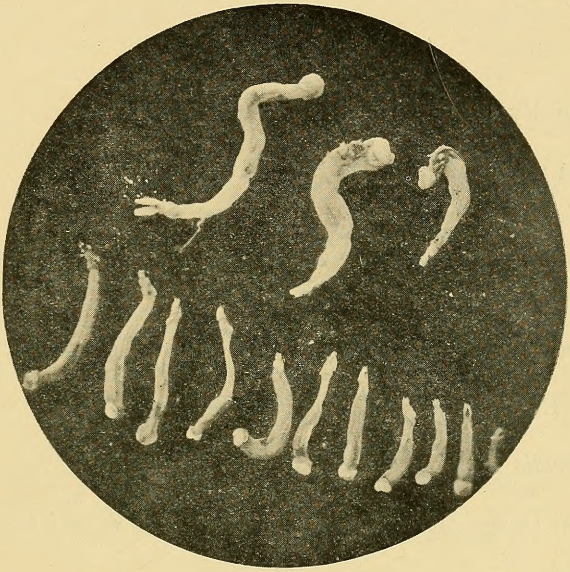
The European Pileworm

A Dangerous Marine Borer in Barnegat Bay New Jersey



MARINE BORING MOLLUSCS
Native species (above); European pileworm (below).

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A Dangerous Marine Borer in Barnegat Bay, New Jersey

by

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Most of us think of clams, oysters, and other bivalve molluscs as animals excellent to eat, and hence as of great value to man. So indeed they are, but just as among some other groups of animals which are mainly beneficial, so among the bivalve molluscs there are a few dangerous pests. The so-called "shipworms," marine boring molluscs, have been known for centuries. These curious animals are not worms, as many people believe, but bivalve molluscs closely related to the common clams. The necessity for protecting the bottoms of sea-going vessels from their attacks has long been recognized.

Destruction by the Pileworm

Until recently the attacks by marine borers upon wooden structures in this state have been confined to those of the relatively slow-growing native species, *Bankia fimbriata* (*Xylotrya fimbriata*, Jeffries), which has done comparatively slight damage. During the past summer, however, there appeared in Barnegat Bay, N. J., the European pileworm, *Teredo navalis,*[1] a pest which for centuries has literally ravaged the coasts of Holland, England, and Scandinavia, destroying dikes and other marine structures with great rapidity. A short time ago this mollusc was in some manner introduced into San Francisco Bay, California, where in the last two years it has extensively destroyed piling and other marine structures entailing a loss of millions of dollars. To show something of the rapidity with which *Teredo navalis* multiplies, and the swiftness with which great marine structures are literally wiped out by its activities, a brief history of its work in San Francisco Bay will be instructive.

From the Report on the San Francisco Bay Marine Piling Survey for 1921 (3), we learn that the European pileworm was first discovered in San Francisco Bay in 1914 by A. L. Barrows. For the next five years it did little damage, but suddenly, in 1920, coincident with a period of unusually low rainfall, the attacks of this mollusc became

[1]Some doubt has been expressed as to whether this form is really *Teredo navalis,* of European waters, or is some native species of *Teredo.* Our material has been sent to Mr. W. F. Clapp, of Harvard University; to Dr. W. T. Calman, of the British Museum of Natural History, and to Dr. Ed. Lamy, Museum D'Historie Naturelle, Paris. The identification given in each case was *Teredo navalis,* L. Dr. Calman writes that our specimens "do not differ more from the specimens labelled *T. navalis* in our collection than the latter do from one another." The writer wishes to express his thanks to each of these gentlemen for making the identifications.

widespread over a large part of San Francisco Bay. Before owners were aware that anything was wrong, the borers had completely cut off at the mudline the piling of many piers, terminals, and other marine structures (fig. 1). Based upon the costs of repairs and replacements made necessary through these attacks, a careful estimate of the damage done during 1920 and 1921 in San Francisco waters alone gives a figure in excess of $15,000,000.

Fig. 1. Municipal Wharf and House, Benicia, California
Collapsed October 7, 1920. (Reproduced by courtesy of San Francisco Marine Piling Committee from their report, 1921, pl. 1, fig. 3.)

