

Biology of Fouling in Neendakara Port, a Tropical Estuary in the South West Coast of India

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Species composition and some aspects of the biology of the fouling community in Neendakara port (southwest coast of India) has been examined for a period of one year. Fouling organisms were collected with a system of glass panels exposed for varying durations and during different months in the port. One species of sponge, nine species of coelenterates, thirteen species of polyzoans, four species of mud-tube dwelling polychaetes, four species of serpulids, one species each of mud-tube forming amphipod and tanaid, two species of oysters, six species of mussels and not less than eight species of tunicates were the macro foulers which settled over the panels. Monthly and seasonal settlement of the different species have been recorded. Fouling has been a continuous process occurring throughout the year in Neendakara port with slightly fluctuating biomass and considerably varying species composition. Alternate species dominance of marine and brackish water forms has been an important feature of fouling in the area. Number of species of the sedentary fouling animals represented on test panels has been high during the highly saline premonsoon period and low during the monsoon period.

Interest in the problem of marine fouling brings together operators of vessels, naval architects, harbour engineers, anti-fouling paint manufacturers and all those concerned with the maintenance of ships and various underwater installations. Diverse talents of biologists, chemists, physicists and engineers are required for a thorough understanding and effective control of fouling. However, basic knowledge indispensable for any advanced study of the problem and to formulate effective preventive measures is the biology of the organisms concerned with fouling, because fouling is a biological phenomenon resulting from the settlement and growth of animals and plants over submerged objects. The severity of the problem of fouling can be realised from the recent estimate that in the United States, military and commercial marine interests suffer an annual loss of about 500 million dollars owing to marine fouling, without including indirect disadvantages such as higher fuel costs and increased frequencies of dry docking (Persoone, 1977). Nearly a decade ago, it was estimated that the mechanised fishing crafts of India alone would require approximately 4.5 million rupees annually to keep their

hulls free from fouling and to have a smooth sailing, that too, for a limited period only (Balasubramanyan *et al.*, 1972). The magnitude of the problem can only be roughly predicted since estimates covering all aspects of loss owing to fouling are very scarce and are extremely difficult to obtain.

Fouling community includes sessile or sedentary representatives from almost all the invertebrate phyla and a few of the lower chordate divisions. Besides, many free living organisms are also found among the sedentary representatives. The structure and composition of the fouling community exhibit wide temporal and regional variations governed mainly by varying hydrographical conditions and geographical location. More than 1400 species of animals have been identified from the fouling complex before 1952 (Anon, 1952) and since then also several species have been continuously added on to the list, but an exhaustive recent review is lacking. The fouling fauna of Indian navigational waters and ports have been inadequately investigated (Karande, 1978) and earlier works pertain to fouling in the harbours or ports at Bombay (Karande, 1968 a, b), Goa (Dehadri *et al.*,

1975; Harkantra *et al.*, 1977), Mangalore (Menon *et al.*, 1977), Cochin (Nair, 1967; Nair, 1967; Balasubramanyan & Nair, 1970; Menon & Nair, 1971; Santhakumari & Nair, 1975), Visakhapatnam (Ganapati & Rao, 1968; Ganapati *et al.*, 1958; Rao & Ganapati, 1978), Madras (Raja, 1959, 1963, Daniel, 1954, 1955), Port Blair (Karande, 1978) and Tuticorin (Renganathan *et al.* in press). With the advent of the culture of oysters and mussels along the coasts of India, the impact of fouling on mariculture has been realised to some extent (Kuriyan, 1950; Harkantra *et al.*, 1977) and the impediments of fouling to pearl oyster culture have also been briefly reported (Alagarswamy & Chellam, 1976).

The present paper represents a part of the results obtained during the course of a detailed study on the marine fouling and timber destroying organisms carried out in Neendakara port situated at the mouth of the Asthamudi backwaters in the south-west coast of India. The objectives of the study are 1. to identify the major fouling animals of the port, 2. to determine the nature and extent of fouling, 3. to determine the relative importance of various species of animals in the fouling community, 4. to find out the period of settlement of the different species, 5. to record the seasonal variations in the nature and intensity of fouling, and 6. to obtain the nature of influence of environmental variables on fouling.

Materials and Methods

Fouling organisms were collected by exposing glass panels of 10 x 10 cm size with one smooth and one rough surface, submerged and held in position at about 1 m below the lowest low water mark in wooden racks suspended from a fixed jetty beam. Individual panels were identified by labelled plastic tags and all possible contacts of the panels among them and with supporting structures were avoided. Three series of test panels were exposed simultaneously from February 1977 to January 1978 as in Fig. 1.

A-series (short-term)

Twelve panels exposed one by one at the beginning of a month and changed at the

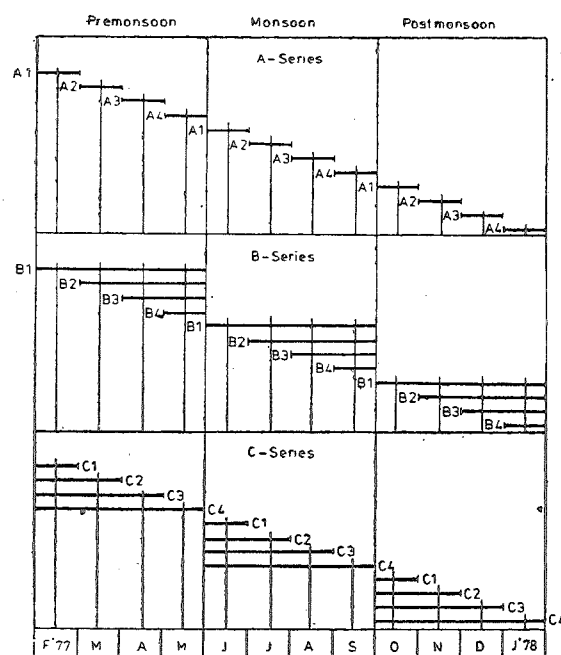


Fig. 1. Plan of test panel exposures

beginning of the succeeding month formed this series. This showed the settlement which had taken place during the period of immersion and gave an indication of the monthly variations of settlement on panels qualitatively and quantitatively.

