STUDIES ON MARINE FOULING ORGANISMS IN BOMBAY HARBOUR

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ABSTRACT

Studies on the fouling organisms in Bombay harbour were undertaken as a part of the Antifouling Research Programme at NCML, Bombay, and the results obtained during a period of about three years (August 1953—May 1956) are described in the present paper. Structural details of the floating Raft on which experimental non-toxic panels were exposed every month have been mentioned. The salinity and temperature of sea-water, surrounding the Test panels, were regularly determined and an attempt has been made to correlate their variations with the intensity of fouling settlement. Seasonal variations in the attachment of the different groups of Fouling Organisms are described in detail. The total weight of fouling present on the panels at the end of each monthly exposure has also been given. Among the various fouling organisms encountered on the panels, Barnacles were the most predominant. There was practically very little fouling during the monsoon months, while heavy fouling was met with usually during the summer months and October. The results obtained have been discussed and the importance of such studies emphasized.

Introduction

Investigations on marine fouling organisms are of great importance in the systematic assessment and scientific formulation of Antifouling Compositions. It has been estimated that the operational efficiency of ships is reduced considerably due to fouling and an increase in fuel consumption up to 50 percent would be required to overcome the frictional resistance caused by fouling in temperate waters after about six months[1,2]. The consequences of fouling in tropics are much more serious and are estimated nearly twice as harmful as in temperate zones (*loc. cit*). Besides reducing speed and increasing fuel consumption, the fouling organisms destroy the protective paint system on ships and cause oxygen concentration cells which aggravate conditions for corrosion. Some of the fouling types are stated to harbour anaerobic sulphate reducing bacteria, which also contribute to increase corrosion[3]. Extensive work on the nature and extent of organisms responsible for marine fouling has been done in temperate waters, round the coast of U.K. and U.S.A.[1]. Studies on the biology of fouling organisms in Australian waters have been conducted recently by Allen and Wood[4], and Allen[5]. But little only is known regarding the occurrence, seasonal variations, bionomics etc., of such organisms in tropical waters around India. Our knowledge of the Marine fouling organisms in Indian waters is restricted to the investigations of Paul[6,7] and Daniel[8] in Madras harbour area, Erlanson[9] in Cochin, Kuriyan[10, 11, 12] around Krusadi island in Gulf of Mannar and that of Rao[13] in Visakhapatnam harbour.

In the present work, systematic collection of data on the nature and extent of the main fouling types prevalent in Bombay Harbour which are important from the point of view of the antifouling problem of ships and marine structures, has been undertaken as a part of the antifouling Research programme. The investigations were carried out during the period August 1953 to May 1956. An attempt has also been made to correlate the fouling intensity with environmental factors like salinity, temperature, rainfall etc. It would be noted that the fouling organisms have been classified into their main groups only. Other biological studies on this problem have been taken up separately.

Material and Methods

Method of collection of the fouling organisms and their rating—For the collection and regular observation of the fouling organisms, non-toxic panels were exposed to sea-water on a Raft which was specially built in the Naval Dockyard. It is made of structural steel parts and provided with a rigid rectangular frame work 16′ × 18′ with five buoyancy tanks on either side. The central portion is divided into 4 bays, each capable of taking 9 angle iron frames that could be firmly slided in between the supports. Round the raft, a gang way 3′ wide is provided for enabling the lifting and inspection of the frames conveniently. The Raft was moored to a buoy at the entrance to Bombay Harbour about 500 yards from the break-water area. This particular location was selected in view of its being practically free from floating oil, debris and other shore contaminants and also in view of easy accessibility from the Naval Boat basin. The non-toxic panels, made of laminated bakelite sheet, each 15″ × 12″ × 1/2″ were rigidly fixed to the angle iron exposure frames, by bolts insulated with bakelite sleeves and washers. Each frame was capable of taking four such panels, two each in the upper and lower row. The top edges of the upper panels were always one foot below the sea water surface while those of lower panels were 3′ below the surface. The gap between the top and bottom rows of panels was 9″. The exposed panels remained almost parallel to the tidal flow as the Raft, which was not rigidly fixed, would align itself in the direction of the tide thus offering least resistance for movement of water. Fresh set of panels were exposed once in every month, when the fouled panels exposed during the previous month were removed for examination and assessment. The fouling encountered on both sides of the panels was studied for—

1. Identity of organisms (groups only).
2. Number present in each group.
3. Area of fouling (approximate).
4. Total weight of fouling.

Averages of the four panels (exposed on a frame) were taken into account in all cases.

For the quantitative assessment of the intensity of fouling organisms found on the panels, the following arbitrary ratings, based on the methods adopted by the Antifouling Research Sub-Committee of the Admiralty Corrosion Committee, were adopted.

	No. of individuals or colonies	Rating
Barnacles, Tube worms, Molluscs	Up to 5	0
	6—10	1
	11—25	2
Bryozoans & Hydroids	26—50	3
	51—100	4
	101—200	5
	Above 200	6

For Bacterial slime, algae and other plant growths as well as encrusting bryozoans, the ratings were based on percentage area covered as shown below—

Percentage area covered	Rating
Up to 5	0
6—25	1
26—50	2
51—75	3
76—100	4

The rating method is generally employed in testing antifouling paints and had to be adopted for the present studies as a matter of convenience. As mentioned earler, biological studies on the organisms concerned have been taken up separately where the method of determining the number of organisms belonging to different species is being used.

