OBSERVATIONS ON FOULING ORGANISMS COLLECTED FROM INDIAN NAVAL SHIPS AT BOMBAY

by

V. Gopalakrishnan and V. V. Kelkar

Naval Chemical and Metallurgical Laboratory, Naval Dockyard, Bombay

ABSTRACT

Fouling organisms collected from Indian Naval Ships dry-docked at Bombay during a period of two years (July 1956—June 1958) were studied in detail. Forty six of the forms collected have been identified. The most important groups of ship-fouling organisms in Bombay waters are Barnacles, Hydroids, Polyzoans and Tube-worms. Eleven different Fouling Communities have been found to dominate the settlements on the hulls at different occasions. Definite zonations that could be observed were restriction of green algae to the boot-top area and of mussels and oysters to the pipes and gratings. An attempt has been made to find the sequence of settlement of the different major fouling groups. Some general remarks on the observations have also been included.

Introduction

The harmful effects of Fouling on the speed and economy of ships are well known and have been discussed in detail in the recent U.S. Naval Publication, "Marine Fouling and its Prevention" [1]. The particular results of Fouling of ships are reduction in speed, increase in fuel consumption, damage to steel plates due to accelerated corrosion, losses in time and expenditure in removing the fouling and applying fresh anti-fouling coatings. Fouling of gratings and pipes distributing sea water in ships affect the normal flow of water. Fouling of propellers disturb the flow pattern thereby decreasing development of the propulsive force to a very great extent. It has also been found that fouling on under-water sound equipments of ships affects the functioning of the instruments to a great extent. It is common knowledge that one of the important aspects of investigations on the fouling problem is the study of settlements on hulls of ships (Pyefinch[2]). The fouling organisms present in Indian Harbours have received the proper attention of workers in recent years only. Very little data have so far been collected from hulls of ships plying in Indian Waters, even though it has been repeatedly emphasized by workers in Temperate Zones that such studies at Tropical stations would yield very valuable information (Pyefinch[2]). The Naval Chemical and Metallurgical Laboratory at Bombay has been conducting investigations on the Fouling Organisms in Bombay Harbour waters and an account of the seasonal variations in the settlement of the different groups of organisms

has already been published (Iyengar, *et al*[3]). The observations presented in this account are based on fouling samples collected from the hulls of Indian Naval ships dry-docked at Bombay during a period of two years (July 1956 to June 1958). The data were obtained on sixty eight dry-dockings of the ships. The fouling organisms described were all collected from vessels that had remained in Bombay and other neighbouring ports only. Collections have also been made from small craft, explosive barges and petroleum barges which had remained in water for long periods.

Material and Methods

The samples were all collected from the hulls of the ships as soon as possible after pumping of water from the docks. Care was always taken to see that the samples were representatives from different regions of the hulls. The fouling on gratings, pipes, asdic domes and propellers have also been studied. The collections were always cleaned free from mud, debris etc., taking care to preserve microscopic fouling whenever necessary (Bishop *et al*[4]). Then the organisms were sorted, identified and also counted and measured to determine the intensity and sequence of settlement in particular instances.

The Fouling Organisms

The undermentioned fouling organisms collected from the hulls of ships that had remained in Bombay and neighbouring areas have been identified so far:—

Diatoms:

Coscinodiscus sp., *Rhizosolenia* sp., *Biddulphia* sp., *Thallasiothrix* sp., *Pleurosigma* sp., *Bacillaria* sp. and *Schizonema* sp.

Other Algae:

Oscillatoria sp., *Ulva* sp., *Cladophora* sp., *Enteromorpha* sp., *Ceramium* sp., *Dictyota* sp., and *Ectocarpus* sp.

Coelenterata:

Pennaria disticha, *Laomedia* sp., and *Campanularia* sp.

Polyzoa:

Crisia eburnea, *Membranipora tenuis*, *Zoobotryon* sp., *Bowerbankia* sp. and *Amathia distans*.

Annelida:

Hydroides norvegica, *Serpula vermicularis* and *Dasychone* sp.

Mollusca:

Mytilus viridis, *Modiolus emarginatus*, *Arca bistrigata*, *Libitina vellicata*, *Ostrea crenulifera*, *Ostrea virginiana*, *Ostrea* sp., *Anomia achaeus* and *Thais tissoti*.

Cirripedia:

Balanus tintinnabulum tintinnabulum, *Balanus amphitrite variegatus*, *Balanus amphitrite communis*, *Balanus amphitrite venustus*, *Balanus amaryllis forma euamaryllis* and *Balanus amaryllis formanivea*.

Amphipoda :

Elasmopus pectenicrus, Corophium acherusicm and *Ericthonius* sp.

