

The problem of marine timber destroying organisms along the Indian coasts

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Abstract. The serious problem of destruction of wood in sea and brackish waters of India has been discussed with special reference to the organisms that are involved, their distribution, nature of infestation and vertical distribution, seasons of settlement, duration of larval period, growth rates and dispersal. The different ecological factors that determine the distribution of borers have been described such as temperature, salinity, primary film, rate of water flow, turbidity, pollution, effects of fouling, parasites, predators and associates. Control measures to check their ravages are also indicated.

Keywords. Marine wood borers; pholads; shipworms; pill bugs; gribbles; cellulolytic bacteria and fungi.

1. Introduction

There has probably never been a period in the history of developing countries when interest in the utilisation of timber and progress in this field have been greater than at present. Conservation and protection, have, therefore, become extremely essential for the effective utilisation of the limited resources. There are two approaches to the problem of the destruction of wooden structures in sea water exposures. One is discarding the home-grown, susceptible timbers as structural materials for marine constructions and seagoing craft, and using more expensive materials such as steel, concrete etc but even these are not exempt from the ravages of all types of deterioration and are vulnerable to one or more of the destructive processes. The utilisation of steel and concrete for all kinds of marine constructions will certainly be impracticable for a long time in developing countries like India. The other approach is the use of home-grown timber as building material, with the use of every device and technique calculated to prolong their service life. Careful conservation and scientific protection are integral parts of this reasonably sound approach. This involves among others a precise understanding of the biology of the organisms which are responsible for the destruction. Successful control measures depend upon a knowledge of the nature of organisms against which the control is directed. Studies along these lines have been in progress in the University of Kerala.

2. The organisms that cause destruction of timber along the coasts of India

Timber in seawater exposures is threatened by decay through the action of bacteria, fungi, and marine boring organisms. The borers are chiefly active below the low water level and decay is mainly above this level. Both damage in the intertidal zone. The borers chiefly belong to two groups, the Mollusca and the Crustacea. The molluscs are

Table 1. The nature of distribution of shipworms along the coasts of India.

| Name of species | West Bengal | Orissa | Andhra Pradesh | Tamil Nadu |
|---|-------------|--------|----------------|------------|
| <i>Bactronophorus thoracites</i> (Gould) | × | × | × | × |
| <i>Neoteredo reynei</i> (Bartsch) | — | — | — | — |
| <i>Dicyathifer manni</i> (Wright) | × | × | × | × |
| <i>Teredothyra excavata</i> (Jeffreys) | — | — | — | × |
| <i>Teredothyra matocotana</i> (Bartsch) | — | — | — | — |
| <i>Teredothyra smithi</i> (Bartsch) | — | — | — | × |
| <i>Teredora palauensis</i> (Edmondson) | — | — | — | — |
| <i>Teredora princesae</i> (Sivickis) | — | × | — | × |
| <i>Uperotus clavus</i> (Gmelin) | — | — | × | × |
| <i>Uperotus rehderi</i> (Nair) | — | — | — | × |
| <i>Teredo aegypos</i> Moll | — | — | — | — |
| <i>Teredo clappi</i> Bartsch | — | — | × | × |
| <i>Teredo bartschi</i> Clapp (<i>T. fragilis</i> Tate) | — | — | × | × |
| <i>Teredo fulleri</i> Clapp | — | — | — | × |
| <i>Teredo furcifera</i> Martens | — | — | × | × |
| <i>Teredo somersi</i> Clapp | — | — | — | — |
| <i>Teredo triangularis</i> Edmondson | — | — | × | × |
| <i>Lyrodus affinis</i> (Deshayes) | — | — | × | × |
| <i>Lyrodus massa</i> (Lamy) | — | — | × | × |
| <i>Lyrodus pedicellatus</i> (Quatrefages) | — | × | × | × |
| <i>Nototeredo edax</i> (Hedley) | — | — | × | × |
| <i>Nototeredo knoxi</i> (Bartsch) | — | × | — | — |
| <i>Spathoteredo obtusa</i> (Sivickis) | — | — | — | — |
| <i>Nausitora dunlopei</i> Wright | × | × | × | × |
| <i>Nausitora fusticula</i> (Jeffreys) | — | × | — | — |
| <i>Nausitora hedleyi</i> Schepman | — | × | — | × |
| <i>Nausitora oahuensis</i> (Edmondson) | — | — | — | — |
| <i>Bankia bipalmulata</i> (Lamarck) | — | — | — | × |
| <i>Bankia bipennata</i> (Turton) | — | — | × | × |
| <i>Bankia campanellata</i> Moll & Roch | × | × | × | × |
| <i>Bankia carinata</i> (Gray) | × | × | × | × |
| <i>Bankia fimbriatula</i> Moll & Roch | — | × | — | — |
| <i>Bankia nordi</i> Moll | × | — | — | × |
| <i>Bankia rochi</i> Moll | × | × | × | — |

×, present; —, not recorded.

represented by five genera of pholads namely *Pholas*, *Martesia*, *Xylophaga*, *Barnea* and *Lignopholas* (piddocks) and by 12 genera of shipworms of the family Teredinidae. The crustacean wood borers are mainly confined to the order Isopoda and are represented by two well-known genera, *Sphaeroma* (pill bugs) and *Limnoria* (gribbles). Thirty four species of shipworms, 7 species of piddocks, 5 species and 1 variety of pill bugs and not less than 9 species of gribbles have so far been reported from the coasts of India (tables 1, 2). Thus the attack on timber is the concerted effort of a heterogenous assemblage consisting of at least 55 different species of crustaceans and molluscs, besides the bacteria and the fungi. These are engaged in a relentless destruction of valuable timber thereby reducing its service life in the sea, in the brackish water and even in almost freshwater. An accurate assessment of the quantum of damage has never been made in

| Andaman and Nicobar islands | Lakshadweep Archipelago | Kerala | Karnataka and Goa | Maha- rashtra | Gujarat |
|-----------------------------------|----------------------------|--------|----------------------|------------------|---------|
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| x? | - | - | - | - | - |
| x | - | x | x | x | x |
| - | x | - | - | - | - |
| - | - | - | - | - | x |
| - | x | - | - | - | x |
| - | x | - | - | - | - |
| - | x | x | - | - | - |
| x | x | - | - | - | - |
| - | x | - | - | - | - |
| - | x | x | - | x | x |
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| - | x | - | - | - | - |
| x | x | x | x | x | x |
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| x | - | x | - | - | - |
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| x | - | x | x | x | x |
| - | - | x | - | - | - |
| x | - | - | - | - | - |
| x | - | - | - | - | - |
| x | x | x | x | x | x |
| - | x | x | x | x | - |
| - | - | - | - | - | - |
| - | - | - | - | x | - |
| - | - | x | x | x | - |

this country. According to one estimate by Becker (1958), the cost of periodic replacement of fishing crafts alone as a result of the activity of marine timber destroying organisms is estimated at Rs 25 lakhs. This does not include the damage done to the numerous water-front structures such as harbour construction etc., the estimation of which is not easy. Therefore, the total property damage caused by these pests each year must be enormous. Purushotham and Rao (1971) estimate that in India, the fishing industry alone suffers an annual loss of about ten million rupees owing to the ravages on wooden catamarans, boats etc, by molluscan and crustacean borers along the coasts. The problem is thus as important as that of coastal erosion and should, therefore, be treated with all the seriousness it certainly deserves.