Environmental factors—Determinations of salinity, temperature and pH, of sea-water, for a period of 36 months (June 1953 to May 1956) were made.

During the initial stage of the present investigations (i.e. up to August 1954) sea water samples were collected daily from the exposure site for estimations of NaCl content, temperature and pH. During subsequent months observations on weekly samples only were made. Samples were always drawn from a depth of 3′ below the sea water surface. Temperature was recorded at the site immediately on collection of samples with an accurate thermometer. For salinity determinations, a known quantity of sea-water was titrated against standard silver nitrate solution using potassium chromate as indicator, following Mohr's method. The chlorine value thus obtained was expressed as NaCl content. This obviously indicates the total halogens and other cations and not the actual NaCl content of sea-water. It is nevertheless an accurate measure of salinity as the proportions of various other salts in sea-water always bear a definite relationship to the NaCl content. Chlorinity and salinity have been calculated from the relation (14)

Chlorinity .. .. $\%\ NaCl \times 6{\cdot}066$

Salinity .. .. $0{\cdot}03 + 1{\cdot}805 \times$ Chlorinity

The p_H values were determined by the system of glass and saturated calomel electrodes in a Cambridge p_H meter.

Results

Changes in environmental factors like Salinity, temperature and P^H of sea water:

As can be seen from Fig. 1, the salinity of the sea-water during the period June 1953 to May 1956 was more or less constant except during the monsoon months when due to influx of fresh water from mainland as well as local rainfall, the salinity dropped down to as low a level as 12·31 in 1953 July, 6·9 in September, 1954 and 9·5 in August 1955 as against normal average value of 35·3. In Bombay the monsoon usually starts by the middle of June and extends up to about the middle of September. An attempt was made during the monsoon season of 1955 to determine the variations in salinity during high and low tides on the same day. From the results obtained (Fig. 2), it will be noted that generally the salinity was slightly higher during high tides. This was evidently due to the rush of fresh sea-water into the harbour during high tide. For the rest of the year, practically no differences in salinity values during high and low tides could be observed and hence these data have not been included in the present account.

From the data obtained it was seen that the range of variation in temperature during different months was narrow, between 23·5° and 31·8°C. The higher temperatures were generally recorded during the months March to June and in October whereas the lower values were from December to February (See Fig. 3).

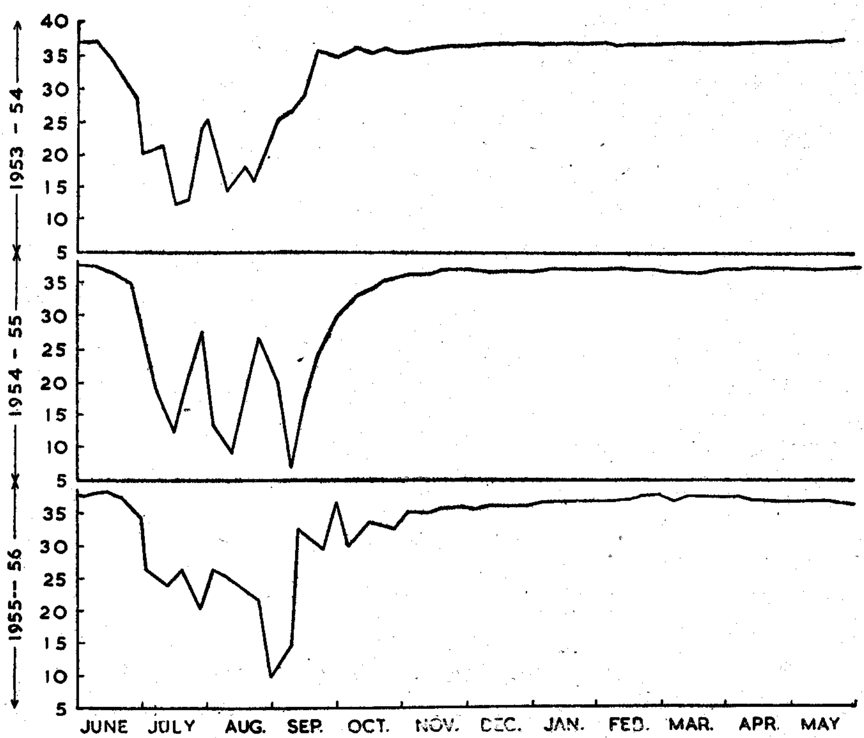


FIG. 1——Salinity Data for Bombay Harbour: June 1953 to May 1956.

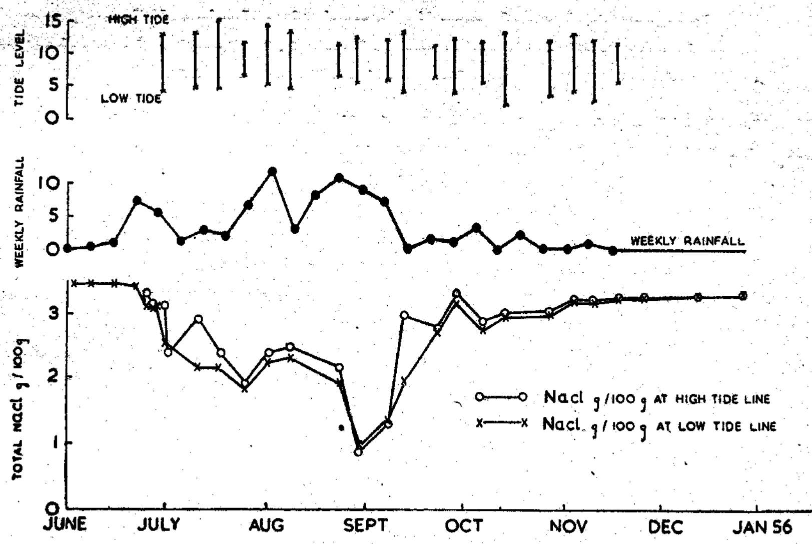


FIG. 2—Graph indicating variation of NaCl (Total Halides as NaCl) content in sea water at high tides and low tides in Bombay Harbour from July '55 to Dec. '55.