Tunicata :

Ascidia sp., *Botryllus* sp., and *Polycarpa* sp.

The Fouling Communities

The settlement of fouling on the hulls is naturally found to vary with the season, ports of call, period elapsed after previous dry-docking, type of antifouling paints used etc. However, different fouling communities were found to dominate on the hulls at different times. Along with such dominant groups other organisms also used to be present but in small numbers only. Observations on the hulls as well as analyses of the samples have revealed the presence of the following dominant ship-fouling communities in Bombay waters.

1. *Barnacle Community.* Among the different communities observed on the hulls of ships, the most important has been the Barnacle community. It has been observed from Raft trials also that barnacles are the most predominant fouling organisms in Bombay Harbour (Iyengar, *et al*[3]). Dominance by barnacle communities was recorded on 13 instances during the period of two years. FIG. 1 shows typical barnacle community on one of the ships examined. Only acorn barnacles have been encountered and among them *Balanus amphitrite variegatus, Balanus amphitrite communis* and *Balanus tintinnabulum tintinnabulum* were the most common forms, their intensity of settlement being in the order mentioned. The maximum growth attained by *Balanus tintinnabulum tintinnabulum* was about 3 cms basal diameter and by *Balanus amphitrite,* about 2 cms. Since barnacles are the most important foulers, it would be of interest to mention the geographical distribution of the different species (Daniel [5]).

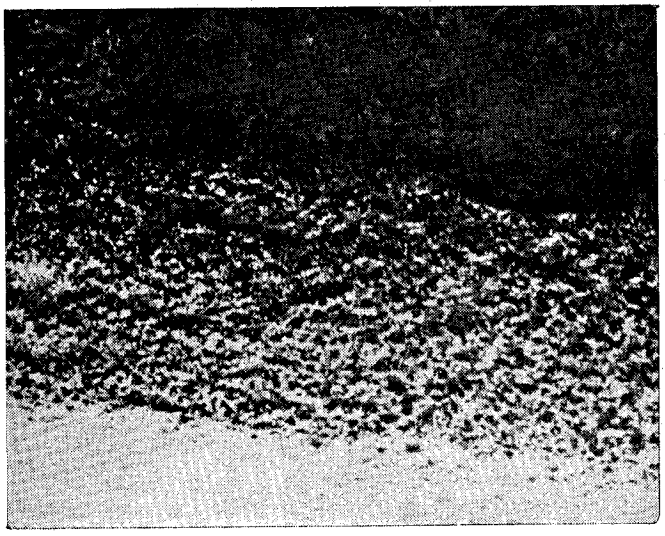

FIG. 1—Barnacle community on ship's hull.

(*a*) *B. t. tintinnabulum*: Mediterranean Sea, Atlantic and Indian Oceans, Bay of Bengal and Arabian Sea.

(*b*) *B. amphitrite variegatus*: Indian Ocean, Arabian Sea, Bay of Bengal, Malay Archipelago, China, New South Wales and New Zealand.

(*c*) *B. a. communis* : Arabian Sea, Bay of Bengal, Indian Ocean, European Seas, Mediterranean Sea, West and South Africa, Malay Archipelago, New South Wales, Pacific Ocean, Japanese waters and Hawaii islands.

(*d*) *B. a. venustus* : Mediterranean Sea, West and South Africa, Indian Ocean, Arabian Sea, Bay of Bengal and Japan.

(*e*) *B. amaryllis forma euamaryllis*: Indian Ocean, Arabian Sea, Bay of Bengal, Malay Archipelago, China, Japan and North Australia.

(*f*) *B. a. forma nivea*: Indian Ocean, Bay of Bengal, Arabian Sea, Malay Archipelago and Pacific Ocean.

2. *Barnacle and Polyzoan Community*—This community was found to be prominent during the summer seasons and was responsible for the fouling observed on 10 occasions. The barnacles in the community were the same as mentioned above and the polyzoans were *Membranipora tenuis* and *Crisia eburnea.*

3. *Barnacle, Polyzoan and Tube-worm community*—It was found on some ships that the fouling encountered was mostly a mixed community comprising of barnacles, polyzoans and tube-worms, each group being in almost equal numbers. Such communities were observed four times.

4. *Barnacles and hydroid community.*—On the hulls of four ships the dominant organisms were only barnacles and hydroids (mostly *Pennaria disticha*).

5. *Barnacle and Tube-worm community.*—This community was observed on nine dry-dockings. Majority of the tube-worms collected belonged to the species *Hydroides norvegica.*

6. *Polyzoan Community.*—Only 2 vessels showed fouling due to Polyzoans alone. The organisms concerned were *Membranipora tenuis* and *Crisia eburnea.* Fig. 2 shows fouling due to polyzoan community on a ship's propeller.