B-series (long-term)

To obtain data regarding the seasonality in the settlement and rate of increase in the biomass of fouling, the year was divided into three periods namely the premonsoon (February to May), the monsoon (June to September) and the postmonsoon (October to January). At the beginning of every month panels were immersed and they were collected simultaneously at the end of each period. Thus, three sets of B-series panels, each set consisting of four panels were exposed for durations ranging from one to four months (Fig. 1) and examined.

C-series (long-term)

Three sets each consisting of four panels were exposed in the beginning of each period and raised one by one at the end of each month, after exposing them for durations ranging from one to four months during

each period. This series gave an idea of the fouling settlement for the respective period of immersion, growth of the community in terms of biomass and indicated how the monthly settlement was modified by the foulers already present on the panels.

The panels with the settled fouling elements were preserved in formalin after determining the total biomass of the community. The foulers were identified upto species level as far as possible and for colonial forms the relative abundance of the different species was determined. In the case of solitary forms which could be counted separately, the exact number of individuals of the different species has been determined.

The locality

The exposure tests were carried out in Neendakara port (Lat. 08°30'N; Long. 76°53.3'E) which is a typical estuarine habitat situated at the mouth of the Ashtamudi backwaters having a permanent connection with the adjoining Arabian sea lying on the west. This is an important fishing harbour of the southwest coast of India, visited by and providing landing jetties to a large number of trawlers daily. The fishing craft of the area include mechanised vessels and canoes. The mouth of this estuary is wide and deep and therefore, the influence of the sea is strongly felt inside the port throughout the year. During the monsoon period, influx of fresh water into the backwater and its outflow through the gut is considerable. From June to September there is heavy rainfall from the southwest monsoon and from October to December there is varying quantities of precipitation from the northeast monsoon. Based mainly on the quantity of rainfall received during different months, the year could be divided into three seasons as stated earlier, even though this division is arbitrary. Usually, the premonsoon is the hot and highly saline period during which the experimental site experiences hydrographic conditions very similar to that of the nearby coastal marine environment. The monsoon period is characterised by almost fluvial conditions with fluctuating low salinity and temperature and the postmonsoon period represents the transitional stage between the other two. However, during

the course of the present study, the southwest monsoon burst over the region during the later half of May with moderate rainfall, which continued during the postmonsoon period also consequent on the precipitation from the northeast monsoon.

Wave action inside the port is considerably reduced as a result of the artificial breakwaters which shelter the port. The rocky and concrete boulders of the breakwaters, the pillars of jetties, and other submerged objects in the neighbourhood, provide excellent substrata for the settlement and growth of a variety of epibenthic fauna, which supply larvae to foul freshly submerged objects and the hulls of fishing craft. Height of the water column at the experimental site reaches a maximum of about 4 m depending on the monsoonal floods, and tidal ebb and flow. Throughout the year, movements of fishing boats and other vessels, and tidal current churn up the water leaving fair amounts of silt to settle over the panels.

Results and Discussion

Ecology

Salient features of the different ecological variables in the port which have been discussed in detail earlier (Dharmaraj & Nair, 1979, 1981) are summarised here. Salinity of surface water remained high during the first three months of the premonsoon period (29.0 to 32.5‰) with an increasing trend from February to April and in May it declined to 26.5‰, but that of the bottom water remained above 31.5‰ throughout this period (Fig. 2). During the monsoon period low salinity prevailed and the lowest value (13.7‰) was recorded during September in the surface water. In the bottom water also salinity declined from June to September to reach the minimum (16.5‰) value. Low saline conditions continued till December during the postmonsoon period with slight fluctuations, and the values again rose up by January to reach 31.5 and 32.4‰ in the surface and bottom waters respectively. Salinity was always found to be high at the bottom and the vertical stratification was more pronounced during the rainy season.

The premonsoon period was characterised by high temperature which showed a rising trend from February to April till it reached the peak value recorded (32.0°C) both at the surface and at the bottom (Fig. 2). With the onset of the southwest monsoon, temperature started falling and the lowest values in the surface and the bottom waters (26.5 and 26°C) were recorded in July and September respectively. Temperature fluctuated between 29.3 and 30.5°C at the surface and 29.2 and 30°C at the bottom during the postmonsoon period. Thermal stratification of the water column varied irregularly with warmer waters at the surface except in July and the stratification was insignificant during the premonsoon period.

Dissolved oxygen of the surface water varied from 4 to 4.6 ml/l, whereas the same of the bottom water ranged between 3.6 and 4.0 ml/l. A definite pattern of seasonal change could not be noticed in the dissolved oxygen, but always a vertical gradient existed with low values at the bottom. Light attenuation coefficients calculated from Secchi disc readings of light penetration depths (Fig. 2), indicate that the water at the experimental site had been highly turbid during most