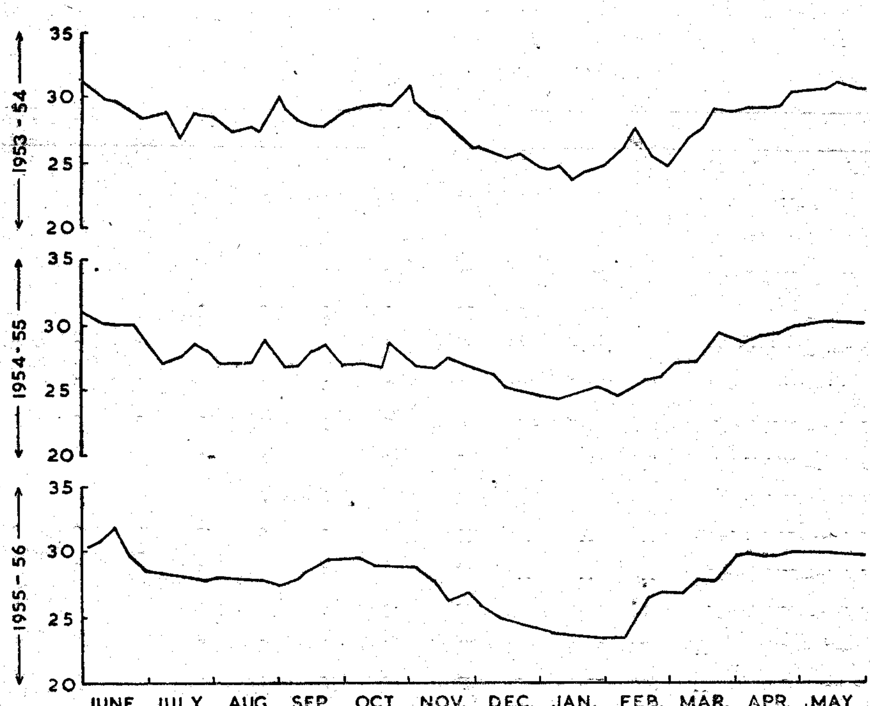


FIG. 3—Temperature of Sea Water at Bombay Harbour: June 1953 to May 1956 (in °C).

The pH of sea-water showed very little variation during different months and for the major part of each year was about 8·2. Regular determinations were made till August 1954, but only occasionally afterwards.

The Fouling Organisms—Among the fouling organisms found in Bombay harbour, the Barnacles, Bryozoans, Hydroids and Tube worms are the most important from the ships' fouling point of view. Molluscs settle in good number on the hulls of ships at anchor, but many of them are swept off during subsequent steaming. However, all the different groups of fouling orgnisms found on the experimental panels were assessed and the data collected during the three years (from August 1953 to May 1956) are presented in Table I. Up to August 1954, the data are based on observations made from middle of a month to the middle of next month, while later values are for calendar months. During the monsoon period (usually from middle of June to middle of September), there was practically very little fouling in Bombay harbour and so in the following description, ratings for the above period have been considered as almost negligible.

TABLE I

Fouling data for the period August 1953 to May 1956

Period of Exposure	Total weight of fouling gms.	Wt. per sq. ft. gms.	Approx. % area covered	Fouling intensity	Fouling Organisms rating						
					Plant growth	Hydroids	Bryozoans	Molluscs	Polychaetes	Barnacles	Ascidians
1	2	3	4	5	6·1	6·2	6·3	6·4	6·5	6·6	6·7
Mid Aug.—Mid Sept. '53	35	13·0	20	L	1	0	2	0	0	1	0
Mid Sept.—Mid Oct. '53	50	18·6	37	M	2	1	2	0	0	2	0
Mid Oct.—Mid Nov. '53	108	40·0	80	H	2	2	2	3	1	5	1
Mid Nov.—Mid Dec. '53	82	30·3	55	M	2	1	3	2	0	2	1
Mid Dec.—Mid Jan. '54	52	19·2	35	M	1	1	2	1	0	2	0
Mid Jan.—Mid Feb. '54	49	18·1	30	M	1	0	2	1	0	2	0
Mid Feb.—Mid Mar. '54	147	54·4	80	H	1	1	3	0	1	5	0
Mid Mar.—Mid Apr. '54	132	48·8	90	H	2	2	4	1	1	6	1
Mid Apr.—Mid May '54	134	49·6	95	H	2	3	4	1	1	6	1
Mid May—Mid June '54	128	47·4	90	H	2	3	3	1	1	6	1
Mid June—Mid July '54	..	..	..	N	0	0	0	0	0	0	0
Mid July—Mid Aug. '54	..	..	..	N	0	0	0	0	0	0	0
Mid Aug.—Mid Sept. '54	52	19·2	40	M	1	0	1	0	0	2	0
September 1954 ..	96	35·5	50	M	1	1	1	0	1	3	0
October 1954 ..	210	77·7	95	H	0	2	1	0	2	5	1
November 1954 ..	128	47·4	70	H	0	0	2	1	2	3	0
December 1954 ..	80	29·6	45	M	0	0	3	2	2	2	0