Of the marine wood-borers that occur and are active along our extensive coasts, the

Table 2. Distribution of woodboring pholads along the coasts of India.

| Name of species | West Bengal | Orissa | Andhra Pradesh | Tamil Nadu |
|--|-------------|--------|----------------|------------|
| <i>Martesia striata</i> (Linnaeus) | + | + | + | + |
| <i>Martesia fragilis</i> Verrill & Bush | - | - | - | + |
| <i>Martesia</i> sp. (<i>obtecta</i> Sowerby?) | - | - | - | + |
| <i>Pholas chiloensis</i> Molina | - | - | - | - |
| <i>Barnea birmanica</i> Philippi | - | - | - | + |
| <i>Barnea manillensis</i> Philippi | - | - | - | - |
| <i>Xylophoga</i> sp. | - | + | - | - |
| <i>Lignopholas</i> n. sp. | - | - | - | - |

+, present; -, not recorded.

shipworms, piddocks and the pill bugs are responsible for most of the destruction. Gribbles though present, have not yet assumed any great importance since they occur only sparsely. Recent studies have shown that there is severe destruction of wood by crustacean borers in the coastal areas (Dharmaraj and Nair 1980) in the estuaries, backwaters (Nair 1965, 1965a, 1966) and also in the mangrove forests (Dharmaraj and Nair 1980a).

3. The nature and extent of damage

After settlement on wood, the shipworm larva transforms into the boring mollusc and grows with remarkable rapidity. Since the rate of growth is proportional to the destruction of timber, each shipworm during its life time destroys a column of wood of the same dimension as its largest size. The bore-hole of the piddock is much smaller than that of shipworm, yet its rapid rate of growth, and its ability to penetrate deeper and deeper in each generation cause speedy destruction of timber. *M. striata* has the ability to live in waters of very low salinity and hence this species is very widely distributed in the estuaries and backwaters of low salinity all along the coasts. On account of their density of attack, quick development, rapid succession of generations and great tolerance to low salinities these pholads are of special importance from the point of view of timber destruction along the Indian coasts. The pill bug (*Sphaeroma*) excavates cylindrical burrows twice as long as its body and are oriented at right angles to the surface of the wood. Their dense settlement, gregarious habits and rapid rate of reproduction contribute to deeper and deeper penetration of timber. Unlike the molluscs, attack on fresh surface is effected by migrating juveniles or adults. Attack is heaviest in the intertidal zone, the maximum intensity being at half tide level. Sphaeromatids constitute a very serious threat to all available pieces of timber in the coastal areas especially the estuaries. *Limnoria* though considerably much smaller than *Sphaeroma* is capable of effecting a progressive tunnelling action on wood and can make a burrow several times the length of its body. Innumerable small holes, produced by these give the wood a sponge-like texture and lace-like appearance. Burrows usually follow the grain and are close to the surface of the wood.

| Andaman and Nicobar Islands | Lakshadweep Archipelago | Kerala | Karnataka and Goa | Maha- rashtra | Gujarat |
|-----------------------------------|----------------------------|--------|----------------------|------------------|---------|
| + | + | + | + | + | + |
| + | + | + | - | - | - |
| - | - | + | + | - | - |
| - | + | - | - | - | - |
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| - | - | + | - | - | - |
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| - | - | + | - | - | - |

Thus the nature of damage by the molluscs and crustaceans is different, producing different effects on timber. This enables them to share effectively, without serious competition, this common substratum which is limited in extent. The crustaceans work from the outside and the molluscs, particularly the shipworms penetrate deep into the 'heart' of timber. The combined action of these two groups of borers converts the wood into a highly porous, weak and fragile mass. The crustaceans have the added ability to enter even creosoted shell of treated timber which the shipworm larvae are unable to do.

Besides the woodboring animals, wood infesting bacteria, and fungi, especially in the Ascomycetes and in the Deuteromycetes (*Fungi imperfecti*), actively participate in a sort of 'conditioning' of the timber, preparing it for the subsequent attack by borers. This is a biological phenomenon of considerable importance in the ecology of marine borers. The activity of the fungi leads to a kind of deterioration called 'soft rot' which is a sort of superficial softening of the wood through a cellulolytic process. These fungi which are resistant to preservatives, release a strong cellulase which hydrolyses the unlignified cell elements leading to the softening and disintegration of the outer tissues of timber. Even though the magnitude of damage by these is not spectacular and may not even be noticed by the layman, the importance lies in the fact that their silent and steady activity soon after submergence of timber prepares it for attack by the crustaceans and molluscs. The borers in turn help the fungi to spread deeper and deeper into the timber, thereby enabling them to expand the field of operation from superficial layers to its very core. The relation between gribbles and these fungi seems to be of a symbiotic type. The fungal infestation on light timbers of the catamarans, dugout canoes and other fishing crafts, according to Becker and Kohlmeyer (1958) is not the usual superficial type, the penetration being deep, affecting the entire log. The periodic drying of these logs accelerates the spread of the fungal hyphae which get effective ventilation through the large vessels of these light timbers. Preliminary studies have revealed the existence of several species of marine fungi in test panels.

4. The pattern of distribution of timber borers along the coasts of India

The pattern of distribution of the teredine, pholadid and crustacean wood-borers along the coasts of India and in the Indian ocean islands is shown in tables 1-3 respectively.