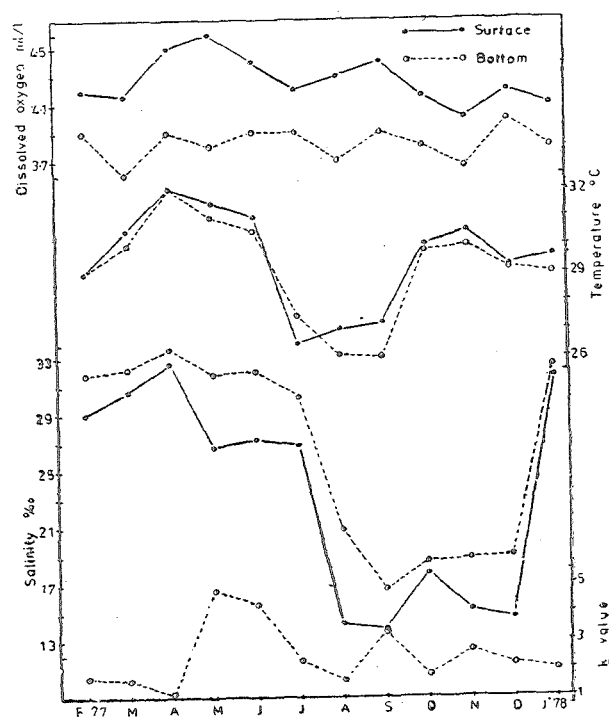


Fig. 2. Monthly variations of environmental facts at the test site

parts of the year. K -values below one has never been obtained and the range was between 1.11 and 4.83. The water was found to be comparatively less turbid during the premonsoon period than during the other two periods.

Composition of the fouling community

Major sedentary animals of the fouling community at Neendakara port consisted of sponges, hydroids, sea anemones, polychaetes, serpulids, cirripedes, oysters, mussels and tunicates. The species composition and certain aspects of the ecology of the macro sedentary animals alone are reported in this paper. Mud-tube forming polychaetes, amphipods and tanaids are also included since they contribute much to fouling. The nature of settlement of the different species of fouling animals over the short-term (A-series) and long-term (B & C series) panels is presented in Tables 1 to 3. Porifera contributed a species of sponge and coelenterates were represented by not less than eight species of hydroids and a species of sea anemone. Diversity of bryozoans in the fouling community was high with as many as thirteen estuarine and marine species. Four species each of serpulids and mud-tube forming polychaetes are recorded. The amphipod *Corophium triaenonyx*, the tanaid *Tanais estuarius* and the cirripede *Balanus amphitrite communis* were the dominant fouling crustaceans of the port. Several other species of free living amphipods, isopods and other groups were also found amidst the bush fouling over the panels. Bivalves were represented by two species of oysters and nearly six species of mussels. One species of simple ascidian and not less than seven species of compound ascidians were noticed in the fouling community, but specific identifications of these posed difficulties and so their cumulative abundance alone is recorded.

Monthly and seasonal settlement of fouling animals

Sponges appeared rarely on the short-term panels during the premonsoon period (Table 1). On the long-term panels (B & C-series) they were very common on those

Table 1. Monthly settlement of major sedentary fouling organisms (A-series)

Sedentary fouling organisms	Period of submergence												1978	
	1977	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	
							Surface area							
SPONGES	S	R	S	R	S	R	S	R	S	R	S	R	S	R
	—	—	—	R	—	—	—	—	—	—	—	—	—	—
COELENTERATES														
<i>Obelia bicuspidata</i>	A	A	A	A	A	C	—	—	—	—	—	—	—	—
<i>Clytia</i> sp.	VR	VR	R	R	—	—	—	—	—	—	—	—	—	—
<i>Bimberia vestita</i>	C	VC	C	C	R	MC	VR	R	—	—	—	—	—	—
<i>Halocordyl edisticha</i>	C	C	A	A	A	C	—	—	—	—	—	—	—	—
<i>Eudendrium</i> sp.	R	R	C	C	C	—	—	—	—	—	—	—	—	—
<i>Garveia</i> sp.	R	R	C	C	—	—	—	—	—	—	—	—	—	—
<i>Ectopleura</i> sp.	—	—	—	C	C	R	—	R	R	—	—	—	—	—
<i>Sea anemones</i>	9	35	12	27	4	13	—	—	—	2	1	3	—	7
														26
POLYZOANS														
<i>Electra crustulenta</i>	—	—	—	—	—	—	R	C	C	R	R	MC	R	R
<i>Electra bengalensis</i>	VC	A	C	VC	VC	A	R	—	—	—	—	—	—	—
<i>Alderina arabianensis</i>	R	R	MC	MC	—	—	—	—	—	—	—	—	—	—
<i>Bugula neritina</i>	C	VC	A	A	A	—	—	—	—	—	—	—	—	—
<i>Bugula cucullata</i>	C	C	C	VC	C	A	MC	VC	VR	R	VC	A	—	—
<i>Schizoporella cochinesis</i>	R	C	VR	MC	MC	VR	—	—	—	—	—	—	—	—
<i>Schizomavella linearis</i>	R	C	MC	C	MC	VC	—	—	—	—	—	—	—	—
<i>Watersipora subovoidea</i>	—	—	—	—	—	—	C	VC	A	A	R	C	VC	R
<i>Victorella pavida</i>	—	—	R	MC	—	—	—	—	—	—	—	—	—	—
<i>Vesicularia papuensis</i>	—	—	—	MC	—	—	—	—	—	—	—	—	—	—
<i>Bowerbankia gracilis</i>	—	—	R	MC	C	—	—	—	—	—	—	—	—	—
MUD-TUBE DWELLING POLYCHAETES														
<i>Eunice</i> sp.	6	8	4	7	2	8	—	—	—	—	2	2	8	5
<i>Polydora</i> sp.	—	—	—	—	—	—	—	—	—	—	3	7	2	4
<i>Pectinaria</i> sp.	—	—	—	—	—	—	2	4	5	3	7	1	1	—
<i>Branchionina</i> sp.	13	16	9	7	3	5	—	—	—	—	2	2	2	9
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														1
SERPULIDS														
<i>Hydroides brachiactantha</i>	7	16	8	14	13	15	3	6	—	—	—	3	5	2
<i>Mercierella enigmatica</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Pomatoleios croslandi</i>	17	53	13	25	7	12	—	—	—	—	—	3	7	6
<i>Ficopomatus macrodon</i>	—	—	—	—	—	—	2	6	5	6	15	3	5	16
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(Contd.)

Table 1. (Contd.)