TABLE I—*contd.*

1	2	3	4	5	6·1	6·2	6·3	6·4	6·5	6·6	6·7
January 1955 ..	58	21·5	25	M	1	1	2	0	0	2	0
February 1955 ..	44	16·3	25	M	1	1	2	0	0	3	0
March 1955 ..	170	62·9	75	H	1	1	4	0	1	5	0
April 1955 ..	191	70·7	85	H	1	1	6	0	1	6	0
May and June 1955 ..	Data not collected as the Raft had been slipped for repairs.										
July 1955	33	12·2	20	L	1	0	1	0	0	1	0
August 1955 ..	24	8·9	5	N	0	0	0	0	0	1	0
September 1955 ..	135	50·0	55	M	1	2	3	0	0	4	0
October 1955 ..	209	77·4	85	H	2	2	2	0	3	6	1
November 1955 ..	142	52·6	55	M	2	2	1	0	0	5	0
December 1955 ..	50	18·5	50	M	1	2	4	0	0	5	0
January 1956 ..	123	45·5	55	M	1	1	1	0	0	4	0
February 1956 ..	167	61·8	65	H	1	1	2	0	0	5	0
March 1956 ..	174	54·4	75	H	1	2	3	0	0	6	0
April 1956 ..	148	54·8	75	H	1	2	5	0	0	6	0
May 1956 ..	190	70·3	90	H	1	2	6	0	0	6	0

* N—Negligible, L—Light, M—Moderate, H—Heavy.

For Fouling ratings from 6·1 to 6·7 please see method of assessment described under material and methods.

Bacteria and Bacterial Slime—These were always present on the experimental panels and were observed before any other major fouling types had settled. When the actual ratings for major types were recorded, the area of the unfouled surface covered with Bacterial slime was comparatively very little and hence no attempt has been made here to describe their seasonal variations.

Algae and other Plant Growths—These were found almost throughout the year, (except during the period of heavy rainfall) confined mostly to the top portions of the upper row of experimental panels. Their abundance near about the water line is a general phenomenon[1] and is due to the availability of sunlight which facilitates photosynthesis. From the histograms prepared to show their distribution during the different seasons (Fig. 5) it will be seen that higher intensities of settlement and growth were observed during September to November 1953, March to May 1954 and October and November 1955. It will be noted that of the months October, November and December, which have maximum number of hours of bright sunshine, only during October and November 1954, there was considerable decrease in intensity of algal settlement. Since the necessary correlating studies could not be taken up at that time, it was not possible to find out the actual reasons for such exceptional low intensity of settlement. As is evident, the intensity of illumination during this period was quite high and hence other factors like the settling stages present in the plankton, nutrients etc., should have been responsible for the change in fouling behaviour. Further studies in this direction are being taken up.

Among the plant growths present on the panels the following genera could be identified: *Ectocarpus*, *Ulva*, *Enteromorpha*, *Cladophora* and *Ceramium*.

Hydroids—A comparative study of the intensity of hydroid settlement during the different periods (Fig 4) shows that a season of very heavy hydroid settlement occurred during middle of March to middle of June 1954 and moderate settlement during October and November 1953, October 1954, September to December 1955 and March to May 1956. Practically very little hydroid fouling could be noticed during February, November and December 1954. It was seen

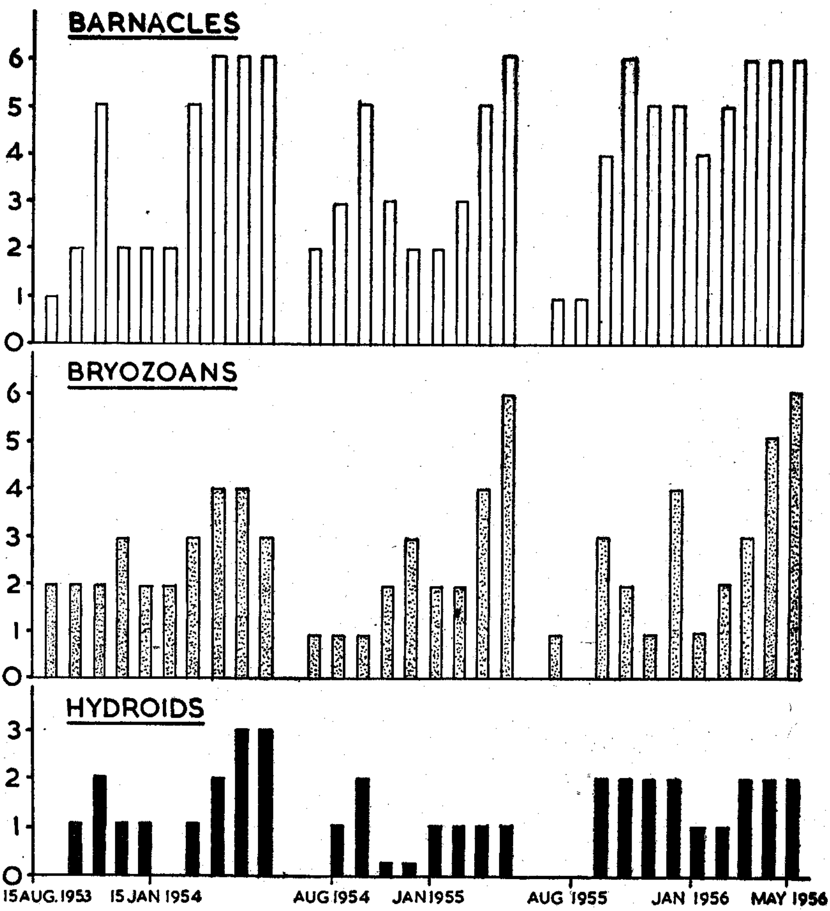


FIG. 4—Assessment Ratings of Fouling Organisms in Bombay Harbour from middle of August 1953 to May 1956.