The two most important reasons why the European pileworm is so much more dangerous than the native species are: first, that it invades the brackish water area and comes much closer to fresh water than do other borers; and second, that it requires but a very short time to reach sexual maturity, and in a single season produces enormous numbers of young.

What it is and How it Lives

Before describing the outbreak of *Teredo navalis* in Barnegat Bay last summer, let us consider briefly some of the most important points in the make-up and the life history of the animals. The figure on the title page shows a number of young specimens of *Teredo navalis*, sexually mature, as removed from their burrows. Three specimens of the native shipworm, *Bankia fimbriata*, are shown above for comparison. Note the two delicate shells which partly cover the front or anterior end, and between which lies the foot (fig. 5). By far the greatest part of the animal is naked, and since it cannot pull its entire body within its shell as does the ordinary clam, it finds protection in its burrow from the attacks of fish and other enemies. Just imagine a soft clam (long-necked clam), in which the neck, or siphons and the soft part of the body were from ten to twenty times as long as the shell, and you will have an animal which closely resembles the pileworm.

As it bores its way into the wood, the pileworm excavates for itself a burrow, which opens to the outside through a small pore not larger than a pinhole (fig. 3). Through this small opening it projects two small tubes, or siphons, the lower (ventral) one being the longer, the upper (dorsal) one much shorter. By means of millions of microscopic hair-like structures, known as cilia, which are beating in one direction, a current of water is drawn in through the lower, or incurrent, siphon, and expelled through the upper, or excurrent, siphon. The water in its course through the body passes through the gills, as it does in other bivalve molluscs. Here it gives up oxygen to the blood, while all food materials are filtered out and carried to the mouth. For like its relatives, the clam and the oyster, the marine borer lives mainly upon the very small microscopic animals and plants in the water. It is still an open question whether the borers may derive some nutriment from the wood which is shaved off in making the burrow, but it should be emphasized that the marine boring molluscs enter the bottom of your boat, or the piling of your wharf, not primarily because the wood is food for them, as it is for the wood-boring insects on land, but because the wood furnishes them with a safe retreat where the soft parts of the body are protected.[2]

Pileworm Repels Invaders

The common soft clam buries itself in the sand, leaving only a small hole above it through which its siphons are pushed up to the water. In much the same way the marine boring molluscs depend upon the very small opening through which they entered the wood for keeping in touch with the outside world. But just here the marine borer goes the clam one better. Those of us who have dug soft clams have seen the long red sand worms or clam worms, which crawl down the hole made by the siphons of the clam, and devour the luckless bivalve at the bottom. No such thing can happen to the pileworm, however, for like many troublesome pests it has developed means of repelling invaders. On either side of the siphons is a spade-like structure, made of lime, which bears two sharp points on its outer edge (fig. 2). These structures, known as pallets, are attached to muscles by which they may be forced together into the hole at the end of the burrow (fig. 3) or

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[2]Harington (2) finds that the larvæ of *Teredo norvegica* are strongly attracted to an alcoholic or an ethereal extract of sawdust, and also to a 1 per cent solution of malic acid. He finds a slight hydrolysis of cellulose by enzymes extracted from the digestive gland of *Teredo*, indicating that at least during the period of growth and burrow enlargement the pileworm may derive some nutriment from the wood.

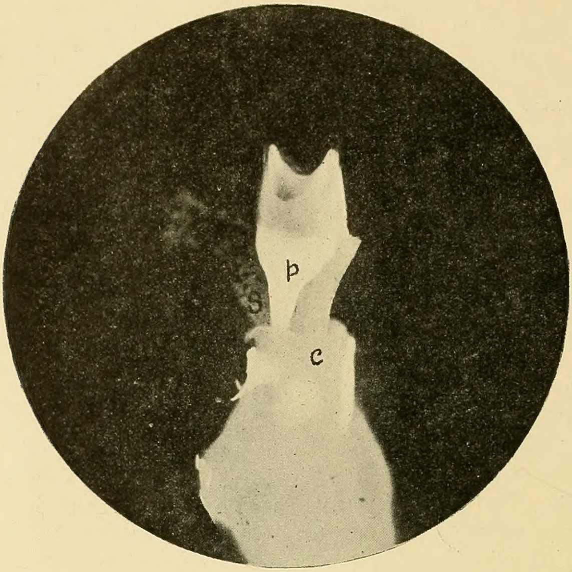

Fig. 2. Posterior, or Hind End of Teredo navalis
c, collar; p, pallet; s, pigmented siphons

