Biodeterioration of Fishing Craft Materials along the Visakhapatnam Coast

R. Raghu Prakash and Leela Edwin[1]
Research Centre of Central Institute of Fisheries Technology
Ocean View Layout, Pandurangapuram, Visakhapatnam- 530 003
Andhra Pradesh, India
E-mail: drraghuprakash@hotmail.com

Biodeterioration caused by marine organisms affects the economy of fishing operations to a great extent. Studies were conducted by Central Institute of Fisheries Technology (CIFT) on the biology of fouling and boring organisms of the Visakhapatnam coast. Indigenous methods of preservation of fishing craft have been prevalent in this region. CIFT has successfully utilized water and oil-borne preservation for protection of fishing craft. This paper discusses the biodetrioration caused by marine organisms in the Visakhapatnam coast, the role of microbial film settlement of foulers and the biology of fouling organisms. Methods for control of biodeterioration are also discussed

Key words : Biodeterioration, craft materials, Visakhapatnam

Biological fouling causes many problems in the marine environment, interfering in a range of maritime activities. The losses due to biodeterioration of materials are enormous. The problem of controlling biofouling and marine borer infestation is extremely complex not only because of the magnitude of organisms and processes involved but also because of the many chemical and physical environmental conditions. The main causes of biodeterioration in the marine environment are biofouling, marine wood borers, fungal attack and corrosion.

Biofouling on ships reduces their speed and maneuverability due to increased drag, causing increased fuel consumption and maintenance costs (Nagabhushanam and Sarojini, 1997). Fishing vessels have to be dry-docked periodically, which is an added economic loss, in addition to the destruction of surfaces of the vessels. On static structures, such as buoys, piers, jetties, offshore oil and gas platforms, biofouling can enhance the corrosion of metal by seawater, increasing the risk of mechanical failure. Blooms of algae can block both fresh and salt water

[1]Central Institute of Fisheries Technology, P.O. Matsyapuri, Cochin-682 029, Kerala, India

filtration systems, and require water pipes to be frequently cleaned to prevent blockage. It also interferes with the efficiency of underwater acoustic devices and causes loss of efficiency of underwater propellers.

The long coastline of Andhra Pradesh coastline is characterized by variable physical and oceanographic features and fishery resources. This has resulted in the development and use of varied types of fishing crafts. In Andhra Pradesh, a total of 1,738 trawlers are estimated to be operating along the coast, in addition to 463 gill netters, 125 liners, 273 seiners and about 6,043 beach landing crafts. A total of around 50,201 traditional crafts operate in Andhra Pradesh, which includes canoes, catamarans and plank-built boats (Anon, 2000).

Fouling is a biological process aided by hydrographical and geographical factors. The establishment of a fouling community can be divided into different phases. Initially a primary film develops comprised of bacteria, fungal spores, diatoms and colloidal organic matter. In the second phase, there is the establishment of macrofoulers, which in Indian waters usually consists of hydroids, barnacles, tubiculous polychaetes, bryozoans, mussels, oysters and ascidians. As a submerged substratum ages, the fouling complex passes from the establishment to the extinction of different communities, whose compositions are influenced by the abundance of local species and physicochemical conditions of the environment.

Biofouling communities

Several studies have been conducted on the organisms that foul hulls of boats in Indian waters (Erlanson, 1936; Ganapathi and Nagabhushanam, 1955; Ganapathi and Rao, 1958; Nagabhushanam, 1959; Rao *et al.,* 1988; Rao and Balaji, 1988). The biofouling communities encountered at Visakhapatnam can be broadly classified into (a) the primary fouling assemblage, which directly attaches to the substratum and (b) the secondary foulers which live among the primary fouling assemblages. The former is comprised of both solitary and colonial forms. There are about 125 species reported at Visakhapatnam of which 84 species belonged to the primary fouling assemblages and the rest to secondary fouling assemblages (Ganapathi *et al.*,1958). The major fouling communities included hydroids, serpulids, ectoprocts, entoprocts, sponges, barnacles, oyster, bivalves, ascidians among the primary fouling group. The secondary fouling community consisted of polychaetes, nematodes, tubellarians, amphipods, copepods, tanaids, isopods, nudibranchs, etc. The micro-foulers include diatoms *Nitzchia* sp., *Pleurosigma* sp., *Rhizosolania* sp. and *Zoothamnium* sp.