Table 3. Distribution of crustacean wood borers along the coasts of the various

| Name of species | West Bengal | Orissa | Andhra Pradesh | Tamil Nadu |
|---|-------------|--------|----------------|------------|
| <i>Sphaeroma terebrans</i> Bate | — | — | + | + |
| <i>Sphaeroma annandalei</i> Stebbing | — | — | + | + |
| <i>Sphaeroma annandalei travencorensis</i> Pillai | — | — | — | — |
| <i>Sphaeroma tuberculatum</i> George | — | — | — | + |
| <i>Sphaeroma walkeri</i> Stebbing | — | — | + | + |
| <i>Sphaeroma triste</i> Heller | — | — | — | + |
| <i>Limnoria indica</i> Becker and Kampf | — | — | — | + |
| <i>Limnoria septima</i> Barnard | — | — | — | — |
| <i>Limnoria tripunctata</i> Menzies | — | — | — | + |
| <i>Limnoria bombayensis</i> Pillai | — | — | — | — |
| <i>Limnoria pfefferi</i> Stebbing | — | — | — | + |
| <i>Limnoria unicornis</i> Menzies | — | — | — | — |
| <i>Limnoria platycauda</i> Menzies | — | — | — | — |
| <i>Limnoria andamanensis</i> Rao and Ganapati | — | — | — | — |
| <i>Limnoria insulae</i> Menzies | — | — | — | — |

+, present; —, not recorded.

This list is not a complete representation of the species that occur since virtually nothing is known regarding their incidence from many areas along our coasts. This list is compiled from observations in certain selected localities or from the vicinity of research institutions which carry out studies on marine boring animals. Reports from other localities are mostly based on a few collections which are not expected to yield satisfactory results. Nevertheless, the members noted in the list would represent the most dominant forms and therefore, the highly destructive species in the respective localities. Some species such as *Dicyathifer manni*, *Teredo furcifera*, *Lyrodus pedicellatus*, *B. carinata*, *B. rochi* and *Martesia striata* are widely distributed along our coasts. Except *Neoterodo reynei*, *Bankia rochi*, *B. fimbriatula*, *Nausitora fusticula*, *Nototerodo knoxi*, *Spathoterodo obtusa*, *Teredothyra matocotana*, *Teredora palauensis*, *Teredo somersi*, *Teredo aegypos* and *Nausitora oahuensis* all others occur along the Tamil Nadu coast. The next higher species representation is along the coast of Andhra Pradesh from where as many as 18 species of molluscan wood borers have been reported. This is roughly proportional to the amount of work carried out from the coasts of the various states. The number of species occurring along the coasts of other states might also be much more than that indicated and it necessitates further detailed surveys along the unexplored coastal zones.

Some interesting features could be observed from the record of occurrence in various localities and from the nature of distribution of the woodboring pests along the coasts. Many species shows a discontinuous distribution, e.g. species of *Teredothyra*, *Uperotus* etc. *T. smithi* has been collected from Tamil Nadu, Gujarat and the Lakshadweep coasts only. Species of *Uperotus* are characteristic in their occurrence only along the coasts of Andhra Pradesh, Tamil Nadu and in the Lakshadweep Archipelago. *T. furcifera*, one of the widely distributed species has not so far been reported from West Bengal and Orissa coasts. *Teredo fulleri* seems to be a characteristic borer occurring in the Gulf of Mannar and the Palk Bay coasts of Mandapam, neighbouring islands and in the Lakshadweep

maritime states in India.

| Andaman and Nicobar Islands | Lakshadweep Archipelago | Kerala | Karnataka and Goa | Maha- rashtra | Gujarat |
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Archipelago. *Teredo bartschi*, *L. affinis*, *Nototeredo knoxi*, *Nausitora dunlopei*, *N. fusticula*, *Bankia fimbriatula*, *B. bipennata*, *Xylophaga* sp. and *Barnea biramanica* also have been reported from the east coast of India but not so far from the west coast.

Table 2 presents the nature of distribution of the crustacean borers. Throughout the west coast and along the east coast bordering Andhra Pradesh and Tamil Nadu, *Sphaeroma terebrans* has been reported to occur abundantly in brackish water and other estuarine localities. *S. annandalei* var. *travancorensis* occurs along Kerala and Karnataka coasts and *S. tuberculatum* is known only from its type locality, Tuticorin. *S. triste* occurs along the coast of Tamil Nadu and in the Andaman and Nicobar Islands. *S. walkeri* has been collected from Maharashtra, Kerala, Tamil Nadu and Andhra coasts. Of the nine species of limnoriids, all but *Limnoria tripunctata* and *L. bombayensis* occur in the Andaman and Nicobar Islands. Limnoriids are apparently not very active along the coasts of Kerala, Karnataka, Andhra Pradesh and Gujarat. In some localities such as Bombay, Madras, Mandapam and the Lakshadweep Archipelago, the incidence of limnoriids has been steadily increasing and this is likely to cause damage to the superficial layers of exposed wood. *Limnoria indica* and *L. bombayensis* are the destructive species along the coasts of the mainland.

Preliminary studies in the Pichavaram mangrove forests on the south-east coast of India have shown that woodboring animals are very active there and these represent a perennial source for infestation along the coasts. At least six species of shipworms namely *Bactronophorus thoracites*, *Lyrodus pedicellatus*, *Teredo furcifera*, *Nausitora hedleyi*, *B. carinata* and *B. companellata*; the pholads, *Martesia striata*, *Barnea biramanica*; and the pill bugs *Sphaeroma terebrans* and *S. annandalei* have so far been recorded.

Studies on the nature of infestation in the aquafarms along the south-east coast revealed that several species occur there and rapidly reduce the service life of timber used. The different types of equipments used in these operations experience different

types of borer activity depending on the level and locality of exposure. In the Karapad creek oyster farms at Tuticorin the most dominant and destructive species are *Teredo furcifera*, *Lyrodus pedicellatus*, *L. affinis* and *Martesia striata*. The teredines infest the piles from surface to mudline with dense settlement near the bottom and the attack of pholad is dense a little below the low water mark.

In the pearl oyster and seaweed farms located along the coast of Krusadai Island in the Gulf of Mannar the relative abundance of different species of shipworms is as follows: *Teredo furcifera*, *Teredo fulleri*, *Lyrodus pedicellatus*, *Teredo triangularis* and *T. bartschi*. The most affected are the sea weed farms where numerous wooden piles have been installed for the rope culture of *Gracilaria* spp. and other algae. In these farms gribbles (*Limnoria* spp) also are active. In the oyster and fish farms wood is riddled mostly by *Teredo furcifera* and *Lyrodus pedicellatus*. Stakes used here are serviceable only for a brief period of about 4 months despite the traditional protective coatings applied on them prior to installation. Along the coast of Hare Island *T. furcifera*, *T. bartschi*, *T. fulleri* and *L. pedicellatus* are destructive. Stray occurrence of *Limnoria* has also been noticed.

