they were totally absent on panels at this site. Though ascidians settled in coastal waters from April to August, they did not settle on panels immersed at the forebay. Sea anemones settled in large numbers from February to

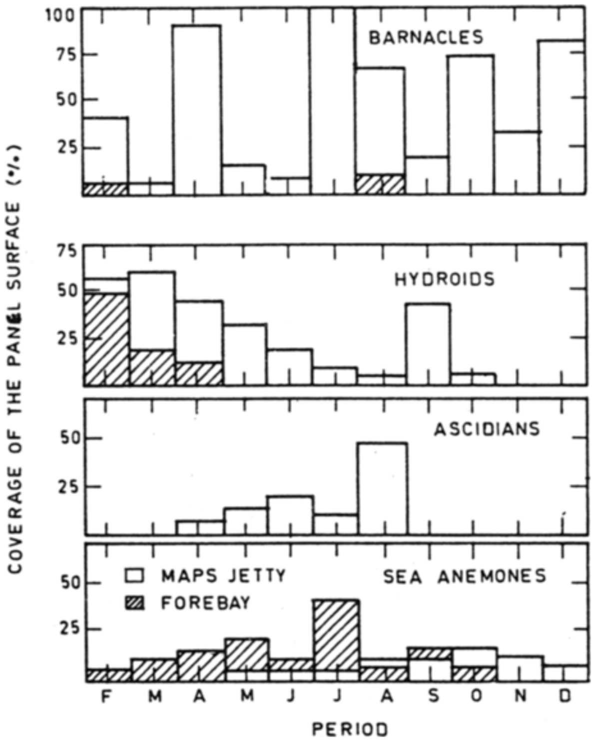


Figure 2. Seasonal settlement of principal fouling organisms in Kalpakkam coastal waters (MAPS jetty) and forebay; data collected from short term panels (15 days) at 1 m depth during 1986–87.

October at the forebay whereas settlement of this group was sparse in coastal waters except from September to December.

In coastal waters, fresh panels exposed for 15 days were completely covered with barnacles and hydroids (figure 3). After 50 days, hydroid colonies declined considerably and ascidians settled on the panels for the first time. Ascidians were the dominant group after 100 days. They covered most of the barnacles settled earlier. However, ascidian population dwindled after 200 days and disappeared altogether. Settlement of barnacles and sea anemones was also observed during this period. At the forebay, hydroids were the first to colonize and were abundant on 40-day old panels. Sea anemones settled after 40 days and covered 75% of the area in 125 days. However, sea anemone population declined after 160 days.

In the coastal waters, species diversity indices of foulants were characterized by 3 maxima (after 80, 200 and 275 days) and 3 minima (after 110, 225 and 300 days) (figure 4). Species richness indices showed two notable maxima, after 200 days (0·19) and 300 days (0·29) and 3 minima (after 100, 150 and 250 days) (figure 5).

Biomass values on short-term panels in coastal waters ranged from 9 g/100 cm^2 in March to 51 g/100 cm^2 in January (figure 6). Similar data on biomass in the forebay ranged from 0·5 g/100 cm^2 in October to 12·6 g/100 cm^2 in February. In coastal waters, long-term panels registered a maximum biomass of 65 g/100 cm^2