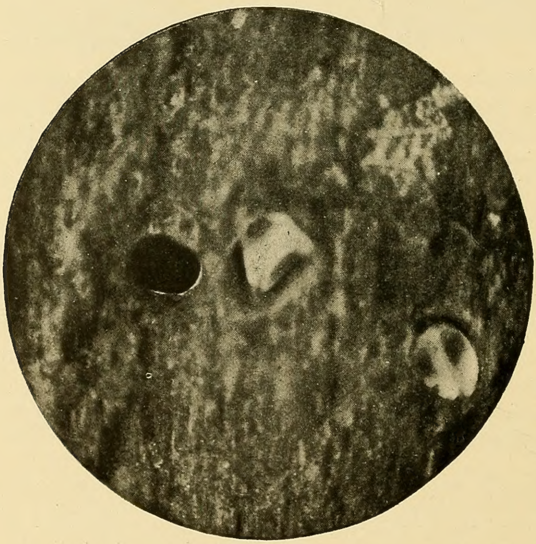

Fig. 3. Protruding Pallets of Teredo navalis
and empty burrow of a third, as they appear on the surface of the wood

withdrawn when the animal extends its siphons to take in water for food or oxygen. Let a worm or other enemy attempt to enter the hole, and instantly the siphons are withdrawn and the pallets thrust out, blocking the entrance.[3] In our native species, *Bankia fimbriata,* the pallets are beautiful feather-like structures of purest white (fig. 4). Anyone may determine, without the aid of a lens, whether he is dealing with *Teredo* or *Bankia,* by examination of these pallets.

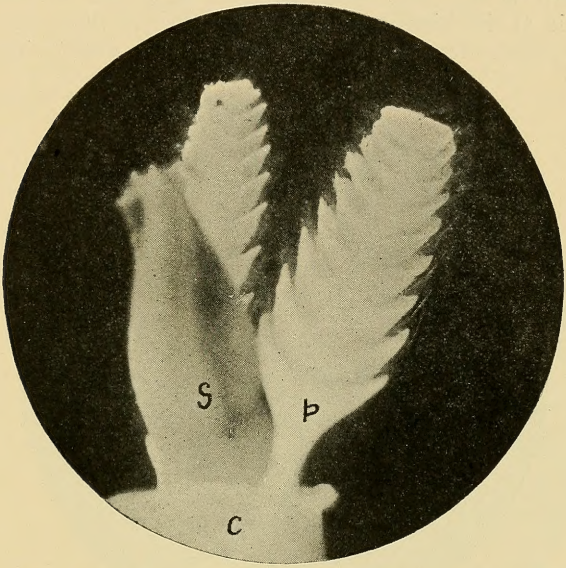

FIG. 4. POSTERIOR END OF BANKIA FIMBRIATA, THE NATIVE SPECIES
c, collar; p, pallet; s, non-pigmented siphons

Bores with its Shell

You may wonder why, since the animal lies completely within a burrow, it has kept any shells at all. Here we see a strange instance of how in nature a structure which originally is developed entirely for protection, as it is in the clams and oysters, becomes by slight changes adapted to quite different ends. For the shell of the pileworm is not used as a protective covering but is the tool by means of which it bores.

The shells of the hard clam, and those of most bivalves, are joined together by a long hinge on the upper, or dorsal, side, and fit together evenly all the way around. In the pileworm and its allies the shells meet only at two narrow points; in the hinge region, and directly opposite on the lower side, where each shell bears a rounded knob. On account of the great development of these knobs the front and back

[3]Calman (1) notes that a species of annelid worm, *Nereilepas fucata,* has been stated to prey on *Teredo navalis,* but there is no evidence that its attacks lessen to any appreciable extent the destruction wrought by the pileworm.

edges of the shells are pushed far apart and never touch as they do in the clam (fig. 5).