In the aquafarms in the Vellar estuary near Porto-Novu occur *L. pedicellatus*, *N. hedleyi*, *S. terebrans* and *S. annandalei*.

The Nethravathy-Gurupur estuary and the coastal waters of Mangalore on the South-west coast harbour *L. pedicellatus*, *Dicyathifer manni*, *N. hedleyi*, *M. striata*, *S. terebrans* and *S. annandalei*. Most of these species are capable of tolerating the fluctuating salinity encountered in such situations.

The Vembanad and the Ashtamudi lakes on the Kerala coast with extensive fishery activity and aquacultural possibilities contain such species as *L. pedicellatus*, *T. furcifera*, *Nausitora hedleyi*, *Dicyathifer manni*, *S. terebrans*, *S. annandalei* and *M. striata*. *B. carinata* is seen occasionally near the bar mouth. *N. hedleyi* is most destructive in the Vembanad Lake.

In the Vizhinjam Bay on the South-west coast the wooden rafts used for the culture of pearl oysters and mussels are attacked by *L. pedicellatus*, *B. carinata*, *B. campanellata*, *T. furcifera*, *L. massa* and *M. striata*.

Timber structures and drift wood in the coastal waters of the Lakshadweep Archipelago were found to harbour not less than 19 species of molluscan borers. The dominant ones in the region are *Teredo fulleri*, *T. clappi* and *Lyrodus massa* (Nair and Dharmaraj 1983).

5. Nature of infestation and vertical distribution

Information on the nature of vertical distribution of woodboring animals is of considerable value since the degree of deterioration at different levels along a pile is based on the intensity of settlement and growth at these levels. Further, a study of the varied biological relations which permit a heterogenous group of boring animals to share a common and limited habitat will be of interest ecologically.

Depending on the depth of exposure of the wooden equipment, the intensity of destruction would vary. Piles and stakes are infested from high water mark to the very mud-line since they run throughout the water column and are subjected to settlement by all kinds of borers. Shipworms generally infest the wood from surface to bottom with dense settlement a little above the mud-line both in coastal waters and in estuaries

(Nair 1966; Nair and Dharmaraj 1979). In the estuarine shipworm *N. hedleyi* significant differences have, however, been noticed in the intensity of settlement at the different levels during the different periods of the year (Saraswathy and Nair 1969). During the monsoon period distinctly greater numbers settled over the bottom. During the post-monsoon the nature of settlement was different with greater strike sub-tidally. This shift in the nature of settlement is probably due to the influence of some ecological factor, most probably salinity. It was not evident from tests whether the larvae were distributed equally throughout the water column and only those at certain levels were successful in settling and surviving giving the impression of greater settlement at those levels. This case suggests that borer activity though generally considered most abundant near the bottom need not necessarily be so at all locations. *Teredo furcifera* has been found to settle abundantly near the low water mark in Visakhapatnam harbour (Nagabhushanam 1960). *Martesia striata* is active throughout the water column in coastal waters, but the region of dense attack in estuarine environments is near the bottom (Nair 1966; Dharmaraj and Nair 1979). Thus in estuarine areas, attack by both shipworms and piddocks is concentrated towards the bottom and this region of the piles becomes weak and breaks off. Sphaeromatids and limnorids abound the timber structures at the intertidal zone. In the backwater and estuarine environments piles and pillars subjected to sphaeromatid attack assume characteristic hour-glass-shape in course of time on account of the combined action of borers and the mechanical action of waves. Floating rafts in coastal areas are likely to be invaded by piddocks, limnorids, and shipworms in the areas of contact with water but the intensity of destruction would be less severe than in fixed structures. Rafts exposed in brackish water and estuarine areas are susceptible to heavy attack by sphaeromatids. Cages and rafts used in mariculture operations would experience varied types of borer activity depending on the depth of exposure and the species of borer present in the area.

Woodboring sphaeromatids are active in brackish water but the allied isopod *Limnoria* is quite different in its preferences, none being recorded as destructive in low saline areas. *Martesia striata* is able to thrive in a wide range of salinity but *M. fragilis* occurs only in the offshore waters where conditions are quite constant. Of the dominant species of teredinids in India *L. pedicellatus* has been highly destructive in estuaries, mangrove swamps, backwaters and also in coastal waters. *T. furcifera* is active mostly in coastal waters and occasionally intrudes into estuaries also when conditions are favourable. *B. carinata* and *B. campanellata* are destructive in coastal and offshore waters. Species of the genus *Nausitora* have mostly been collected from estuaries, backwaters and mangroves. *B. thoracites* and *Dicyathifer manni* are also normally confined to brackish water localities. *T. clappi*, *T. bartschi*, *T. fulleri*, *Lyrodus massa*, *B. rochi*, *Teredora princessae* and *Uperotus rehderi* are also destructive in certain coastal and offshore localities.

6. Season of settlement

The time of settlement is of special interest apart from its biological importance because it is then that the infestive free-swimming larvae come into contact with fresh surfaces and experience the effect of preservatives used on them. Precise knowledge of the times of settlement of the different species in a locality is of importance in connection with such operations as replacements, dry docking, and repainting of wooden boats, pile

driving etc. Biologically, the period and extent of settlement are significant since they are reflections of the breeding season and a reliable measurement of the breeding success. This is due to the fact that there is the possibility of spawning without settlement. In certain instances detailed studies on the season of settlement of timber boring organisms have shown effective ecological adjustments, the different species occurring in an area showing interrelationships so that interspecific competition is reduced to a minimum through characteristic zonation in settlement (Nair 1959). Alternation of breeding periods prevents simultaneous settlement, the different species occurring in the area settling over the limited amount of available timber at different times of the year leading to a succession in settlement (Nair 1965). The breeding activities of closely allied species show differences and even those of the same may vary according to the hydrographic conditions prevailing in the area (Nair 1965). The density of distribution of shipworms has fluctuated over long periods and within the same period their attacks have differed considerably in various locations along the same stretch of coastline (Becker 1958).