MUD-TUBE FORMING
AMPHIPODS & TANAIDS

<i>Corophium triaenonyx</i>	14	17	9	12	12	16	17	23	31	40	67	85	14	26	7	16	9	13	14	35	23	45	16	21
<i>Tanais estuariis</i>	—	—	—	—	—	—	3	4	2	5	9	6	13	17	24	18	3	6	14	12	3	—	15	11

CIRRIPEDES

<i>Balanus amphitrite communis</i>	—	—	9	16	13	18	23	31	21	45	29	73	4	97	35	56	9	13	35	87	17	33	—	3
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BIVALVES

<i>Anomia</i> sp.	—	3	1	2	—	4	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2	—	—	3	
<i>Crassostrea madrasensis</i>	1	2	3	5	9	14	1	4	—	—	2	6	17	24	2	1	—	—	—	—	—	—	1	4	2	9
<i>Perna indica</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	2	8	—	—	—	—	—	—	—	
<i>Perna viridis</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	2	6	4	—	—	—	2	5	—	—	—	—	
<i>Modiolus carvalhoi</i>	4	3	3	6	2	7	4	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
<i>Modiolus plumicens</i>	—	—	2	6	5	7	3	8	—	—	2	—	—	—	—	—	—	—	2	—	1	—	—	—	—	
<i>Musculista senhousia</i>	1	4	2	3	4	6	7	4	2	9	3	5	4	8	5	13	—	—	—	—	3	5	9	2	13	
<i>Musculista arcuata</i>	—	—	—	—	—	—	—	—	—	—	—	—	5	6	2	4	5	3	2	7	4	3	4	7	7	

TUNICATES

Simple ascidians	—	—	—	—	2	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Compound ascidians	C	VC	MC	C	R	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	R	MC	

Key: S = smooth; R = rough; A = abundant; VR = very rare; MC = moderately common; C = common; VC = very common; — = absent

Key: S = smooth; R = rough; A = abundant; VR = very rare; MC = moderately common; C = common; VC = very common; — = absent

Table 2 (Contd.)

SERPULID POLYCHAETES

<i>Hydroides brachiacantha</i>	15	23	17	24	12	30	3	6	3	5	5	7	4	7	—	—	8	21	12	16	8	11	3	12
<i>Mercierella enigmatica</i>	—	—	—	—	—	—	—	—	—	11	83	10	14	9	16	9	12	14	24	9	12	3	3	—
<i>Pomatoleios croslandi</i>	12	25	17	23	7	11	—	—	—	—	—	—	—	—	—	—	26	47	33	40	29	37	15	48
<i>Ficopomatius macrodon</i>	—	—	—	—	—	—	—	—	7	31	20	33	6	12	6	13	13	18	12	17	9	13	—	—

MUD-TUBE FORMING
AMPHIPODS & TANAIDS

<i>Corophium triaenonyx</i>	3	9	2	7	—	—	17	23	50	77	40	45	29	36	7	16	17	26	14	22	9	15	16	21
<i>Tanais estuarius</i>	2	6	—	—	—	3	4	21	29	25	31	17	28	24	18	2	1	10	19	12	16	15	11	

CIRRIPEDES

Balanus amphitrite communis

	35	53	26	31	10	18	23	31	107	139	98	130	77	95	35	56	49	108	20	31	10	13	—	3
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BIVALVES

<i>Crassostrea madrasensis</i>	—	2	2	4	3	4	—	—	—	—	—	—	—	—	—	—	1	3	—	2	1	—	—	3
<i>Perna indica</i>	5	8	7	9	4	6	1	4	11	24	13	24	9	17	2	1	2	3	7	9	3	5	2	9
<i>Perna viridis</i>	—	—	—	—	—	—	—	—	2	4	—	6	—	2	—	4	—	—	—	—	—	3	—	—
<i>Modiolus carvelhoi</i>	—	—	—	—	—	—	—	—	3	8	3	—	—	1	4	6	4	3	—	4	—	6	—	—
<i>Modiolus plumiceus</i>	8	9	14	17	3	6	4	6	—	—	—	—	—	—	—	—	4	7	4	7	—	2	—	—
<i>Musculista senhousia</i>	6	13	3	9	2	5	3	8	—	—	—	—	—	—	—	—	3	8	5	6	2	1	—	—
<i>Musculista arcuata</i>	18	35	12	16	3	7	7	4	19	36	21	34	12	18	5	13	11	23	20	31	3	7	12	13
	—	3	—	—	—	—	—	—	10	17	12	26	14	30	2	4	—	—	2	8	3	6	4	7

TUNICATES

Simple ascidians	1	4	6	9	2	7	1	—	—	—	—	—	—	—	—	—	2	3	2	4	3	4	—	—
Compound ascidians	A	A	C	VC	R	MC	—	—	R	R	—	—	R	R	—	—	VC	A	VC	A	VC	A	R	MC

Key: S=smooth; R=rare; MC=moderately common; C=common; VC=very common; A=abundant; —=absent

Table 3. Settlement of major sedentary fouling organisms on long-term (C-series) panels

