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Teredinidae, Ocean Travelers

By CHARLES HOWARD EDMONDSON
BERNICE P. BISHOP MUSEUM

INTRODUCTION

The geographic location and means of dispersal of marine wood borers are fascinating subjects. Although some species of Teredinidae appear to be restricted in their distribution, investigations reveal that many have become dispersed over vast areas of the oceans, apparently limited only by temperature, salinity, or the lack of dependable transportation. Most representatives of the family favor tropical and subtropical latitudes, in which some localities support numerous species of marine wood borers. As many as 12 to 15 species of shipworms can be recovered from waters about Guam, Luzon in the Philippine Islands, Samoa, or Hawaii. Conversely, the colder waters of the northwestern coastal zones of North America are typically represented by a single species.

A recent Annual Progressive Report of the W. F. Clapp Laboratories (7)[1] indicates that more than 20 species of Teredinidae are common to the Atlantic and Pacific Oceans, many of them recognized in localities separated by thousands of miles. Nair (10) records some of the same species from the coastal waters of southern India.

One of the more familiar of the widely dispersed shipworms is *Teredo navalis* Linnaeus. This species, well known in European waters, is also recovered from the waters of both the eastern and western coasts of North America and is reported from numerous localities in the far western fringes of the Pacific. Although recognized in Japanese and Philippine waters, apparently it has not yet invaded the vast area of the central Pacific, which supports a rich and varied

[1] Numbers in parentheses refer to Bibliography, page 59.

fauna of Teredinidae. As numerous other shipworms have distributional records equal to or approaching that of *T. navalis,* it is clear that some species of the Teredinidae may be considered seasoned ocean travelers.

Most surveys of marine wood borers are confined to coastal situations and to the protected waters of bays, harbors, or estuaries. This is due to a lack of offshore facilities for experimental phases of the work or to the fact that the biological studies are tied in with industrial economics, which involves such structures as piers and wharfs. Furthermore, the investigator is sure of finding material near shore, as the boundaries of harbors and the narrow coastal zones, where wood is available, are the normal areas of operations of most shipworms.

The question of whether adult and larval marine wood borers can survive if removed from the comparative safety of their normal environment to distant offshore waters has not been answered, but the recovery of recently infested flotsam in the open sea indicates that larvae of marine borers spawned in midocean can endure long enough to contact drifting timber and continue a chain of seafaring generations.

That species of Teredinidae can be transported far and wide by the wooden hulls of ships is undisputed, although the degree of dispersal cannot be estimated with certainty. This means of distribution probably rated high for a long time, declining in recent times as wood has given way to metal in ship construction. However, the appearance of exotic species of shipworms in Honolulu and Pearl harbors during World War II is substantial evidence that surface craft are still a factor in the dispersal of marine wood borers.

Most of my observations on marine wood borers have been confined to bays and harbors of Pacific islands or to open reefs a hundred yards or so from shore. Rarely have I had the opportunity to extend my observations into the sea, and then for no great distance. Some years ago I assisted the United States Navy in fouling experiments off the west coast of Oahu, where a station was set up about a mile offshore. Several small metal buoys were suspended from surface to bottom on a chain anchored in 75 feet of water, and wooden panels were attached to the chain at the surface and at depths of 25, 50, and 75 feet. When the installation was lifted at the end of three months, the surface test panel had been lost but those at lower levels were infested by several species of Teredinidae typical of the inshore waters and harbors of Oahu. The panels at the 50- and 75-foot levels were