Table 1. Major groups of foulers of Visakhapatnam

PORIFERA

Halichondria panicea
Sigmadocia punila
Tethya aurantium

COELENTERATA

Clytia noliformis
Diphasia sp.
Haleciidae
Halecium sp.
Laomedia bistriata
Pennaria disticha
Sagartia sp.
Sertularia sp.

PLATYHELMINTHES

Planocera sp.
Pseudoceros indicus
Stylocopoma sp.

ANNELIDA

Capitella capitata
Cirratulus cirratus
Dasychone cingulata
Diopatra neapolitana
Heteromastus sp.
Hydroides norvegica
Loimia medusa
Mercierella enigmatica
Neodexiospira pseudocorrugata
Nereis glandincta
Notomastus sp.
Paradexiospira vitrea
Perinereis cultrifera
Phyllodoce sp.
Polydora ciliata
Pomatoceros triqueter
Pomatoleios crosslandi
Pseudoeurythoe microcephala
Pseudoneries anomala
Pseudoneries dumerilli
Pseudoneries gallapagensis
Sabellastarte sp.
Serpula vermicularis
Syllis variegata
Syllis gracilis
Vermilopsis pygidialis

ARTHROPODA

Alpheus strenuous
Ampelisca zamboangae
Ampithoe sp.
Apseudes sp.
Balanus amphitrite
Balanus tintinnabulum
Charybdis orientalis
Cirolana fluviatilis
Corophium acherusicum
Corophium triaenonyx
Dynamella sp.
Elasmopus rapax
Elasmopus pectinicrus
Erichthonius brasiliensis
Exosphaeroma sp.
Grapsus grapsus
Hyale honolulensis
Laophonte cornuta
Laophonte hirsuta
Ligia sp.
Oniscus sp.
Pachygrapsus minutus
Podoceros brasiliensis
Pycnogonum indicum
Sphaeroma walkeri
Synidotea variegata

ECTOPROCTA

Alderina arabianensis
Amathia distans
Bowerbankia gracilis
Buskia nitens
Conopeum commensale
Crisia elongate
Electra bellula
Electra bengalensis
Electra pilosa
Electra tenella
Hippopodina feegeenensis
Hippopodina lafontii
Membranipora tenuis
Membranipora tuberculata
Nollella papaunensis
Scrupocellaria diegensis
Scrupocellaria harmeri
Scrupocellaria talonis
Sundanella sibogae
Victorella pavida
Zoobotryon verticellatum

ENTOPROCTA

Barentsia gracilis
Loxosomatoides laevis
Pedicellina cernua

MOLLUSCA

Anomia achaeus
Arca sp.
Avicula sp.
Bugula bengalensis
Bugula neritina
Bugula stolonifera
Caloria militaris
Cellana radiata
Crassostrea forskalii
Crassostrea madrasensis
Discodoris concinna
Doriopsilla miniata
Isognomon legumen
Littorina subgranosa
Littorina undulata
Modiolus metcalfei
Modiolus striatulus
Musculus strigatus
Mytilopsis sallei
Nellia tenella
Nerita albicella
Nerita plicata
Perna viridis
Septifer bilocularis
Thais tissoti
Turbo sp.

PROTOCHORDATA

Ascidella sp.
Botryllus leachi
Botryllus schlosseri
Herdmania ennurensis
Molgula sp.
Symplegma viride

Among the crustaceans, barnacles dominated the fouling group of which *Balanus amphitrite* and *Balanus tintinnabulum* were dominant. Among bivalves *Crassostrea madrasensis*, *Anomia* sp. and *Mytilopsis sallei* were dominant. The main fouling communities attached with fishes at Visakhapatnam are crustacean barnacles and serpulid worms. The climax community in fishing vessels consisted mainly of serpulid worms such as *Serpula vermicularis*, *Hydroides elegans*, *Hydroides lunulifera*, *Hydroides albiceps*, *Hydroides brachyacanthia*, *Pomatoceros crosslandi*, *Pomatostegus polylraema*, *Pomatocera triqueter*, *Mercierella enigmaica* and *Brandiomma nigromaculata* (Chandramohan and Aruna, 1994). The major groups of foulers encountered at Visakhapatnam are given in Table 1.