7. *Polyzoan and Tube-worm community.*—These communities were observed on 5 occasions. The Polyzoan frequently met with was *Membranipora tenuis* and the tube-worm, *Hydroides norvegica.*

8. *Tube-worm community.*—Fig. 3 shows fouling due to tube-worm communities on a ship. Such communities were observed on 11 occasions during the period of two years. The common organisms recorded were *Hydroides norvegica* and *Serpula* sp.

9. *Hydroid community.*—Dominant hydroid communities were recorded on 7 instances. Generally two species of hydroids were common, one of them being *Pennaria disticha.* The other form resembling *Laomedia* has not yet been identified.

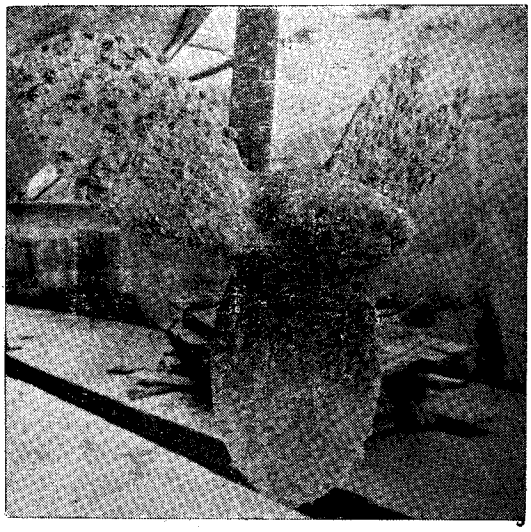

FIG. 2—Polyzoan Community on a propeller.

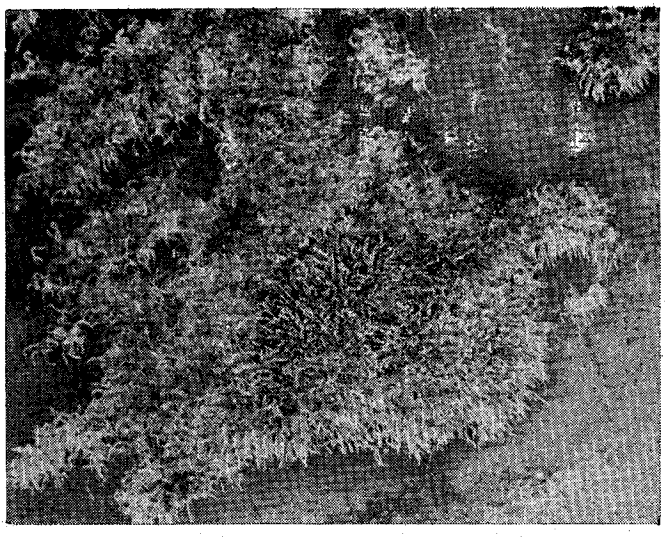

FIG. 3—Typical Tube-worm Community on a ship's hull.

10. *Mixed community.*—Three vessels, which were very heavily fouled, showed the presence of several of the above communities with more or less equal intensities of settlement.

11. *Enteromorpha community.*—This algal community was always restricted to the boot-top area and was observed on most of the ships examined.

Almost all the barges examined had been in water for long periods. As a result of this, the fouling observed was invariably very heavy and no definite communities could be marked out. In addition to the organisms listed earlier, a few ascidians and sea anemones have been collected from these barges, but they are yet to be identified.

Zonation

The only definite vertical zonation that could be observed on the hulls examined was the restriction of green algae, mostly *Enteromorpha* sp., to the boot-top area. Such regions of algal fouling usually extended to depths of one to two feet below the water level. The distribution of green algae nearer the water surface is known to be due to availability of maximum illumination at the surface[1]. Other algae were collected from different vertical zones of the hulls, but they did not show any special depth preferences. No well-defined zonal distribution of the animal fouling organisms could be observed except in the case of mussels and oysters, which were generally confined to the gratings, pipes etc. 'Asdic' domes of ships showed the presence of different groups of fouling organisms. The propellers, when fouled, had settlements of various organisms, but barnacles were the most common.

Although no vertical zonation of the different groups of animal foulers could be seen on the hulls, it was noted that the settlement of barnacles of the species *Balanus amphitrite* was generally heavier below a depth of 4 feet from the water line. Also, the intensity of settlement of the hydroids was found to increase gradually from a depth of about 3 feet from the water surface towards the keel, the maximum being at the lowest portions. Polyzoans and Tube-worms usually showed more or less equal intensities at various levels. However, it is felt that there might be definite zones of maximum activity for the individual species of organisms. Experiments in this direction have been undertaken by exposing non-toxic panels at different depths.