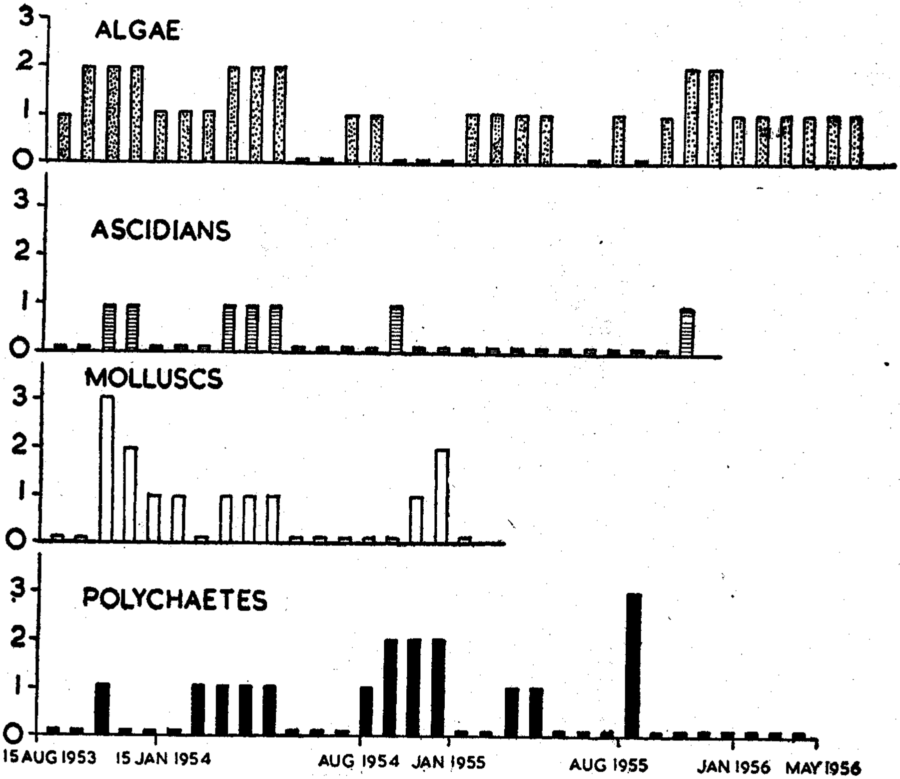
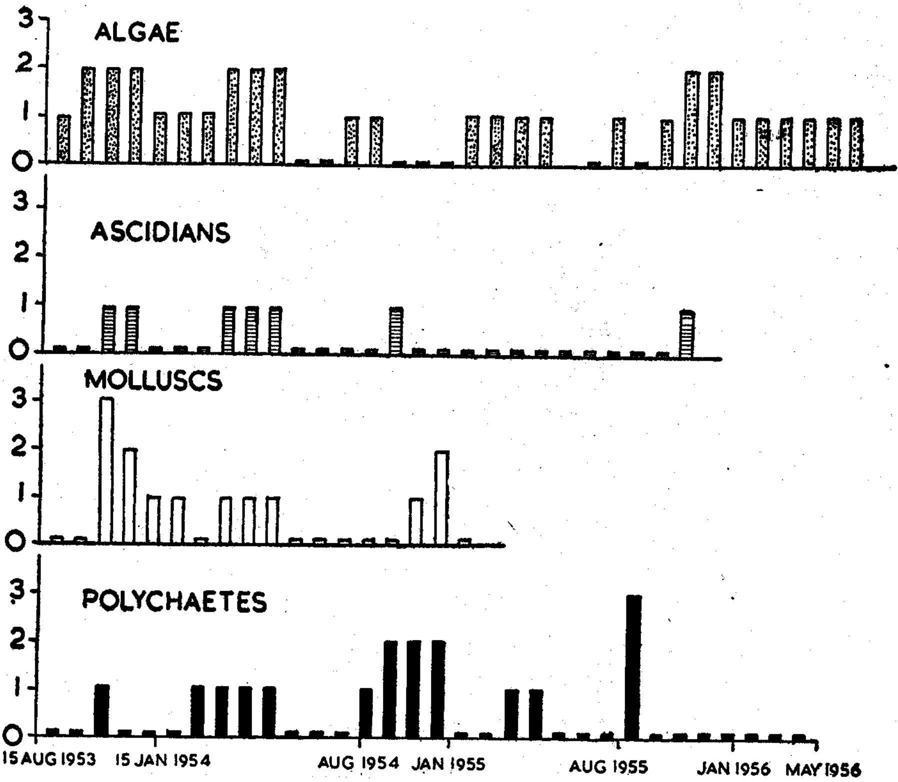


FIG. 5—Assessment Ratings of Fouling Organisms in Bombay Harbour from middle of August 1953 to May 1956

that heavier hydroid settlements usually occurred during hotter months but the summer period of 1955 appeared to be an exception to this. It was also observed that on most of the frames maximum hydroid fouling occurred on the lower row of panels. The hydroid colonies were generally found to grow from the periphery of the panels with their stems adherent to the panel surface, appearing as if they were spreading towards the centre. Two distinct types of hydroids were frequently met with. In certain cases it was found that hydroid colonies were growing by the side of erect bryozoans.