Everyone who has seen a clam on the half shell has noticed the two rounded pinkish white adductor muscles, one in front and one behind, by which the shells are closed. In the pileworm these muscles do not work together as they do in the clam, but alternately, so that the shells instead of opening and closing as do those of the clam, rock backward and forward on the knobs where they are in contact with each other. The muscle at the hinder end is much stronger than that in front, and has a greater leverage, so that it is able to exert a considerable force.

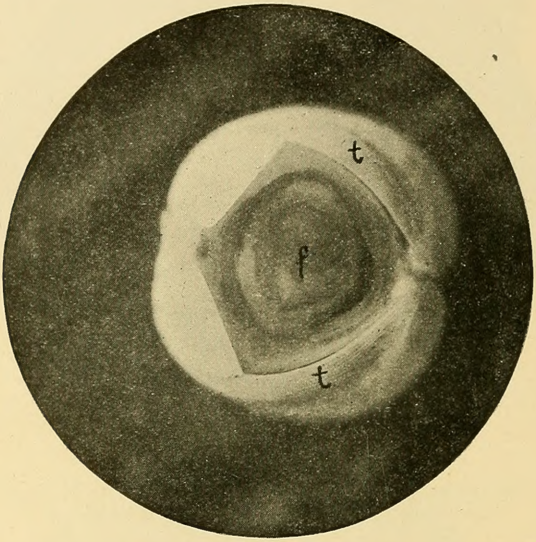

Fig. 5. Anterior, or Front End of Teredo navalis Showing Shells Enclosing the Circular Foot

f, foot; t, the rows of rasping teeth which are carried on the front edge of the two shells

How Burrows are Made

The outer front surfaces of the shells bear several rows of rasping teeth which point backward (*t*, fig. 5). Consequently, when the hinder adductor muscle contracts, the front edges of the shell are sprung apart with such force that the teeth scrape off little shavings of the wood. The foot, which is circular and hollowed out, acts as a sucker and keeps the front edges of the shells, which bear the teeth, tightly against the end of the burrow while the animal is boring (fig. 5). As the mollusc grows it rasps away more and more of the wood, lengthening and enlarging the burrow. The shavings pass through the digestive tract, where they are held for some time, and then cast to the outside through the excurrent siphon.

As its burrow is extended the pileworm lines the walls with a thin layer of white shell which acts as a further protective covering for the animal, and also prevents any injury to the soft part of the body through contact with splinters of wood. The burrows of older borers are quite heavily lined with smooth white shell. It is an interesting fact that no matter how closely the marine borers may be crowded together, their burrows never run into each other, though the walls of wood separating them may be thin as tissue paper (fig. 6).

Pileworm Breeds Rapidly

An astonishing fact in the life of the pileworm is the rapidity with which it becomes sexually mature and begins to breed. The oyster in New Jersey does not usually breed until it is 2 years old, while clams

FIG. 6. PIECES OF CYPRESS FROM PLATFORM RIDDLED BY THE BURROWS OF TEREDO NAVALIS
Note the white shell which lines the burrows

require from 1 to 2 years to reach breeding age. As compared with this, Potts (6) found at Samoa, in the Pacific Ocean, with temperatures of the water ranging from 80 to 86° F., that *Teredo navalis* became sexually mature within 24 days of the time it entered the wood. The shallow coastal waters of this state are often warmed to 80° F. and above, during the summer, so that growth almost as rapid may occur here.

In Barnegat Bay, N. J., breeding teredos have been found in less than 6 weeks from the time they attached themselves to the wood, and when they averaged only 3/5 inch in length. In *Teredo navalis* the eggs are fertilized within the gills of the female by spermatozoa thrown out through the excurrent siphon of a nearby male, and entering with the stream of water passing into the incurrent siphon of the female. Curiously enough there is only one male to about every 500 females.