Marine borers

Shipworms are the most destructive of the marine borers. They are molluscs of various species that superficially are worm-like in form. *Teredo furcillatus* and *Bankia campanellata* occur abundantly in Visakhapatnam throughout the year (Nagabhushanam, 1962). The biology of shipworms have been described by Nagabhushanam (1959). In the early stages of their life, they are minute, free-swimming organisms. Upon settling on the wood, they quickly develop into a new form and bury themselves in the wood. A pair of boring shells on the head grows rapidly in size as the boring progresses, while the tail part or siphon remains at the original entrance. Thus, the animal grows in size within the wood but remains a prisoner in its own burrow, which it lines with a shell-like deposit. It lives on the wood borings and the organic matter extracted from the seawater that is continuously being pumped through its system. The entrance holes never grow large, and the interior of wood may be completely honeycombed and ruined while the surface shows only slight perforations.

Martesia striata has a very wide distribution and has been recorded, all along the Indian coast including Visakhapatnam and Kakinada. Like the shipworms, the *Martesia* enter the wood when they are very small, leaving a small entrance hole, and grow larger as they burrow into the wood. They generally do not exceed 64 mm in length and 25 mm in dia but are capable of doing considerable damage. General biology of *Martesia striata* has been described by Nagabhushanam (1960).

The principal crustacean borers are *Limnoria* spp. and *Sphaeroma* spp. Their attack differs from that of the shipworms and the *Martesia* in that the bore hole is quite shallow; the result is that the wood gradually is thinned from the surface inward through erosion by the combined action of the borers and water. *Limnoria* and *Sphaeroma* do not become imprisoned in the wood but may move freely from place to place. *Limnoria* are of small size measuring 3 to 4 mm in length and bore small burrows in the surface of wood. Although they can change their location, they usually continue to bore in one place. When great numbers of *Limnoria* are present, their burrows are separated by very thin walls of wood that are easily eroded by the flow of water.

Protection of fishing craft

One of the primary ways to prevent biofouling is selection of appropriate materials. For example, zebra mussels find aluminum-bronze distasteful, so they tend to avoid such structures. Cupronickels (copper-nickel alloys) have good biofouling and corrosion resistance, and are therefore often used for surfaces or surface coatings (Younqblood *et al.*, 2003). Two of the most popular materials used are 90/10 and 70/30 copper-nickel alloys (90% Cu-10% Ni and 70% Cu-30% Ni, respectively) (Mathiyarasu *et al.*, 2002). This method may not be effective in every situation, especially with ships that travel great distances through waters of different temperatures and salinity, rendering a change in materials resistance to biofouling.

One of the earliest methods of solving the problem was simply to scrape the hulls of ships. This solution, although simple and relatively effective, poses one not so obvious problem, *viz.*, spread of invasive species. This is illustrated best with the population explosion of *Mytilopsis sallei* in the harbour waters of Visakhapatnam. The mussels are picked up by fishing equipment, ships and other vessels and transported to non-native waters where they may cause ecological problems.

One of the most widely accepted methods of controlling and preventing biofouling is antifouling coatings (Baier, 1994). One of the most popular of these is tin-based coatings, specifically TBT-coatings. These are also considered self-polishing, as there is a controlled hydrolysis (decomposition) of the surface, which releases the TBT in a slow, steady fashion from the substrate. When a substrate (e.g. a ship's hull) is in motion, the water wears the compound away, leaving behind particles. TBT-coatings are highly effective in reducing and controlling biofouling; however, they are also highly toxic to marine organisms (Karande and Ganti, 1994). TBT-coatings are toxic to biofouling organisms, but also to non-target organisms. TBT interferes with major biological processes such as growth, reproduction and immunity, on a cellular level. Some antifouling paints have a leaching rate of more than 4 µg of TBT per day. Organisms could be affected in concentrations - as low as 1 ppb and the life of a TBT coating can be as great as five years.