Bryozoans—The Bryozoans, which form a major group of fouling organisms at Bombay and are next in abundance to Barnacles only, were found settling in large numbers throughout except during months of heavy rainfall. The ratings obtained have been plotted as histograms (Fig. 4) from which it will be seen that this group exhibited marked seasonal fluctuations in its settling behaviour. They were predominant during middle of March to middle of June 1954, March, April and December 1955, and April and May 1956. Their fouling intensity was low during middle of August to October 1954, November 1955 and January 1956. In all the above ratings, both the encrusting as well as erect types of Bryozoans have been included. It was noticed that on many of the panels colonies of encrusting Bryozoans were found in much larger numbers than the



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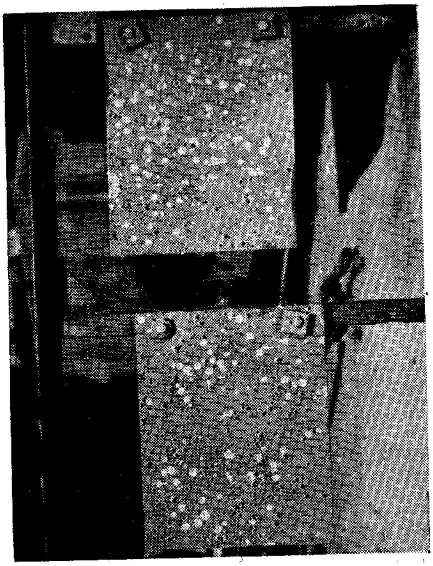

Plate 1—Erect and encrusting Bryozoans.

Molluscs—From the data obtained on the intensity of attachment of molluscs on the test panels (Table I and Fig 5), it is seen that higher settlement of these organisms was encountered during the period October—December 1953 and December 1954. But during the same period in 1955 very few molluscs were found. Throughout 1955 and up to May 1956 there was only negligible molluscan fouling.

The Molluscs consisted mainly of mussels and gastropods and these could be dislodged easily because of their loose attachment to the substratum. Oysters alone, when present, had attached firmly. On certain panels barnacles and bryozoans were found to grow on oyster shells. In view of the fact that similar molluscs were usually found to grow to large sizes on neighbouring stationary buoys, it is felt that the ratings obtained do not give an exact idea of the actual number of molluscs that got settled, as some of them might have been dislodged from the panels before the routine inspections were made.

Polychaetes—Generally two types of tube dwelling worms were found to grow on the panels, one the thick, long and brownish erect type and the other, thin white and encrusting one. The former were seen growing in big clusters while the latter were usually scattered here and there in between other bigger organisms. The tube worms were particularly predominant on the experimental panels during October to December 1954 and October 1955 (Table I and Fig 5).

They were present in moderate numbers (Rating 1) in October-November 1953, February to June, and September 1954 and March and April 1955 (Plate 2). From the observations made so far, it appears that tube worms are not important foulers in Bombay harbour. However since they are invariably found on hulls of ships, further studies are necessary to arrive at definite conclusions.

Barnacles—The Barnacles were the most dominant of the fouling organisms during all seasons of the year (excepting monsoon period). In view of their abundance and importance as the most prevalent fouling organisms from the ships' point of view, it would be of interest to study their seasonal distribution with reference to environmental factors like salinity and temperature. From the ratings (Table I) as well as the histograms (Fig 4) it is clear that very large barnacle populations were found on the panels in October-November 1953, February—June and October 1954, March and April 1955 and October 1955 to May 1956. The temperature chart (Fig 3) shows that generally during March to June and October each year, the average temperature of sea-water was higher than other months. It is during the above warmer months that heavier barnacle settlements have been encountered. However, Barnacles were almost uniformly predominant during the entire period starting from October 1955 to May 1956. It is likely that their occurrence in large number during November 1955 to February 1956 might have been due to some other factors concerning breeding habits, presence of very heavily fouled structures anchored nearby etc. Further,

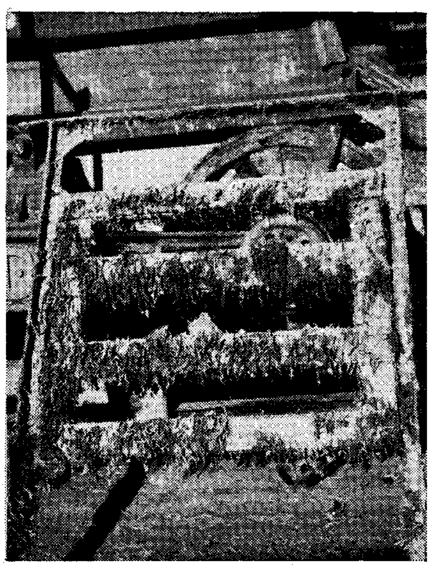

Plate 2—Tube worm fouling.