Sequence of Settlement

Data obtained from the analysis of fouling samples collected from ships do not give an exact idea of the sequence of settlement because the earlier settlers prevent the attachment of some of the other groups of organisms (Bishop *et al*[4]). However, it has been possible to reconstruct to a certain extent the fouling sequence in some cases. It appears that the first settlement is the "primary film" composed of diatoms, algal spores and bacteria. This is followed by the barnacles and the hydroids almost simultaneously and then the polyzoans and tube-worms in succession. In certain instances the tube-worms have been found to attach to the surfaces before the barnacles. Such variations are possible due to the nature of the antifouling paints and also ecological changes. Further settlements of barnacles occur at different stages resulting in secondary and tertiary growths.

General Remarks

Investigations on fouling of ships have received only very little attention from Indian workers. The observations presented above have established the nature of ship-fouling organisms present in Bombay and neighbouring areas. The most important of these organisms are the barnacles. The more

common barnacles observed on ships are *Balanus tintinnabulum tintinnabulum, B. amphitrite variegatus* and *B. a. communis*. The important barnacles recorded in Madras and Visakhapatnam harbours are also the same (Daniel[6], Rao[7]). The usual barnacles met with in temperate areas are, *Balanus balanoides, Balanus crenatus, Balanus glandula, Balanus improvisus, Balanus tintinnabulum californicus* etc. (Marine Fouling and its prevention[1]), In sub-tropical areas, the important species found are *Balanus eburneus, Balanus improvisus, Balanus trigonus, Balanus amphitrite cirratus* and *B. a. communis* (*loc. cit*). The tube-worm *Hydroides norvegica*, which is found in large numbers in Bombay waters and also Bay of Bengal, has been reported from the Atlantic Coast of Europe, the Mediterranean and Red Seas and also from the Pacific islands. As regards the other species of organisms it may be said that some of the species have been recorded at Madras and Visakhapatnam also and most of the genera are common to both Arabian Sea and Bay of Bengal.

Analysis of the data obtained shows that the most important ship-foulers at Bombay are Barnacles, Hydroids, Polyzoans and Tube-worms. The large number of dominant fouling communities is due to the very great intensity of fouling settlement in Tropical seas and also due to the absence of well-marked seasons. The variations in the intensities of settlement on the hulls generally corresponded with the seasonal differences in fouling observed in Bombay harbour (Iyengar *et al*[3]). Significant exceptions to this was the very heavy Polyzoan fouling observed on ships during the first quarter of 1958 (Gopalakrishnan and Kelkar[8]) and the very little fouling encountered during the months of May and June 1958. These variations were found to be due to biological peculiarities of the respective periods and are being studied in detail.

The distribution of green algae at the boot-top area and of mussels of and oysters on the gratings and pipes have been found in other areas also (Millard[9]). It may be mentioned that in certain areas very conspicuous zonation of Barnacles near the surface has been observed (Marine Fouling and its prevention[1]). From the present studies it could be seen that the settlement of *Balanus amphitrite* was generally heavier below a depth of about 4 feet from the water surface. Further experimental studies on this aspect are expected to give interesting results.

Acknowledgements

Our thanks are due to Dr. A. Daniel for information regarding certain barnacles, to Shri P. I. Thampy for his help in the identification of Polyzoans and to Shri K. Nagappan Nair for the identification of the Amphipods.

References

1. *Marine Fouling and its Prevention* United States Naval Institute, 1952.

2. Pyefinch, K. A., *J. Animal Ecol.*, **19**, 29, 1950.

3. Iyengar, S. Ranga, Gopalakrishnan, V. and Kelkar V. V., *Def. Sc. Jour.*, **7**, 123, 1957.

4. Bishop, M. W. H., Pyefinch, K. A. and Molly, F. Spooner, *Iron and Steel Instt.*, p. 35, 1949.

5. Daniel, A., *Bull. of the Madras Government Museum*, N.S., N.H. Section, 6, No. 2, 1954.

6. Daniel, A., *J. of the Madras University*, B, **24,** 189, 1954.

7. Rao, M.V.L., Fouling Organisms in Visakhapatnam harbour area. Abstracts of symposium papers and Discussions, Oceanography of Bay of Bengal, Government of India, 1956.

8. Gopalakrishnan, V. and Kelkar, V. V., *J. of the Bombay Natural History Society*, **55,** 588, 1958.

9. Millard, Naomi, Trans. Roy. Soc. (South Africa), **33,** 415, 1952.