Within the gills of the female many thousands and even millions of eggs develop into very small larvae looking much like those of the clam or of the oyster (fig. 7). (Compare with figures 5 to 11 in reference 5.) They have a pair of thin transparent shells of lime joined together by a straight hinge, the whole animal resembling a

Fig. 7. Larvae of Teredo navalis Taken From the Gills of the Parent

These larvae are ready to be thrown out into the water. Note the swimming organ, the velum, which projects from between the shells

purse. Between the shells the ciliated swimming organ, the velum, is pushed out. After the larvae are cast out into the water through the excurrent siphon of the parent they swim actively about with the aid of the velum while carried to and fro by currents.

It is not known just how long the larva of *Teredo* remains free-swimming in the water, but it is believed to be about one month in San Francisco Bay. In the warmer waters of this state the time is probably somewhat shorter. During the free-swimming period the larva grows to be about 1/100 inch long, or about five times the length it was when it left the parent. It then settles down on the surface of unprotected wood and attaches by means of a sticky thread, the byssus, which it spins out of the base of its foot. Then occurs a series of changes too complex to consider here, by which the velum is lost, and after the shells are modified for boring, the little pileworm enters the wood. When sexually mature it begins giving off larvae as did its parent. Since one teredo liberates from 500,000 to 1,000,000 larvae in a season, it is easy to understand how from one piece of infected wood an entire harbor might become infested with borers. Luckily for us the great majority of marine borers die before spring of each year, so that only a few live over to propagate the species.

Teredo navalis in Barnegat Bay

During the course of oyster investigations carried on in Barnegat Bay last summer, the writer came accidentally upon a heavy invasion of *Teredo navalis*. On July 3 a platform of cypress shingling lath, 3 by 6 feet, was covered with clean oyster shells and sunk on the northwest line of the Sloop Creek natural bed, some 2½ miles southeast of Barnegat Pier. The platform stood on legs which raised it