This aspect of the biology of shipworms has been the subject of study in three localities along the coasts of India. At Cochin Harbour Nair (1965) observed that *T. furcifera* settles chiefly during the hot, highly saline pre-monsoon period February to June, with sparse settlement during the early part of the monsoon and later part of the post-monsoon periods. The settlement of the estuarine species *N. hedleyi* is confined to the low saline periods of the monsoon and post-monsoon periods (August–February) with apparently no settlement during the premonsoon. Thus the settlement of these two species alternates in Cochin Harbour. Nagabhushanam (1962) noted at Visakhapatnam (east coast of India) the occurrence of *T. furcifera* on test panels throughout the year with a maximum attack during the summer months between March and June with a peak in May of 1956. The difference noticeable in the nature of settlement along the south-west coast and east coast of India may be explained on the basis of the prevailing hydrographic conditions.

The period of settlement of *B. companellata* common at Visakhapatnam is from August till February and the species is absent from the panels during March to July, the maximum intensity of attack was noticed in November to January. Nagabhushanam (1962) pointed out a direct relationship between the relative abundance of shipworm settlement and temperature and salinity. The comparatively smaller attack rate by *Teredo* during the winter months (November–January) was attributed to a biological competition with *B. companellata* whose intensity was greatest during the winter months.

Confirmatory studies of Saraswathi and Nair (1969) on the settlement of *N. hedleyi* showed that it is strictly seasonal from July to February with November representing the peak period.

Based on a detailed study of the frequency of occurrence of veliger larvae in the plankton, presence of post-settled stages on test panels and the condition of the gonads of the adults, Nair (1955, 1957) concluded that the period July–August is the best for larval development and attachment of *B. carinata* at Madras.

In general it seems that under tropical conditions the settlement continues without interruption in the marine zone (Nair 1957). Even under such conditions the extent of settlement varies from month to month. In special habitats such as estuaries, the influence of salinity may prevent the uninterrupted breeding and settlement of some species (Nair 1965). The number of generations which would be produced in a single

season varies with the time required for the species to grow to maturity and with the length of the period during which suitable conditions persist. In warmer regions development is more rapid and many generations may be produced each year. In regions other than the tropics temperature appears to be the principal condition determining periods of breeding. Adult animals can frequently survive under extremes of temperature which are unfavourable for reproduction. Consequently a species may maintain itself where conditions are suitable for reproduction during only a small part of the year.

In making generalisations one should not forget that variables other than temperature may be directly or indirectly influencing events. For example, especially along the south-west coast of India, rainfall reflects the passing seasons, causing great reduction of, as well as fluctuations in, salinity and so creating conditions unsuitable for breeding and settlement of certain species.

Events leading to settlement are dependent on the interplay of a large number of factors including the physiological characteristics of the species involved, their geographical distribution, local variations in the character of temperature changes and the seasonal influence of other and less obvious aspects of the environment (Nair and Saraswathy 1971).

7. Duration of larval period

The average duration of the free-swimming stage of the veliger is apparently constant for a given species at a given locality. Naturally this period is shorter in the warmer waters of the tropical and subtropical regions. The duration of free-swimming period in the non-incubatory species vary. In *B. carinata* it is about 17 days in Madras (Nair 1956) and in *B. campanellata* about 13 days in Visakhapatnam (Nagabhushanam 1959). In the tropical incubatory species *T. furcifera* larvae attack timber normally between 24–72 hrs and they need no food prior to settlement (Karande *et al* 1968). The source of energy for the larvae has been attributed to the stored glycogen (Lane 1955). Preparatory to settlement they crawl over the surface of the wood searching, probing and prospecting the surface for a suitable spot, the period of crawling varying greatly, extending even upto an hour. During this period activity diminishes till the foot comes to rest in a depression on the surface. Subsequently the shell is lifted while the byssus attachment is made. The velum is retracted. At this stage both the velum and the foot are both functional so that the larvae can alternately swim and crawl a stage aptly termed 'pediveliger'. If a suitable substratum is not available the free swimming larval life could be continued for several days, and the pediveliger has the ability in certain species to postpone metamorphosis (Nair 1956). This ability is probably of survival value permitting the larvae to cover a wide area in their search for the appropriate substratum. In some species such as *Lyrodus pedicellatus*, larvae denied access to wood lost their ability to penetrate it within 4 days and invariably died in 2 weeks. The infective period for this species was the first 96 hrs after release from the parent (Lane 1959).

Larvae are attracted to wood, at least in the sense that, should they chance to encounter it, they remain upon it and there metamorphose. The wood must be properly conditioned for penetration and this involves among others saturation with water and the development of a suitable microflora and fauna (Nair 1965).

8. Growth rates

Information on growth rates is important because growth rates are directly related to the damage done to timber. Each shipworm destroys a column of wood of the same dimension as its largest size. Comparison of growth rates of different species of shipworms recorded from different kinds of timber from different localities do not seem to have much meaning.

The growth rates of different species occurring in widely separated places are likely to be different and even in the consideration of growth rates of the same species, unless the latitude, substrate involved etc., are the same the values are likely to vary. Growth rates need not be identical even when latitude, species and substrate are all the same during the different seasons since they are likely to be influenced by the prevailing hydrographic conditions. The same species has different rates of growth at different localities of the same estuary during the same time depending on the number of individuals which have settled. In *Bankia carinata* of Madras the growth rates recorded by Nair (1960) are as follows:- 9 mm in 17 days, 23 mm in 32 days, 142 mm in 68 days, 224 mm in 95 days, 257 mm in 125 days, 274 mm in 165 days, 290 mm in 191 days and 302 mm in 219 days, representing an average rate of boring of 4.3 cm/month. Growth was very rapid during the first 90 days and thereafter slackens and the trend indicates that growth becomes negligible at the end of about 220 days. Retardation in growth has been attributed to depletion of woody materials on the panel as a result of overcrowding. In *B. campanellata* a growth of nearly 51.5 mm/month has been recorded with a maximum of 60 mm in December and *T. furcifera* attains a length of 90 mm at the end of 5 months in Visakhapatnam (Nagabhushanam 1959). Studies on the estuarine shipworm *N. hedleyi* for six months indicated that growth was rapid between 45 and 153 days after settlement with the maximum growth between 105-120 days of age. Thereafter growth slackened and the trend indicated that growth was negligible at the end of 150 days (Saraswathy and Nair 1974).

9. Dispersal of shipworms

Notwithstanding the stationary, hidden life within the confines of their wooden burrows, shipworms are distributed far and wide through their free swimming larval stages. While some species liberate eggs into the water, others brood the eggs, the veligers being released when ready. During the free swimming period which may last from a few hours to even a month depending on the species and the region, the larvae are drifted about and widely transported in the surface currents.