Traditional fishing crafts of Visakhapatnam are mainly made of wood. Two major factors responsible for biodeterioration are decay by fungi and insect damage. Wood is also attacked by marine boring and fouling organisms. Traditional fishermen of Andhra Pradesh use various indigenous materials for preservation of their craft. They include sardine oil, shark liver oil, cashew nut shell liquid and various vegetable oils. These are effective only for a short duration and require to be applied periodically. Their action is generally limited to provide a water repellent surface.

Wood preservatives

Chemical wood preservatives contain ingredients that protect the wood against action of organism that are responsible for deterioration of timbers. Three types of wood preservatives, *viz.*, water-borne, oil-borne and solvent type are now available. Water-borne wood preservatives like copper-chrome-arsenic (CCA) commonly known as ASCU are effective against fungi and insects. Among oil-borne preservatives, creosote, which is a fraction of distillate from coal tar is effective against decay due to fungi, insect attack and reduce the risk of splitting and surface cracking of wood. Creosote is recommended for preservation of timbers in marine applications. Solvent type preservatives like pentachlorophenols, naphthanates of zinc, copper and tributyl tin oxide do not affect the strength of wood and do not leach out from the timbers.

Due to concerns about pollution and negative impacts on organisms, many have pursued research to create non-toxic coatings. One of these is known as a foul-release coating. Usually made of polymers, these coatings are non-toxic and are thought to have a natural resistance to biofouling by creating a low surface tension. Polymers utilized in these coatings are silicones and fluoropolymers and ethyl vinyl acetates.

Another technique commonly used against diatoms is called pulse laser irradiation (Nandakumar *et al.*, 2003). Unfortunately, this radiation is not species-specific and can harm non-target organisms. Plasma pulse technology does not use chemicals or heat; it transmits energy directly into the water, which may cause harmful shockwaves or steam bubbles. Pulsed electric fields, frequently used in pipes, create acoustic waves. Unlike plasma pulse technology, this process does not create shockwaves that could affect cooling/heating systems. In addition, electric fields do not kill, but stun organisms, thus lowering mortality of non-target organisms.

Due to concerns of pollution and toxicity, there have been attempts to develop non-toxic coatings such as foul-release coating (Brady, 2003). Usually made of polymers, these coatings are non-toxic and are thought to have a natural resistance to biofouling (Stein, *et al.*, 2003). Polymers utilized in these coatings are silicones and fluoropolymers and ethyl vinyl acetates (Blidberg, 1997)

The use of non-toxic or environmentally benign antifoulants have considerable advantage. One important area of activity in this direction is research on marine natural products. There are a variety of organisms that have bioactive antifouling compounds. Extract from a member of the ascidian group, *Distaplia nathensis*, has been reported to inhibit byssal production in the mussel *Perna indica*. A byssus is a mass of filaments which the mussel uses to attach itself to a surface (Murugan and Ramasamy, 2003). Dark brown bacteria provide the best attachment for oyster larvae, but there are other bacteria, which produce polysaccharides that are toxic to oysters; in other words, they may be used to prevent biofouling by oysters. Immunoglobulins provide a natural biocide for planktonic and sessile bacteria (Gomez *et al.*, 2001). Some species of bacteria can be used against other biofouling organisms. *Pseudoalteromonas* spp. produces bioactive compounds with an inhibitory effect and can be used to prevent biofouling by algae like *Ulva lactuca* and by barnacles like *Hydroides elegans* and *Balanus amphitrite* (Bakus *et al.*, 1994).

Enclosed marinas are much more likely to contain biofouling organisms than un-enclosed marinas. Tides and currents assist in the flushing and renewal of water in a marina. Harbours can be designed to ensure maximum flushing capacity, because marinas with breakwaters retain more water than marinas without, leaving a greater build-up of fouling species.

Protective sheathing

Experiments have shown the lasting protective value of a metallic sheathing on the wooden hull below the water line. Aluminium-magnesium alloy sheathing has been extensively used as barrier against marine borers and foulers. The alloy is light, resistant to seawater and cheap (Balasubramanyan, 1968). Fibreglass sheathing is also effective as protection against marine wood boring organisms (Balasubramanyam, 1978).

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