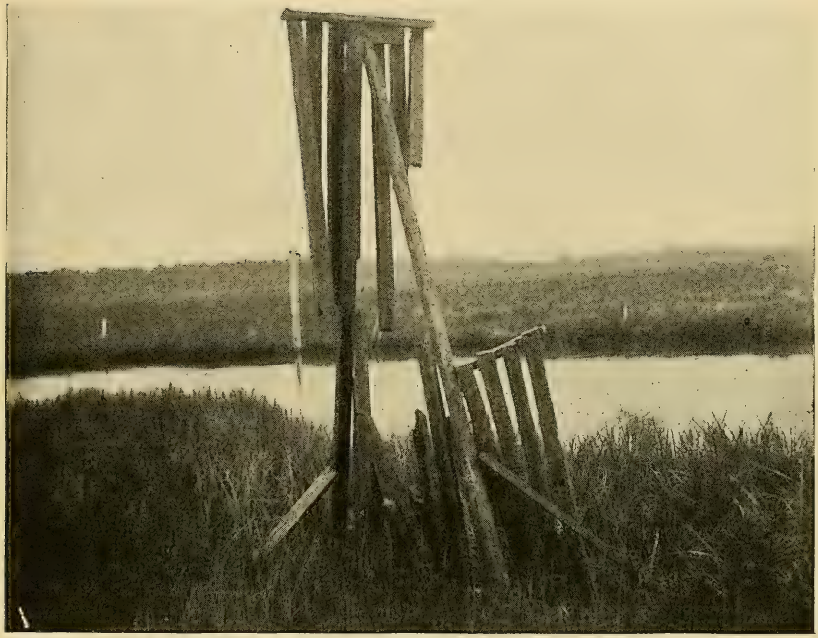

FIG. 8. CYPRESS PLATFORM WHICH COLLAPSED IN LESS THAN SIX WEEKS AFTER IT WAS PUT OVERBOARD IN BARNEGAT BAY

about 8 inches off the bottom in 6 feet of water. On July 25 the platform was raised and taken into the tidal creek south of Potter's Creek, Bayville, N. J. Here it remained suspended from the laboratory houseboat, just beneath the surface of the water, until August 15, when it collapsed. Upon examination it was found to have been completely riddled by *Teredo navalis* (fig. 6 and 8). The pileworms, which averaged about 3/5 inch in length, were so closely crowded together that a single piece of lath, 1 by 2 inches, in a swath 2/5 inch wide around the lath showed 77 pairs of protruding pallets. The majority contained larvae ready to throw out. *Teredo navalis* becomes full grown by autumn of the season in which it attaches to the wood, reaching a length of about 8 inches. Of the native species, *Bankia* *gouldi,* a close relative of *Bankia fimbriata,* according to Sigerfoos (7) becomes full grown in about a year in California waters, at which time it may attain a length of 2 feet.

The exact date when the larvae of *Teredo* became attached to the platform is unknown, but as it must have occurred soon after July 3, it is probable that the growth of the pileworms to sexual maturity, with incidentally the complete destruction of the platform, must have occurred in about 5 weeks.

One reason for the very heavy infection of the platform by borers was the unusually high density of the water. From the reports of the United States Weather Bureau for New Jersey we find that the year 1921 was one of the five driest on record. The rainfall for the state as a whole was 8.08 inches below the normal, and for the seacoast area, 10.6 inches below the normal. During these 22 days in July when the platform was in Barnegat Bay, the water at the bottom near the platform ranged in salinity from 10,125 to 10,170, with an average of 10,145 (fresh or distilled water being 10,000), This is from 40 to 60 parts per 10,000 higher than would be found here in normal years. The average temperature of the water at the bottom during this period was 78° F., with a maximum of 80° and a minimum of 76°. During the period the platform was in the creek, the maximum density observed was 10,125, and the minimum 10,090. The maximum temperature during the same period was 87°, and the minimum 70°.

A remarkable feature of the higher salinity of last year, and one which should receive full recognition by engineers, is that during the summer water of relatively high salinity crept upstream along the bottom far above its normal limits. For example, on July 8 water samples taken in Toms River, just below the last boathouse in the town of Toms River, showed a salinity of 10,040 at the surface, while at the bottom, 6 feet, it was 10,095. The bottom sample contained numerous clam and oyster larvae which had worked at least 3 miles up the river from the nearest beds. The larvae of *Teredo* were not found at this time, but the salinity of the water was such that had they settled on the piling of the water front of the town of Toms River, they would have been able to develop into mature pileworms.

A Situation Dangerous to Oyster Shippers and Wharf Owners

Little fear is felt ordinarily of the attacks of marine borers in the bottoms of vessels which return every few days or oftener to a harbor in fresh water. The native shipworms, *Bankia fimbriata,* probably do not live in waters the density of which falls much below 1010 for any long periods.[4]

In contrast to this, however, according to the experience in San

[4]A platform similar to the one sunk in Barnegat Bay was put out in the tidal creek some 50 feet below the laboratory houseboat on May 23. When examined on August 15 it was found to be slightly infected with *Bankia fimbriata.* The salinity of the water during this entire period, deduced from records which were taken twice daily, varied from 1006 to 1012, averaging about 1010.

Francisco Bay, the European pileworm may survive for long periods and do great destruction where the salinity of the water at no time rises above 1006 (4, p. 74). It makes little difference if the water becomes absolutely fresh at each low tide; the teredo merely pulls in its siphons and, plugging the opening into its burrow with the pallets, it awaits the more salty water coming in with the flood tide before beginning again to feed. According to Dr. Kofoid, *Teredo navalis* in pieces of wood lived for 8 days in running fresh water in San Francisco.

The salinity of the water at many points in New Jersey from which oysters are shipped is sufficiently high to permit the pileworm to do untold damage. Should it once gain a foothold at the mouth of Maurice River, for instance, the vast system of wharves, piling and oyster floats might be wiped out in a single season.

This is not a fanciful dream. This very catastrophe visited the Southern Pacific Railroad Terminal in San Francisco Bay. Three piles were drawn for examination in June, 1921, and showed no Teredo; in August the entire structure, worth several millions of dollars floated downstream, the piling cut off at the mudline by Teredo navalis.