Three types of larval life could be recognised among shipworms: (i) oviparous; (ii) short-term larviparous; (iii) long-term larviparous. The pattern of distribution of many species is based on the temperature and salinity requirements of the larvae during their plankto-trophic life. The members of the genus *Nausitora*, generally denizens of brackish water habitats, are oviparous and fertilisation is external. Since the larvae are incapable of tolerating high salinities (Saraswathy and Nair 1974), those larvae transported by the medium into areas of high salinities would perish. This accounts for their occurrence in isolated pockets of brackish water. In this case colonisation of new areas could be effected only by the adults which are more tolerant to higher salinities than their planktonic larvae and are transported through the agency of drift wood etc.,

to a suitable brackish water environment within the life time of the adult. The picture of the distribution of this genus seems to support this contention. *N. hedleyi* and *N. dunlopei* have so far been reported only from isolated brackish water areas along the tropical Indo-West Pacific, and *N. dryas* and *N. excolpa* along the tropical eastern Pacific.

Species of *Bankia* are also oviparous with protracted planktotrophic larval stages but their habitat is normally marine. In this case the limiting factor in distribution is apparently temperature. Therefore, species characteristics of higher latitudes are restricted in range incapable of spreading into sub-tropical or tropical areas as may be seen in *B. setacea* of eastern and northern Pacific, *B. gouldi* of northern and Western Atlantic. Similarly the tropical species *B. carinata*, *B. campanellata* and *B. bipennata*, though established all round the world are restricted by the temperature factor and have apparently not spread beyond the sub-tropical zone.

While discussing the dispersal of marine species with long term larviparous young such as the members of the genus *Lyrodus*, and *T. furcifera*, *T. clappi*, *T. somersi* and *T. bartschi*, Turner (1966) enumerates the reasons for their worldwide distribution: (i) in common with other shipworms the adults can be transported to great distances in ships or floating wood; (ii) the young are protected within the parents during the early critical stages of development; (iii) the larvae are not spawned unless optimal conditions for their survival exists; (iv) being further developed, the young are less sensitive when extruded; (v) the larvae are ready to settle shortly after they are extruded and so are not carried away from the floating log or ship from which they emerged; and (vi) most woodenships and pieces of driftwood are covered with a good growth of hydroids, bryozoans, algae and other organisms which form a protective forest cover within which the larvae can swim until time of settlement.

Dispersal of shipworms is commonly effected by driftwood or through the agency of wooden hulls of ships, etc. Extended and intensive intercourse between nations in the long years of maritime activity contributed to the spread of this menace in widely separated places, the chief agents in transport being the hulls of wooden ships, wooden sea water tanks of ship and log-booms. Rapid increase in maritime shipping in the past two centuries helped this transport. The European species reached the American shores during world war I. Ships transported at least one species to South Africa, China, Japan and Australia. It is also true that infested driftwood carried by the surface currents played a major role in their wide distribution. Floating nuts and seeds drifting passively in the surface currents distributed at least one nut infesting species (*Uperotus clavus*) in the region between east coast of Africa and the Philippines. From the Philippines and neighbouring areas many species have reached Hawaii in drift-wood and in light ocean going craft of wooden construction. The whole Indo-West Pacific area contains many common species. There is also the possibility of the release of larvae from infested waterlogged wood lying on the sea bottom. This picture of wide distribution can be explained either on the basis of passive dispersal of free swimming larvae and of adults through the prevailing surface currents and drift-wood respectively or through the active transport of adults by ships. Thus a few species like *B. carinata*, *B. campanellata* and *B. bipennata* have succeeded in establishing themselves around the world in both tropical and sub-tropical waters. It has also been noted that the larvae can be effectively transported amidst the thick growth of fouling organisms that accumulate over the bottoms of the steel hulls of ships. Larvae taken in the feeding current in one locality by certain attached species on the ships hull may pass through the alimentary canal

apparently undamaged and emerge along with the faecal pellets when the ship reaches another locality. These observations reveal that several species of shipworms have been dispersed and others may be expected to be so, over wide areas of the oceans. Certain species such as *T. princessae* can spend the life cycle from larva to adult in the open sea supported by some suitable floatsam without making contact with stationary structures in coastal waters. The larvae of these 'seasoned ocean travellers' can endure long enough to contact drifting timber and continue a chain of seafaring generations. While specimens from drift logs and wooden hulls may serve as a record of the locality they may not represent established fauna. Conditions must be sufficiently suitable for spawning, for the survival of the larvae and successful penetration of the wood before a species can become an established member of any local fauna (Turner 1966).

10. Ecological factors

There are several environmental factors which affect the natural populations of shipworms. These are the physico-chemical variables of the seawater, such as temperature, salinity, oxygen tension, turbidity and pollutants, the presence and intensity of fouling organisms, the nature of the wood, depending on the species of timber, its softness and orientation of the grain; the length of exposure of the wood sample in water; the presence or absence or the nature of preservatives used on it; the location of the wood in relation to tidal changes, whether or not it is periodically exposed to desiccation; the orientation of the sample in relation to depth; nature of the bottom; mechanical effects of currents, their velocity; conditions of illumination; the interaction of the species of woodboring animals present in the area; the availability of a suitable substrate during settlement; the effectiveness of local larval sources in the case of shipworms and the presence or absence of predators and parasites. The occurrence, abundance, and so the intensity of attack in any locality is dependent on these factors which vary widely from year to year. Probably there are several more, but these factors are the most important. Variations in the borer populations from year to year in any locality are not doubt due to a very involved association of these factors, some of which occasionally stand out as the most responsible ones while other factors, none attaining conspicuous importance by itself, may collectively exert as much or more influence than more prominent and easily followed factors. It is by a constant shifting of importance of these factors and new alignments in their association owing to ever varying conditions that accounts for variations in local abundance of shipworms. This would explain periodically recurring devastations separated by often lengthy intervals of comparative freedom from attack. Reasons for increased attacks have not all been investigated but they may be different in different localities such as lowered salinity caused by inflow of fresh water or reduced rainfall causing an increase in salinity, high temperature and dry summers or an unusual increase in water temperature.

Temperature is a major influence on the activities and distribution of shipworms and is a limiting factor in growth, reproduction and distribution. There is a complex correlation between the biological effects of temperature and salinity, the former can modify the effects of the latter and change the salinity range of an organism. Depending on the temperature tolerance some species are characteristically restricted to the cold waters of higher latitudes, others are typically inhabitants of sub-tropical areas while a majority are denizens of the tropical regions illustrating the general rule that tropical

biotopes are typically rich in species. Thus along the coasts of Norway 3 species of shipworms occur (Nair 1959), 5 species in the Mediterranean, 7 species in Hawaii and Midway islands, 16 species in the Philippine Islands and as many as 34 species in India. Uniformly high tropical temperatures hasten metabolic activities and accelerate growth rates, leading to attainment of sexual maturity at a surprisingly early age. Some species breed almost continuously and several generations are produced in rapid succession within a single year. Such speeding up of life histories favour the acceleration of the evolutionary process. This probably accounts for the richness in the represented species in the tropics.