Sedentary fouling organisms	1977												Period of submergence								1978			
	Feb	Feb-Mar	Feb-April	Feb-May	June	June-July	June-Aug	June-Sep	Oct-Nov	Oct-Dec	Oct-Jan	Oct-Feb	June	June-July	June-Aug	June-Sep	Oct-Nov	Oct-Dec	Oct-Jan	Oct-Feb				
SPONGES																								
COELENTERATES																								
<i>Obelia gracilis</i>	—	—	R	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R				
<i>Obelia bicuspidata</i>	—	—	MC	C	R	C	VR	VC	—	—	—	—	—	—	—	—	—	—	—	MC				
<i>Clytia</i> sp.	—	—	R	R	MC	C	C	C	—	—	—	—	—	—	—	—	—	—	—	R				
<i>Biminia vestita</i>	VR	VR	MC	MC	C	C	MC	MC	—	—	—	—	—	—	—	—	—	—	—	MC				
<i>Halocordyl edisticha</i>	C	C	A	A	A	A	C	VR	C	ER	R	—	—	—	—	—	—	—	—	VR				
<i>Eudendrium</i> sp.	R	R	MC	C	C	C	VR	VR	—	—	—	—	—	—	—	—	—	—	—	MC				
<i>Garveia</i> sp.	R	R	MC	VR	VR	VR	C	C	—	—	—	—	—	—	—	—	—	—	—	MC				
<i>Ectopleura</i> sp.	—	—	R	R	MC	C	MC	VR	—	—	—	—	—	—	—	—	—	—	—	MC				
Sea anemones	9	35	15	24	13	29	17	23	—	—	—	—	—	—	—	4	6	1	3	1				
POLYZOANS																								
<i>Aetea anquina</i>	—	—	—	—	A	MC	MC	MC	—	—	—	—	—	—	—	—	—	—	—	—				
<i>Electra crustulenta</i>	—	—	—	—	—	—	—	—	R	C	—	—	—	—	—	—	—	—	—	—				
<i>Electra bengalensis</i>	—	—	MC	VR	C	C	C	VR	—	—	—	—	—	—	—	—	—	—	—	VR				
<i>Alderina arabianensis</i>	VR	A	C	VR	C	VR	A	A	R	R	—	—	—	—	—	—	—	—	—	R				
<i>Bugula neritina</i>	R	R	MC	C	R	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—				
<i>Bugula cucullata</i>	C	VR	VR	A	A	A	VR	VR	—	—	—	—	—	—	—	—	—	—	—	C				
<i>Schizoporella cochinchensis</i>	C	C	VR	VR	A	VR	A	—	R	—	—	—	—	—	—	—	—	—	—	MC				
<i>Schizomavella linearis</i>	R	R	MC	MC	MC	C	MC	MC	—	—	—	—	—	—	—	—	—	—	—	R				
<i>Watersipora subovoidea</i>	R	C	R	R	R	MC	R	C	—	—	—	—	—	—	—	—	—	—	—	MC				
<i>Viotorella pavidula</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				
<i>Vesicularia papuensis</i>	—	—	C	C	VR	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—				
<i>Bowerbankia gracilis</i>	—	—	MC	C	MC	VR	R	R	—	—	—	—	—	—	—	—	—	—	—	R				
<i>Averillia setigera</i>	—	—	R	MC	MC	C	R	MC	—	—	—	—	—	—	—	—	—	—	—	MC				
MUD-TUBE FORMING POLYCHAETES																								
<i>Eunice</i> sp.	6	8	11	13	9	16	12	10	—	—	—	—	—	—	—	—	—	—	—	—				
<i>Polydora</i> sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				
<i>Pectinaria</i> sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				
<i>Branchiomma</i> sp.	13	16	5	8	4	10	6	7	—	—	—	—	—	—	—	—	—	—	—	—				

(Contd.)

Table 3 (Contd.)
SERPULID POLYCHAETES

<i>Hydroides brachiacantha</i>	7	16	13	16	9	17	15	23	—	—	—	—	—	—	3	5	3	5	8	11	12	15	8	21
<i>Mercierella enigmatica</i>	—	—	—	—	—	—	—	—	—	2	7	12	13	18	11	23	3	7	12	27	10	17	14	24
<i>Pomatoleios croelandi</i>	17	53	16	26	14	29	12	25	—	—	—	—	—	—	—	—	—	—	9	13	23	36	26	47
<i>Ficopomatius macrodon</i>	—	—	—	—	—	—	—	—	2	6	8	11	15	24	7	31	3	5	8	17	12	16	13	18

MUD-TUBE FORMING
AMPHIPODS & TANAIIDS

<i>Corophium triaenonyx</i>	14	17	4	10	13	14	3	9	31	40	43	59	54	73	50	77	19	13	13	24	27	43	17	26
<i>Tanais estuarius</i>	—	—	—	—	3	2	2	6	2	5	12	17	14	23	21	29	3	6	7	12	13	18	2	1

CIRRIPEDES

<i>Balanus amphitrite communis</i>	—	—	17	28	26	39	35	53	21	45	82	115	96	133	107	139	9	3	42	94	54	102	49	108
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BIVALVES

<i>Anomia</i> sp.	—	3	—	2	1	4	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	3
<i>Crassostrea madrasensis</i>	1	2	3	6	1	9	5	8	—	—	14	23	12	20	11	24	—	—	—	2	1	4	2	3
<i>Perna indica</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	5	2	4	2	8	—	2	—	—	—	—
<i>Perna viridis</i>	—	—	—	—	—	—	—	—	—	—	—	2	5	7	3	8	—	—	4	5	2	3	—	3
<i>Modiolus carvolhoi</i>	4	3	5	8	8	12	8	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	7
<i>Modiolus plumicens</i>	—	—	7	11	3	9	6	13	—	—	—	—	—	—	—	—	2	—	—	—	1	4	3	8
<i>Musculista senhousia</i>	1	4	5	12	13	27	18	35	2	9	7	13	21	39	19	36	—	—	4	9	12	18	11	23
<i>Musculista archatula</i>	—	—	—	—	—	—	—	3	—	—	2	6	12	14	10	17	5	3	3	8	2	4	—	—

TUNICATES

Simple ascidians	—	—	—	3	8	4	1	4	—	—	—	—	—	—	—	—	—	—	—	—	2	1	2	3
Compound ascidians	C	VC	MC	C	C	A	A	A	—	—	—	—	—	—	R	R	—	—	—	MC	C	VC	UC	A

Key: S = smooth; B = rough; VR = very rare; MC = moderately common; C = common; VC = very common; A = abundant; — = absent

exposed for four months during the premonsoon period (Tables 2 & 3). The settlement of sponges was poor during the postmonsoon period and it was totally absent during the monsoon period.