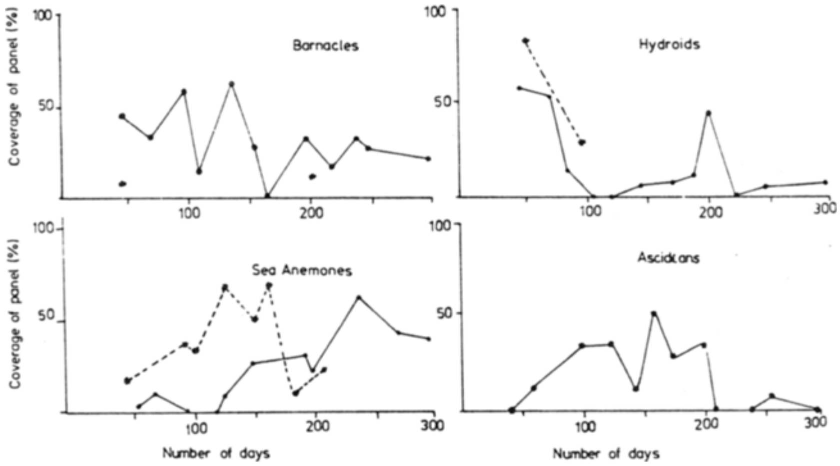
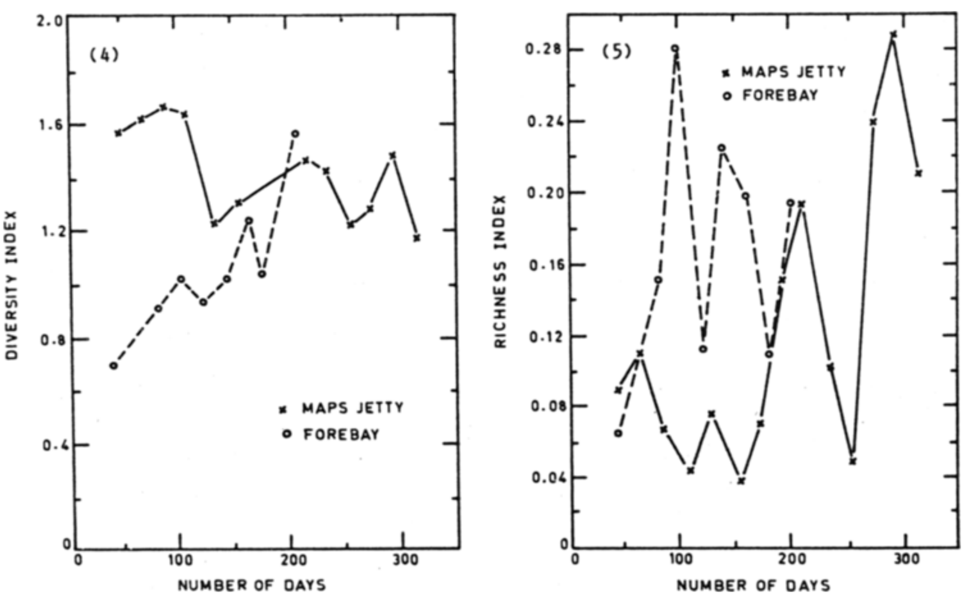


Figure 3. Settlement and colonization of principal fouling organisms on long term panels in coastal waters (MAPS jetty) and forebay during 1986–87. (●), MAPS jetty; (∗) forebay.



Figures 4 and 5. Shannon Weaver diversity indices (H) (4) and richness indices (5) of fouled panels (long term series) exposed in coastal waters (MAPS jetty) and forebay during 1986–87.

(after 150 days) whereas maximum at the forebay was 13·3 g/100 cm^2 after 170 days (figure 7).

4. Discussion

The study has helped to bring out the differences in the settlement pattern of

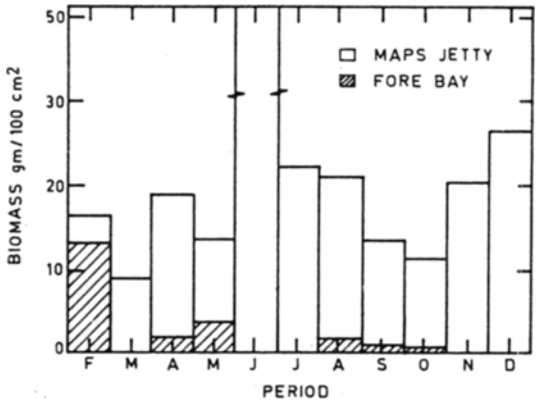


Figure 6. Seasonal variation in fouling biomass in coastal waters (MJ) and forebay (FB) during 1986–87. Data represent wet weight in g/100 cm^2 from short term panels.