it is known that several fouling organisms exhibit yearly variations in their seasonal abundance and settlement. Plate No. 3 shows a typical heavy settlement of barnacles on the panels during this period. On the other hand, when the temperature of sea-water was low during November 1953 to February 1954 and November 1954 to February 1955, the number of Barnacles present on the panels was comparatively less. The rate of settlement of Barnacles was found to be directly proportional to the salinity of the medium. It will also be seen that during the monsoon months, when sea-water was of low salinity, barnacle communities were found to attach in negligible numbers only. The observations indicate the combined effect of low salinity and low temperature in retarding fouling by barnacles during the above period (Figs. 1, 3 and 4). Even those few individuals, which were present on the panels during these periods of low fouling intensity, were of very small size i.e., less than 1 cm. dia. During the periods of heavy settlement the barnacles were found to grow in large clusters. In this connection it may be mentioned that on certain panels some of the barnacles had died leaving empty shells at the time of inspection. However, as the panels were changed at the end of every month, the empty shells have also been included in the ratings. Definite reasons for the death of the barnacles could not be ascertained. During casual intermediate examinations it was found that fresh set of barnacles had attached to the earlier settlers. During May, tertiary settlement was also observable. It is inferred that the high temperature, normal salinity and slacker tidal flow were quite favourable for heavy barnacle infestation. During summer months Bryozoans were also found to settle in large numbers on the barnacles Goose-barnacles were not encountered on the experimental panels during the entire period of investigation.

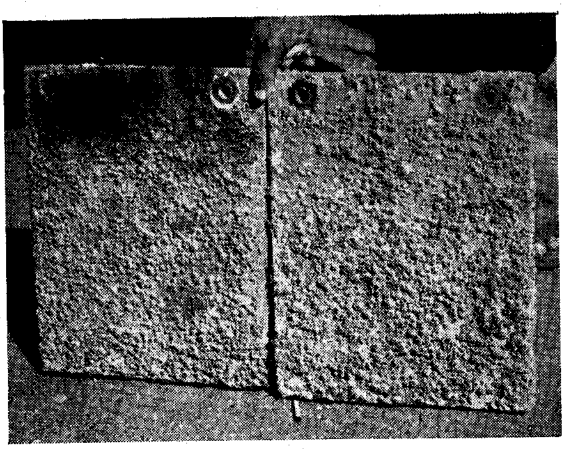

Plate 3—Heavy settlement of Barnacles

Ascidians—Both simple and compound Ascidians were met with though their intensity was very low throughout the entire period. From the data obtained (Table I and Fig 5), it is evident that the Ascidians do not constitute a serious fouling community in Bombay Harbour. Incidentally it may be mentioned that a particular ship that had been berthed in Naval Wet-Basin for about 6 months was found to have had a heavy attachment of Ascidians when dry-docked. It is felt that the particular location of the wet-basin might have been favourable for Ascidian growth. Further observations are expected to throw more light on this problem.

Weight of Fouling Organisms—After the usual monthly examination of panels, the weight of total fouling present was determined by taking the weight of panels before and after thorough scraping. Care was taken to remove as much of adherent water as was possible before taking the initial weight, i.e. with fouling. The total weight of fouling has been expressed in Table I as grammes per square foot of exposed area. In all cases the averages of the 4 panels exposed simultaneously have been taken into account, and the results are presented graphically in Figure 6. Maximum weights of fouling were observed during October in each year and again during February/March up to the outbreak of monsoon by about the middle of June. The salinity fluctuates within very narrow limits only during these months (see Fig 1) and so the higher temperature and normal salinity of the sea-water during this period are mainly responsible for the heavier fouling.

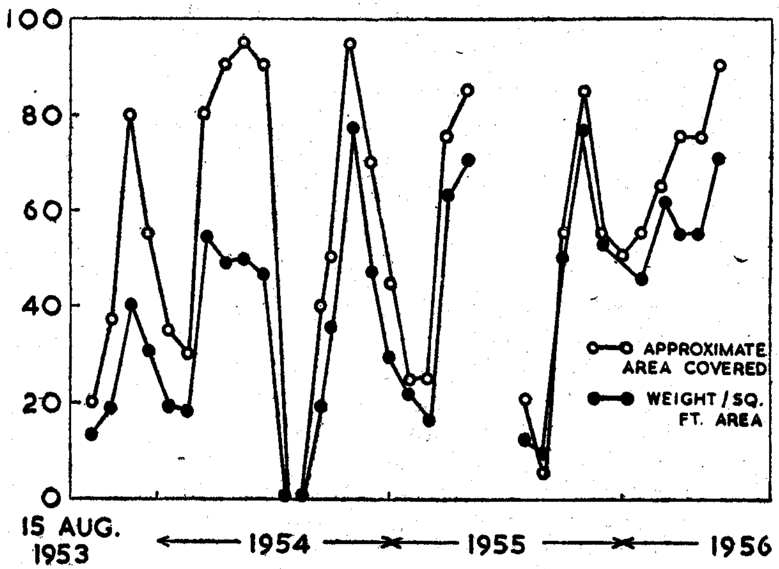

FIG. 6—Total weight of fouling per sq. ft. area and approximate area of Panel covered from August 1953 to May 1956.