Among the hydroids, *Obelia bicuspidata* was abundant during the premonsoon and common during the postmonsoon months with no evidence of settlement from June to August. The pattern of its settlement was almost similar over the long-term panels also, with increasing density corresponding to the duration of exposures. Over the long-term series, *Obelia gracilis* also appeared during the pre and postmonsoon periods. The incidences of other hydroids such as *Clytia* sp., *Bimeria vestita*, *Halocordyl edisticha*, *Eudendrium* sp. and *Garveia* sp. were also intense during highly saline summer months. Some of them appeared in lesser abundance during the postmonsoon months also, and the representation of *Ectopleura* sp. was erratic. In general, hydroids were represented very poorly during the monsoon period. Sea anemones were abundantly noticed on the short-term panels submerged during the pre and postmonsoon periods. On the long-term panels also, abundant settlement of sea anemones was discernible during the pre and postmonsoon periods. They were found on all the four panels of the B-series and the longest submerged panels of the C-series in lesser numbers during the monsoon period.

Electra crustulenta and *Victorella pavida* were the brackish water polyzoans which fouled the panels considerably during the monsoon and postmonsoon periods. Both of them did not appear during the premonsoon period. *Bugula cucullata*, *Schizoporella cochinchensis*, and *Schizomavella linearis* were common during the postmonsoon and very common during the premonsoon periods. *Aetea anquina* and *Averrillia setigera* were found only on the longterm panels. *Electra bengalensis* appeared rarely on the short-term panels and commonly on the long-term panels during the premonsoon period. *Alderina arabianensis*, *Bugula neritina* and *Watersipora subovoidea* were also very commonly found on all the three series of panels during the pre-monsoon period. *Vesicularia papuensis* and *Bowerbankia gracilis* appeared erratically during the pre-

monsoon period only. In general, fouling by bryozoans were heavy during the premonsoon, moderate during the post monsoon and poor during the monsoon periods if the two brackish water species were excluded.

Polychaetes such as *Eunice* sp., *Polydora* sp., *Pectinaria* sp. and *Branchiomma* sp. assisted towards the accumulation of significant quantities of mud over the panels. Even though some of the above mentioned forms are errant, they are sluggish and were living on the panels almost like attached forms. Over the short-term panels, *Eunice* sp. and *Branchiomma* sp. were invariably noticed during the pre and postmonsoon periods. *Polydora* sp. and *Pectinaria* sp. were abundant during the monsoon period, the former extending its settlement to the postmonsoon period too. The nature of the settlement of these polychaetes was almost similar on the long term panels also, however, with increasing numbers with the duration of exposure during the monsoon and postmonsoon periods. In the case of the settlement of *Branchiomma* sp. over the premonsoon C-series panels, maximum number was recorded on one month panel than over the panels exposed for two to four months.

Serpulid polychaetes encountered during the present study were *Hydroides brachiacantha*, *Mercierella enigmatica*, *Pomatoleios croslandi* and *Ficopomatus macrodon*. *Hydroides brachiacantha* fouled the A-series panels during the pre and postmonsoon periods. Over the B-series panels, its incidence was noticed during the monsoon period also though poorly. Fouling by this species exhibited a similar trend over the C-series panels with heavy incidence during the pre and postmonsoon periods. *Pomatoleios croslandi* appeared densely during the first three months of the premonsoon and last two months of the postmonsoon periods on the short-term panels. Settlement of this species was heavy during the postmonsoon period on the B-series panels and during the premonsoon on the C-series. *Mercierella enigmatica* and *Ficopomatus macrodon* were not found during the premonsoon period over any of the series. These two species appear to be brackish water forms settling densely during the monsoon and postmonsoon periods.

Mud accumulating crustaceans such as the amphipod *Corophium triaenonyx* and the tanaid *Tanais estuarius* also heavily fouled the panels of all the three series. *C. triaenonyx* was present throughout the year with peak incidence during the monsoon and *T. estuarius* was collected during the monsoon and postmonsoon months from the A-series. Over the B-series, settlement of *C. triaenonyx* was dense during the monsoon period and over this series, its incidence was poor during the premonsoon on the panels exposed for two to four months. The nature of the settlement of *T. estuarius* on the B-series panels was similar to that on the A-series, however, with more numbers. C-series also exhibited the same pattern of fouling by these two species as over the A and B-series.

The most dominant fouling crustacean from the Neendakara port was the cirripede *Balanus amphitrite communis* and it appeared throughout the year on all the series except during February when it was absent on the A-series. The peak months of its settlement were August and November on the A-series. The nature of its settlement over the B-series indicated that it has heavily fouled the panels during the monsoon and the beginning of the postmonsoon periods. C-series also exhibited a similar pattern of fouling by this barnacle.

Bivalves came next in abundance to barnacles in the fouling community, represented among others by *Anomia* sp. and *Crassostrea madrasensis*. *Anomia* sp. was rare sporadically over all the series of panels. On the A-series, *C. madrasensis* settled densely during August and April. On the B-series, settlement of *C. madrasensis* was discernible over all the panels, however, it was done over the panels exposed during the monsoon period. C-series panels also showed heavy fouling by *C. madrasensis* during the monsoon period. Two species of mussels namely *Perna indica* and *P. viridis* appeared erratically on the panels and the nature of their settlement suggests that they settle during the later half of the monsoon and the first half of the postmonsoon periods.