The uniformly high temperature of the tropics can stimulate sexual activity, accelerate development of the gonad, hasten maturity and shorten the free-swimming larval period. These contribute towards the production of several spawnings in a single year leading to an almost continuous settlement of waves of borers which bring about speedy destruction of timber. Similarly the period of free-swimming of larvae and growth rates may also be influenced by temperature.

11. Salinity

Salinity effects the organism by influencing the density of the medium and through variations in osmotic pressure. In tropical estuaries the wet season with low salinity is in summer. Though lowered salinities may be tolerated at summer temperatures, where this drops suddenly and then continues at a low level for a long period, stenohaline species are likely to be killed.

The reaction of shipworms to different salinities varies widely. Some species can tolerate only high salinities others can tolerate a fairly wide range of salinities while a few are capable of enduring very low salinities and even freshwater. Further the salinity tolerance of the same species may vary according to the geographic location depending on the prevailing temperature and may even vary in the same locality during the different seasons of the year. This is due to the existence of a complex correlation between the biological effects of temperature and salinity, the former having the ability to modify the effects of the latter and change the salinity range of an organism (Kinne 1963).

According to Nagabhushanam (1962) *B. campanellata* in Visakhapatnam occurs in areas where the salinity is between 21 and 34‰. The magnitude of strike decreased with decreasing salinity. The genus *Nausitora* is generally confined to brackish water although some species have occasionally been taken from marine habitats (Nagabhushanam 1960; Nair 1954). In *N. hedleyi* a majority of the adults are typically euryhaline capable of enduring a wide range of salinities (0.65–33.68‰) but the breeding is apparently restricted to the low saline period.

The first record of this genus was by Wright (1864) who obtained specimens of *N. dunlopei* from freshwater (?) 150 miles above the mouth of the Ganges. Rajagopalaiengar (1961) reported *N. lanceolata* (= *N. dunlopei*) from Sajnakhali, 24 Parganas District of W. Bengal, *N. hedleyi* occurs in the low saline waters of the Pulicat lake on the east coast (Nair 1963). Records show that this genus is sensitive to higher salinities and so restricted to estuarine areas. *N. hedleyi* can apparently withstand wider changes of salinity than other species of the genus and is capable of tolerating much lower salinities than typical marine species. Great damage can be expected from species

of this genus in the low saline localities of river mouths etc. where species sensitive to low salinities cannot survive. Thus the genus *Nausitora* effectively occupies an ecological niche and so extends the zone of operation of shipworms to river mouths and even farther upstream. The construction of dams and barrages for hydroelectric power and for irrigation across the rivers and the consequent check on the river flow may lead to greater spread of the tidal water upstream and this can result in the extension of shipworm activity. Observations at Cochin on *N. hedleyi* suggest that for the early development of the species the most suitable salinity range is from 11.24–14.54‰ (Saraswathy and Nair 1974a). Above and below this, segmentation is abnormal and the percentage of normal embryos decline. In salinities lower than 4.36 and above 27.14‰ there is no evidence of development (see Nair and Saraswathy 1971). Most species of shipworms require normal marine conditions for successful spawning but the adults may withstand unfavourable conditions by closing the burrow with the pallets. They are also able to utilise the stored glycogen under anaerobic conditions.

12. Occurrence in freshwater

Shipworms are not limited to the sea and brackish water. *Nausitora dunlopei* has been reported in timbers in the river Comer, a tributary of the Ganges, 150 miles above the mouth where the water is fresh (Wright 1864). Shipworm activity has also been reported in almost freshwater up the Mississippi, in the Panama canal, Chulalongkorn Lock in Thailand, in the Sacramento river California etc.

13. The primary film

Contrary to the finding of Nagabhushanam (1959a), Karande *et al* (1968) noted that the settlement of *T. furcifera* in Bombay harbour was independent of both light intensity and the presence of a primary film comprised of bacteria, algae or fungi since larvae settled and grew even on sterilized 'clean' timber blocks, the latter being maintained in sterilized seawater for a number of days. According to Karande *et al* (1968) it is the softening effect of sea water, rather than the microfilm that helps borer larvae to abrade the wood.

Wood infesting bacteria and fungi especially in the Ascomycetus and in the Deuteromycetus (*Fungi imperfecti*) participate in a sort of 'conditioning' of the timber preparing it for the subsequent attack by borers. This is a biological phenomenon the importance of which has only recently been stressed (Kohlmeyer 1963). The activity of these fungi leads to wood deterioration called 'soft rot'. These are resistant to preservatives and release a strong cellulase which hydrolyses the unligified cell elements leading to the softening and disintegration of the outer tissues of timber. Even though the damage is not spectacular and may not even be noticed by the laymen, their steady activity following submergence prepares timber for attack by crustacean and molluscan borers. These in turn help the fungi to spread from superficial layers to the very core of the timber. Fungal infestation on light timbers of catamarans, dug-out canoes and other fishing crafts, according to Becker and Kohlmeyer (1958) is not of the usual superficial type, the penetration being deep, affecting the entire log. The periodic drying of these logs accelerates the spread of the fungal hyphae which get effective

ventilation through the large vessels of these light timbers. Our studies at Cochin Harbour have revealed the existence of several species of marine fungi in the timber test panels such as *Gnomonia longirostria* Cribb & Cribb, *Halosphaeria quadricornuata* Cribb & Cribb, *Torpedospira radiata* Meyers, *Corollospora pulchella* Kohm, Schmidt and Nair, and *Lulworthia* sp (Nair 1968). The exact role played by these fungi in the ecology of shipworms is under investigation.

14. Rate of water flow

The rate of water flowing over them is of considerable significance in the distribution of sessile marine invertebrates. The effects of water currents upon the rate of settling of *Teredo furcifera* and *B. campanellata* on timber have been studied by Nagabhushanam (1961). He found that these borers "require some water current velocity for settling on timber and that they settle more rapidly, when the waters are flowing than when waters are still". Probably a flow is beneficial in carrying larger number of larvae to the test site.