The salinity of the water at the mouth of Maurice River is well above that capable of supporting the life of *Teredo navalis,* in fact it is of such a salinity that oysters set and grow to maturity for some distance up the river above the point where the wharves are located.

It cannot be urged too strongly that the Central Railroad of New Jersey and the Pennsylvania Railroad should draw some of the piling at Maurice River and at Bivalve and conduct a thorough examination. Let the pileworm once gain a foothold and the great extent of piling wharves, and oyster floats will be threatened with destruction. What has just been said of the mouth of Maurice River applies equally as well to all similar regions where unprotected piling occurs.

The teredo attacks most heavily just above the mudline, partly because the water here is of higher salinity than that at the surface and possibly also for other reasons. Any inspection, to be of value, therefore must be conducted by a diver, or better yet, piling should be pulled and sawn into 2-foot sections for examination.

Means of Protection

Since an ounce of prevention is always worth a pound of cure, it behooves all dock owners, marine engineers, shipping men, fishermen, and oyster growers to be on the alert for the first signs of invasion by the European pileworm. Any infested wood should be removed immediately, and old vessels, discarded wharfing, and other abandoned wooden structures should be carried away to avoid a possible source of infection of nearby structures. One infested piling is a menace to all others in the neighborhood. If you find wood infested with borers get in touch at once with Mr. R. T. Betts, Chief Engineer, Robbins-Ripley Co., 50 Church Street, New York City, who is Chairman of the National Committee on Marine Borer Investigations, or inform the writer at Rutgers College, New Brunswick, N. J.

Our knowledge of protective coverings is relatively slight. Copper paint as used on the bottom of vessels is of little use for piling, as it soon rubs off. Thoroughly creosoted piling stood up fairly well in San Francisco Bay during the recent invasion, though it must be emphasized that even in the wharves having the best records, standing entirely on creosoted piling, as high as 30 per cent of the piles showed more or less infection by the teredo. Any knot or bolt hole, or any deep scar formed in handling the piling, gives opportunity for the borers to enter. The storage and after-treatment of piling should be attended to with as much care as the actual creosoting; this is well set forth in the report of the San Francisco Committee (4).

Finally, it must be remembered that there are creosotes and creosotes—some good, others very poor. Based upon their experience in San Francisco Bay the San Francisco Committee has formulated specifications covering the grades of creosote to be used and the methods to be followed by the creosoting companies. These specifications are to be found in the report of the Committee (4).

Recommendations

The heavy invasion of the cypress platform by *Teredo navalis* as described in this circular, shows that somewhere in Barnegat Bay there must be infected wood. The menace of this to unprotected woodwork in the bay cannot be too strongly emphasized. It is recommended, therefore, that immediate inspection be made of the following structures in Barnegat Bay:

1. The public dock at Seaside Park.
2. Private and public wharves at Berkeley.
3. Traffic bridge from Island Heights to Berkeley (very important).
4. Pennsylvania Railroad bridge crossing Toms River at Island Heights.
5. Falkenberg's wharf, Barnegat Pier.
6. Pennsylvania Railroad bridge crossing Barnegat Bay from Toms River to Seaside Park. (In response to a letter to the Division Engineer, Trenton, N. J., informing him of the destruction of the platform by *Teredo navalis* as herein described, a visual inspection was made of the bridge on November 16, 1921. It was reported that only a few of the piles showed signs of the work of borers).

It would be most advisable in the last mentioned case to draw such piles as show any signs whatever of the presence of *Teredo*. All the piles in the bridge are creosoted, but if the experience in San Francisco Bay means anything to us, even treated piling is not to be considered immune from attack.

Remember that all our old ideas regarding the nearness to fresh water to which borers will come must be given up. We are not dealing with the native shipworms, but with a foreign enemy, having habits very different from those of our native species.

Let us not wait until lives are lost next summer as a bridge or wharf collapses with a holiday crowd, but let the inspection as above outlined BEGIN AT ONCE.

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