The bivalves which contributed substantially to the bulk of fouling were four species of mussels namely *Modiolus carvolhoi*, *M.*

plumicens, *Musculista senhausia* and *M. arcuatula*. On the A-series, the first two of these mussels appeared only during the premonsoon in considerable numbers. *M. senhausia* settled almost throughout the year and *M. arcuatula* fouled the panels during the postmonsoon and the later half of the monsoon periods. The pattern of fouling by these mussels over the B-series indicated that *M. carvolhoi* and *M. plumicens* settle densely during the premonsoon with some incidence during the postmonsoon months. Over, all of the B-series panels, fouling by *M. senhausia* was discernible with erratic heavy settlement. *M. arcuatula* was abundant during the monsoon period. The nature of the settlement of these mussels over the C-series also was in similar pattern.

Simple ascidians appeared during April and May over the A-series and their settlement over the long-term panels was erratic with no sign of settlement during the monsoon period. Compound ascidians were poorly represented on the A-series appearing only during the highly saline period. Over the B and C-series, the settlement of compound ascidians was dense with not less than seven species during both the pre and post-monsoon periods.

Biomass of the fouling community

Over the A-series maximum biomass (72.8 g) was recorded during September and the minimum (16.9 g) during October (Fig. 3). The biomass was considerably high during the premonsoon and monsoon months and low during the postmonsoon period over the short-term panels. The nature of accumulations for four months over the B-series (Fig. 3) indicates that, among the three periods, the premonsoon recorded the maximum value (170.5 g), the monsoon the lowest (144.8 g) and the postmonsoon the intermediate (159.3 g). But, in three month exposures, post monsoon panels registered the lowest (112.6 g), monsoon the intermediate (123.3 g) and premonsoon the highest (142.0 g) biomass values. The pattern over the two month exposure panels was also similar to that of the three month exposures.

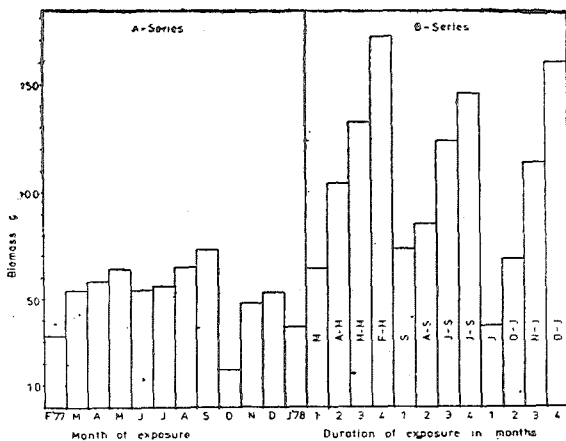


Fig. 3. Biomass of fouling over the A & B series test panels

In the C-series, the biomass accumulations over the four month panels were identical to those of the B-series. On three month panels, maximum biomass was recorded during the premonsoon period (165.9 g), minimum during the monsoon period (129.5 g) and intermediate value (136.8 g) during the postmonsoon period (Fig. 4). A similar pattern was noticed on the two month panels also.

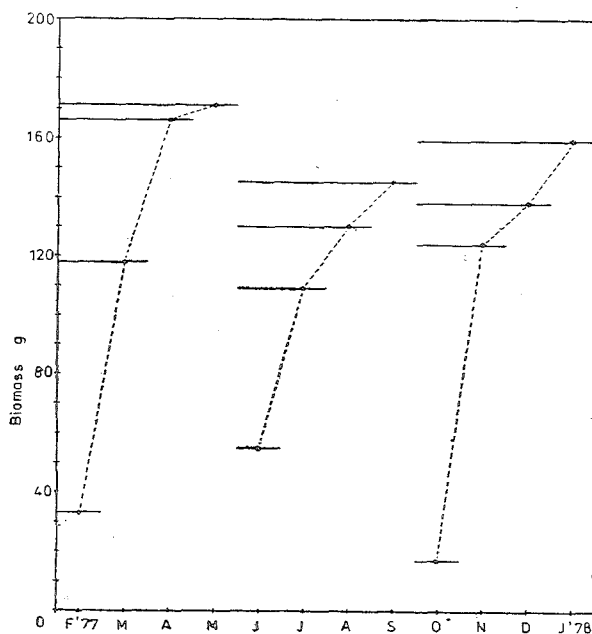


Fig. 4. Rate of increase of fouling biomass during different seasons (C-series)

The present study reveals that the settlement of fouling organisms at the Neendakara port is a continuous process occurring throughout the year with fluctuating densities and varying species composition. The diverse nature of fouling and the dominance of different groups of organisms are illustrated in Figs. 5 to 8. Although certain dominant species settle almost continuously, the density of their settlement significantly varies during different months and seasons. Many species show a regular seasonal pattern of settlement comparable with the reports from other estuarine regions of India (Menon & Nair, 1971; Nair, 1967). There is fairly heavy fouling during all the months over the short-term panels. The biomass of fouling over the long-term panels indicate a constant growth of the already settled fouling community, along with the fresh recruitment depending upon the reproductive characteristics of the concerned species.

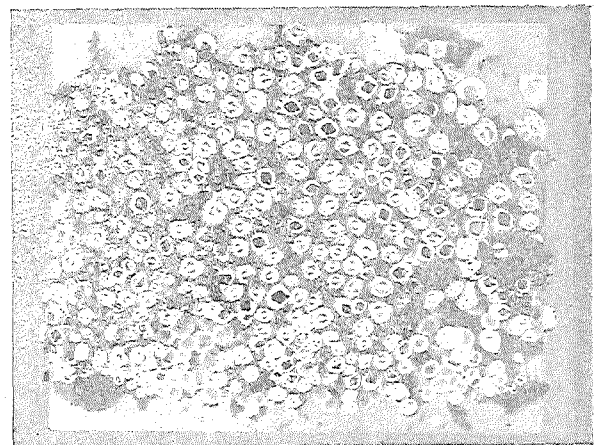


Fig. 5. Photograph of the fouling community dominated by barnacles on the smooth surface of a panel

In general, most of the foulers settled more densely on the rough surfaces of the panels than over the smooth surfaces, the former being more favourable for securing a foothold for the free swimming larvae under a constantly moving medium. However, in some instances greater settlement of certain selected species of foulers was, in fact, noticed over the smooth surface than on the rough surface.