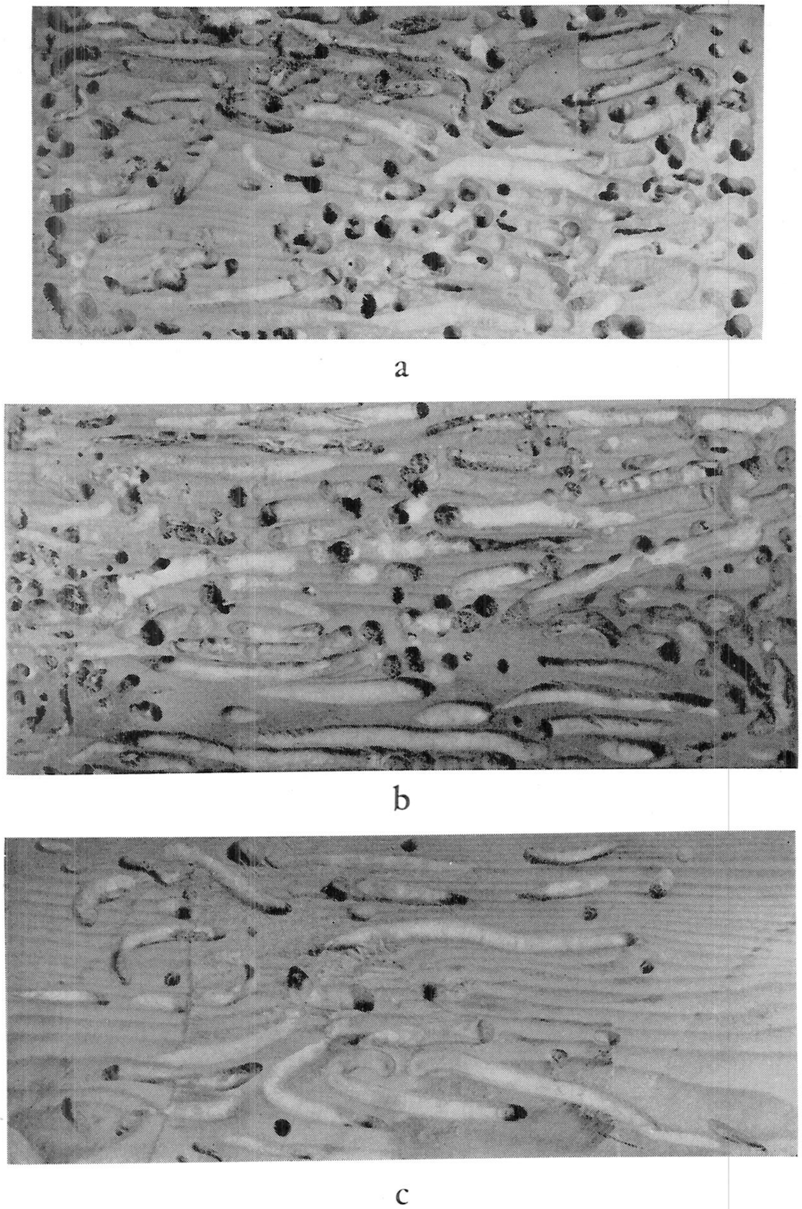

FIGURE 1.—Seven-inch test panels anchored to ocean bottom off Waikiki, Oahu, for three months: **a**, 1 mile from shore, depth 70 feet; **b**, 1.5 miles from shore, depth 70 feet; **c**, 2 miles from shore, depth 85 feet.

about equally damaged, showing much more marine borer activity than the panel at 25 feet (Edmondson, 3). Thus the larvae of inshore species of shipworms are capable of considerable endurance and of spreading outward into the sea for an undetermined distance, with greater concentrations at deeper water levels.

I made further observations of the outward spread of shipworm larvae in 1960 on test panels installed by volunteer skin divers. These test panels were secured to the ocean floor off the south coast of Oahu at distances of 1, 1.5, and 2 miles in depths of water 70, 70, and 85 feet respectively (fig. 1). The panels which were installed on November 20, 1959, were recovered on February 21, 1960, after being submerged for three months. The panels 1 and 1.5 miles from shore were heavily, and about equally, damaged by shipworms, whereas the panel 2 miles offshore was only moderately damaged. The two species of *Teredo* recovered from the panels were common inshore forms, *T. milleri*[2] and *T. trulliformis*. *T. milleri* occupied all three of the panels, but *T. trulliformis* was recovered from only one, the panel 2 miles from shore. This panel was the least crowded by borers and supported the largest specimens. The maximum penetration of the wood was about 100 mm. There was no way of determining the incidence of larvae in the upper levels of the sea, but the degree of destruction showed that saturation at the bottom level and 1.5 miles from shore was approximately that found in Honolulu Harbor. There was no trace of *Limnoria* on any of the panels.