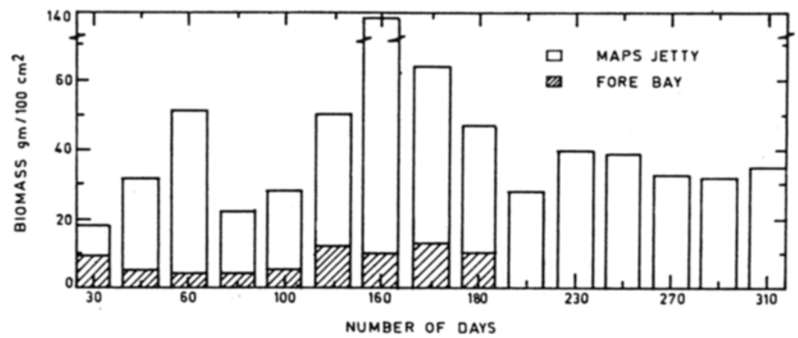


Figure 7. Cumulative biomass of foulants (long term series) in coastal waters (MJ) and forebay (FB) during 1986–87. Data represent wet weight in g/100 cm^2.

macrofoulants, their species diversity and biomass levels between coastal waters and forebay. While in coastal waters macrofoulants showed heavy settlement throughout the year, their settlement has been relatively low at forebay. Thus, barnacles and hydroids showed poor settlement in the forebay and ascidians, a group common in coastal waters were totally absent in the forebay. Sea anemones settled in larger numbers in forebay as compared to coastal waters. It looks reasonable to speculate that the presence of chlorine residuals, high flow rates and absence of predators could have made the forebay a substantially different environment from the coastal waters leading to the development of a different fouling assemblage. Such differences in colonization pattern between adjacent sites has also been observed by Sutherland (1981).

In a natural habitat, development of a fouling community is influenced by seasonal variations in larval recruitment, competition by dominant species and frequency of disturbance by other forces including predation (Sutherland 1981). During the process of colonization, these factors may influence abundance of species and often lead to total disappearance of many species. Such selection pressures eventually lead to the dominance of a better adapted competitively superior species. In open coastal waters, such dominance by superior species appears to be a periodic phenomenon and no single species dominates the community for a very long time. This is mainly due to the frequent variations in larval abundance and settlement in open coastal waters (Raymond 1983). Under such conditions, heavy settlement of a species can eliminate a 'climax species' (Odum 1969). Sutherland (1981) suggested the term 'stable point' to describe the succession of fouling organisms and preferred this expression to the term 'climax' in this context. Such stable points can also contribute to heavy biomass build-up on a surface. Development of such heavy fouling biomass on harbour structures has been reported from Bombay (Karande 1968) and Visakhapatnam (Satyanarayana Rao and Balaji 1987) harbours, wherein *Mytillopsis sallei* has been the dominant species. In the present instance in coastal waters, the coverage of asidians on the panel has resulted in total disappearance of barnacles and other fouling organisms. However, ascidians dropped off from the panels after a while. This was followed by settlement of barnacles and hydroids once again. Thus, settlement and colonization of ascidians has been a major event in the succession of the fouling community in this area. Ascidians can therefore be considered as a temporary 'stable point' in the fouling community development in the coastal waters. However, such a stable point was absent at the fore-bay. Moreover, sea anemones, a major settler in the fore-bay appear to have had no significant influence on the nature of fouling community development.

Species diversity indices of foulants from the test panels showed relatively low values at forebay as compared to coastal waters. However, indices of species richness was high at forebay. Sutherland (1981) observed a decline in number of species in a polluted habitat at Puget Sound as compared to an unpolluted site. It appears reasonable to presume that such low species diversity and high species richness at forebay could be a result of selection pressures at this location.

At the forebay, seasonal and cumulative biomass data also showed low values as compared to coastal waters. Maximum fouling biomass observed at the forebay was approximately 10 times lower than that of coastal waters. Relini (1984) also reported similar differences in fouling biomass due to poor settlement at the outfall of Torvaldaliga Power Station.

Thus, species diversity, biomass and colonization pattern of macrofoulants showed significant differences between forebay and coastal waters. Further studies on the influence of selection pressures on community development in impacted environments are desirable.

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