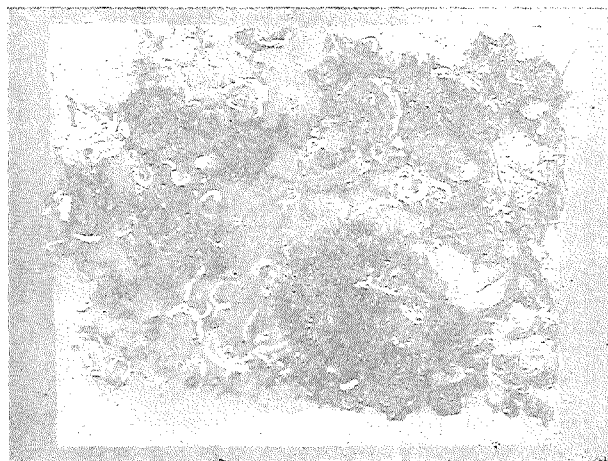


Fig. 6. Fouling community composed of serpulids, mussels and an oyster

An obvious and important feature of fouling at Neendakara port is the alternate seasonal dominance of marine and estuarine forms in the community. During the premonsoon period, coastal marine sedentary organisms abundantly settle and dominate, during the monsoon period typical estuarine forms dominate and during the postmonsoon period representatives from both these forms are noticeable. All the nine species of coelenterates encountered during the present study can be considered marine forms occurring densely during the premonsoon period. Among the thirteen species of fouling bryozoans, only *Electra crustulenta* and *Victorella pavida* were able to survive and occur in abundance during the monsoon period and these two species were absent during the premonsoon period. All the other bryozoans were more common during the premonsoon than during the other periods and may, therefore, be considered as marine.

Polydora sp. and *Pectinaria* sp. are estuarine forms which fouled the panels in large numbers during the monsoon period and *Eunice* sp. and *Branchiomma* sp. are marine forms settling densely during the pre and postmonsoon periods. Among the serpulid polychaetes, *Mercierella enigmatica* and *Ficopomatus macrodon* seem to be restricted to low saline period while *Hydroides brachiacantha* and *Pomatoleios croslandi* seem to prefer highly saline periods. Polychaete fouling was rich and varied during



Fig. 7. Heavy fouling with mud matted over the panels by mussels, mud-tube dwelling amphipods and polychaetes

the postmonsoon owing to the settlement of both estuarine and marine forms. The contribution of the edible mussels *Perna indica* and *P. viridis* to the fouling was considerable only over the long-term panels exposed during the monsoon and postmonsoon periods. Among the other mussels, *Musculista arcuatula* is an estuarine form fouling densely during the monsoon and postmonsoon and *Modiolus carvolhoi* and *M. plumicens* are marine forms which preferred highly saline periods for their dense settlement.

Only three species, namely *Balanus amphitrite communis*, *Corophium triaenonyx* and *Musculista senhausia* have been found to foul the panels almost throughout the year. By virtue of its dense settlement during certain period and the almost continuous nature of its presence, the barnacle *Balanus amphitrite communis* may be considered as the most dominant of the fouling animals at the Neendakara port. Barnacles have been reported to have different peak periods of settlement in different localities of India (Menon *et. al.* 1977). The continuous breeding activity of barnacles (Pillai, 1958; Nair, 1967) and the consequent supply of larvae for recruitment throughout the year would have been responsible for the fouling by barnacles recorded over almost all the panels.

Major factors that could influence the quality and quantity of fouling at Neenda-



Fig. 8. Fouling by oysters, barnacles and serpulids with the dominance of oysters

kara port are 1. salinity structure and other hydrographical conditions, 2. movements of fishing and other vessels into and out of the port, 3. reproductive periodicities of the endemic epibenthic fauna, and 4. interspecific and intraspecific competition among the foulers. During the premonsoon period, larvae of the epibenthic fauna of the rocky boulders of the breakwaters facing the Arabian sea and the pillars of the Neendakara bridge find their way to the experimental site through tidal and other water movements. During this period almost a typical littoral epibenthic faunal assemblage fouls the panels. This faunal assemblage is nearly eliminated during the monsoon period when brackish water species dominate in the fouling complex with lesser species diversity. The larvae of the brackish water forms could be recruited from the endemic epibenthic fauna of the piles and laterite banks of the upper reaches of the Ashtamudi backwaters.

The existence of certain species of mussels, bryozoans, serpulids and other fouling organisms in the backwater during the monsoon period when the salinity is greatly reduced may be due to long-term physiological adjustment and gradual acclimatisation. Among the several species dominant during the premonsoon period, only very few which can tolerate low saline conditions settle and survive along with other brackish water forms during the monsoon period. The postmonsoon period represents a transitional stage between the other two periods

with regards to hydrographical conditions and fouling during this period also has been of intermediary nature. The mesohaline conditions prevailing during the postmonsoon period allow the brackish water representatives of the fouling community to survive until salinity increases beyond their limits of tolerance during the premonsoon period.

Species diversity of the fouling community of Neendakara port has been high during the pre and postmonsoon periods and low during the monsoon period. This is due to the incidence of a large number of species of hydroids and bryozoans during high saline periods. Salinity seems to play the major role in regulating the species abundance in the fouling community. However, fouling biomass has been little affected by the species abundance, because many of the species found to dominate during the monsoon period are larger forms such as mussels and oysters which contribute substantially to the biomass. Besides, during the monsoon period, accumulation of mud by mud-tube forming amphipods, tanaid and polychaetes has also been intense along with the natural siltation over the panels. These factors are responsible for the heavy biomass of fouling recorded during the monsoon period when the species diversity of the fouling community was low.

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