Discussion

The results obtained from the present investigations conducted during a total period of 33 months, reveal clearly that in Bombay Harbour, fouling takes place throughout the year except during the period of heavy rainfall. During the latter period the salinity of sea-water drops down considerably and this accounts for the very low fouling intensity observed. This type of settlement of fouling organisms throughout the major part of the year is a common phenomenon in tropical waters[1]. At the same time, the attachment of the organisms in Bombay, though continuous, shows in each year two periods when definite increases in fouling intensity are noted. Such increased rates are usually seen during the summer months (March—June) and October. It has been observed by Daniel[8] that some of the fouling organisms present in Madras Harbour also exhibit two peaks of abundance. Paul[7] has shown that in Madras, though there are two periods of higher temperature, i.e. in April and towards end of October, only a single period of higher attachment by several organisms was observable. It has been suggested by Redfield and Deevy[15] that the seasonal variations of fouling at Madras appear to be correlated with the effects of two annual monsoons rather than with variations of temperature. Similar views have been expressed by Millard[16] who was unable to find out any clear correlation between water temperatures and fouling in Table Bay Harbour in South Africa. However it is accepted by most of the workers in the field that fouling intensity is closely related to the temperature of the environmental medium. Several published records show that in temperate waters fouling periods are much more restricted than in tropical situations. Investigations conducted at different stations in United States showed different rates of fouling, heavier settlements being from places nearer the tropics[1]. The abundant settlements encountered at Capetown[16], at Hawaii[17]; and at Australia[18], also appear to substantiate the above observations.

In Bombay harbour, although fouling takes place throughout the year (except during monsoon) different groups of organisms predominate at different periods. This is evidently due to characteristic breeding habits of the different organisms. It is known that the sequence of settlement and growth of fouling organisms on non-toxic panels is a function of the chronological order in which the larvae of the organisms appear at the site and also their rate of growth[19]. Since the organisms have not been specifically identified and their individual seasonal settlement behaviour studied, no attempt is made here to discuss this aspect. It is also seen that in addition to seasonal variations, the fouling organisms exhibit yearly variations in intensity of settlement. Similar observations have been recorded by earlier workers[1,20].

Conflicting views have been expressed regarding the role of bacterial slime as a precursor to fouling[1]. It has been suggested by many workers that a primary slime, though not essential for settlement of fouling organisms, may facilitate heavier attachment. On the other hand it has also been stated that slime may delay the onset of fouling when the film has disintegrated or been stripped off[19]. Since the effect of primary film on fouling has not yet been studied in Bombay, the merits of the case are beyond the scope of this paper. It may be mentioned that Bacterial slime was present on experimental panels throughout the year and further studies are expected to give more information on this aspect.

Plant growths which are mostly confined to the water line are not serious fouling organisms. Hulls of ships examined in our dry-docks also showed that the plant growths were mostly restricted to the boot-top area. Brown and red algae were occasionally met with on the lower row of test panels.

The analysis of fouling on the panels has shown that the different groups of fouling organisms exhibit variation in their individual seasonal settlement. Such variations have been recorded from many parts of the world, and are due to the different interacting factors like physiological characteristics and geographical distribution of the organisms, environmental changes etc.[15]. The differences exhibited in the intensity of settlement of the fouling organisms are of great importance in the assessment of antifouling compositions[21].

The bottom region of the lower row of the test panels had greater number of barnacles and bryozoans than the upper row. Similar results have been obtained by McDougall[22] for *Balanus eburneus*, where greatest attachment on a floating pile was at the lowest level, i.e. 6′ below the surface. The above author has suggested that the barnacle larvae were more concentrated at that particular depth. The same view would be applicable for the present observations also.

It is known that most of the fouling organisms do not survive under low salinity conditions. Some of them however, have been found to tolerate very low salinities at certain stations[23]. The results given above show that the majority of the fouling organisms at Bombay do not settle or grow on the panels during the periods of heavy rainfall. Even though measurements of the organisms have not been taken, it was observable that the barnacles and bryozoans had stunted growth during periods of low salinity. Such retarded growth due to lower salinity of the medium has been described by several workers[1].

It is considered that the data obtained are applicable to both shallow and deep draft type ships, as it is known that except for restriction of the algal zone near the water line, there are no significant regional differences in the distribution of fouling organisms on the various regions of the hull. But there may be different optima level for the individual species of animals and it is proposed to suspend experimental panels at different depths by a special arrangement, in order to study fouling at various levels.

On the basis of the results obtained it is suggested that ships can berth in Bombay Harbour without fear of fouling during monsoon months. Further, since heavy fouling occurs during the summer months and October, Naval Ships may adjust their cruise- sailings in such a manner as not to anchor in the harbour during these periods. The importance of adequate knowledge of the seasonal variations in the settlement of fouling organisms for assessment of antifouling compositions has already been emphasized. Since barnacles are the heaviest foulers, toxins which are specific towards them are of primary importance in formulation of antifouling compositions. Specific identifications of the fouling organisms at Bombay and Cochin harbours and studies on other biological aspects of the fouling problem have been taken up in this Laboratory, and are expected to give further valuable information. Studies on the fouling organisms at other coastal stations also would contribute largely to the design, formulation and use of suitable antifouling compositions.

Acknowledgements

This work was started in 1953 under the guidance of Dr. G.E. Gale, R.N. S.S. Thanks are due to Prof. D. V. Bal and Principal Scientific Officer (Navy) for helpful suggestions. The authors are particularly indebted to Shri V.M. Kelkar and Shri V.S. Sarang for assistance in collection of salinity and fouling data respectively. They are also obliged to the Meteorological Observatory, Colaba, for supplying the meteorological data.

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