15. Turbidity

Turbidity is an important factor especially for the inhabitants of shallow coastal waters and of estuarine regions where turbid conditions are often created by heavy rains and consequent river discharge, wind action, dredging operations, boat and ship traffic, etc. In the tropical regions during the time of the monsoon highly turbid conditions may exist for weeks or even months. Presence of silt affects organisms by providing food and influences the transparency of the water affecting the rate of organic production. The apparent immunity from borer attack of the base of the piles of Kidderpore Docks in Calcutta has been attributed to the silty and muddy bottom (Devenish-Meares 1904). Nair (1962) has reported that both crustacean and molluscan borers are much less active where the bottom sediment is being continually churned up by propellers.

16. Pollution

The habitat of shipworms, especially those in estuaries, harbours and similar situations are subject to the effects of pollution either through industrial wastes or by human sewage. The pollutants may consist of solid matter or soluble chemicals of a toxic nature the presence of which can affect the organisms directly or they may influence the water, for instance its oxygen content. Some effluents may be beneficial in small quantities. Waters with heavy sewage pollution or which are influenced by H_2S as in some of the backwaters of Kerala are comparatively free from shipworms. That pollution of harbour waters is unfavourable for shipworm activity is evident from the observations of Nair (1962) who found that the activity of mat-forming fouling organisms over timber structures in areas with sewage pollution is beneficial since these organisms form a protective cover against the settlement and penetration of borers.

17. Effects of fouling

Dense fouling accumulations over underwater surfaces can effectively inhibit the attack by both crustacean and molluscan borers. Of the different groups of fouling organisms, the barnacles are perhaps the most effective agents hindering attachment of shipworm larvae although other mat-forming organisms may also serve as protection (Nair 1962). Nagabhushanam (1960a) found that fouling has a profound effect on the attack of marine borers, fouled blocks showing only about one-ninth as much attack as did weekly cleaned panels.

18. Parasites and associates

The role of molluscs as hosts of zoo-parasites has been well-known for over two centuries yet no detailed study has been made of the parasites and associates of wood boring organisms. Several organisms are associated with shipworms in their natural habitat but so far no cause and effect relationship has been established. There is always the possibility that certain parasites and predators may be utilised as effective agents of biological control. Our recent studies have brought to light an interesting fauna of protozoan associates from shipworms (Nair 1968). So far we have collected species belonging to Boveridae, Urceolaridae, Thigmophryidae, Spirostomidae, Licnophoridae, Hysteroconinetidae, Stentoridae and also *Zoothamnium*, *Lagenophrys* and *Trochilioides*. Detailed taxonomical and ecological studies on these protozoans are in progress. Association between hydroids of the genus *Eugymnanthea* and bivalves has been reported from time to time. The first record of this interesting association between a hydroid recognizable as belonging to *Eugymnanthea* and shipworms has been by Santhakumari and Nair (1969) who reported its occurrence in *N. hedleyi* and *T. furcifera* from Cochin backwaters. This hydroid, however, differs from all other species of *Eugymnanthea* in the nature of the polyps which are not solitary but branched. The incidence of the hydroid is seasonal in this locality during November–May with nearly 100% infestation in shipworms collected during December to March. The number of colonies present in a host ranged from 1 to 80 and the hydroid was found exclusively attached to the ctenidia. Attachment is by a basal disc which is firmly implanted within the tissue of the ctenidium and is further strengthened with the aid of protrusions or 'holdfasts' that project from the basal disc—a feature very different from that in species of *Eugymnanthea* previously studied. There is no evidence of fatal damage to the host tissue. The more intimate nature of the association and the tendency towards colony formation are interesting features. Studies of Santhakumari (1970) on the medusa of this form led her to assign this to *Eutima commensalis*. Turbellarians (Polyclada), predaceous polychaetes, commensalic copepods and amphipods have also been recorded from the burrows of shipworms.

With their characteristic boring habits and a boundless appetite for wood, the shipworms attack vegetable matter of every description both living and dead. The record of their ravages reveal a long list of objects from the sea, brackish waters and also from freshwaters. Roonwal (1954) reports from the 24 parganas forest division in the Sunderbans in West Bengal, that the shipworm *Bactronophorus thoracites* attacks several species of both living and dead trees in the mangrove swamps. A recent survey (Nair and Dharmaraj 1980) in the mangrove forests connecting the Vellar and

Coleroon estuaries and the adjacent coastal zones revealed the existence of several species of woodboring animals (eight species of teredinids, two of pholadids and two of sphaeromatids), including *B. thoracites* and the estuarine species *N. hedleyi*. Extensive damage has been recently reported (Dharmaraj and Nair 1980) from the aquafarms along the coasts of India.

The attack especially of shipworms is not confined to objects like wooden hulls of boats, barges and docks, but also to such objects as buoys and floats which they indiscriminately attack. Shipworms also attack floating objects like cork, corky seeds and coconuts, jute or gutta-percha covers of submarine cables, ropes, plywood and lobster traps. All fixed objects of plant origin too are unsparingly attacked such as pillars of piers, wharves, stakes, poles etc., wooden water tanks in ships as well as oyster culture equipment causing huge financial loss.

Since the beginning of mans maritime activity, he has been trying every known mechanical, chemical, electrical and biological means to deter, discourage or destroy these pests. The fishermen of Bengal practice a method of suspending the boat infested by shipworms across two poles and lighting a fire beneath to destroy them. The charring of the bottom hinders further attack for a period (Wright 1864). This method is based on the fact that desiccation is fatal for these soft bodied creatures and is practised with suitable modifications in various countries. Impregnation with hydrocarbons and charring them, desiccating the infested timber, exposure to freshwater, introduction of poisons into the ambient water, fixing hard particles or completely sheathing the exposed surfaces, exploding dynamite, electrolytic protection, electrocution, chlorinating the water etc., are some of the methods used against borers other than chemical preservatives on timber. In aquafarms chemical preservatives should be tried with caution. Purushotham and Rao (1971) tentatively classified ascu, creosant and creosote-coal tar as good preservatives, creosote-fuel oil, pure creosote and copper resinate as moderate preservatives and pentachlorophenol as poor preservative in their trials of the various preservatives. Perhaps the most economical and effective method for checking the ravages of shipworms may be the least tried, namely biological control using the predators and parasites.

Despite man's ceaseless fight against shipworms with all available resources and techniques, their relentless destruction continues and a thorough reorientation in our techniques of warfare has become imperative. The discovery of an effective panacea depends on a better understanding of the ecology of these specialised bivalves.

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