I paid special attention to the stenomorphic features of the shipworms infesting the panel 2 miles from shore (fig. 2). Abnormalities were not detected in the shells; but they were obvious in the heavy, overdeveloped pallets of *T. trulliformis*. The pallets of *T. milleri* lacked none of the typical characters found in species recovered from nearshore areas. As the most seaward test panel was only moderately attacked by shipworms, the unusual features of the pallets cannot be ascribed to overcrowding but must be attributed to some other cause or causes, possibly physical in nature. Increased pressure is suggested.

A Technical Report of the Marine Laboratory at the University of Miami (12) concludes that the larvae of *Teredo* are unable to enter wood unless they do so in a period of less than five days after release

[2] In 1924 Miller recognized a Hawaiian species as *T. affinis* Deshayes (1863, Reunion Island). Dall, Bartsch, and Rehder (1, p. 210), convinced that Miller's determination was in error, suggested the name *milleri* for the Hawaiian form; but some authorities still prefer the nomenclature of Deshayes and Miller. In my opinion, the matter is unsettled and cannot be resolved until substantial amounts of material from Reunion and the central Pacific are critically compared.

from the adult. If this is true for Teredinidae in general, it indicates that the radial spread of larvae into the ocean from shore stations may equal or exceed a half mile each day, at least for short distances.

There is evidence that some near-shore species of Teredinidae show considerable durability in the open sea and are capable of normal activity after having been carried long distances in surface waters. Annual Reports of Progress of the W. F. Clapp Laboratories record operations from lightships in which well-known species of Teredinidae have been trapped in the Atlantic Ocean at as much as 40 nautical miles from the coast of Massachusetts (6).

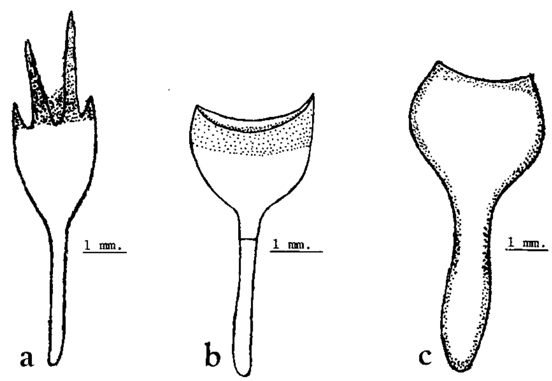

FIGURE 2.—Pallets of *Teredo* recovered from off-shore test panels, Waikiki, Oahu: **a**, of *T. milleri;* **b**, of *T. trulliformis,* a typical form of near-shore waters; **c**, stenomorphic pallet of *T. trulliformis,* typical of 85-foot depth 2 miles from shore.

Certain Teredinidae may have adopted a typically oceanic existence, spending their life cycle from larva to adult in the open sea, supported by some convenient flotsam, but seldom, if ever, making contact with stationary structures in near-shore waters. In this respect they resemble species of the closely allied *Xylophaga,* which are typical of driftwood and are often recovered from considerable depths but are seldom recovered from such installations as piling in bays and harbors. These observations have lead me to consider the known activities of *Teredo* (*Teredora*) *gregoryi* Dall, Bartsch, and Rehder; *T.* (*Uperotus*) *clava* Gmelin; and *T.* (*Teredothyra*) *palauensis* Edmondson. The results of my observations on these three species are given in the following pages.

THREE KNOWN OCEAN TRAVELERS

Teredo (Teredora) gregoryi

There is considerable evidence that *T. gregoryi* is typically an open-ocean species and attacks drift logs only after they are well started on their maritime journey. By the time the logs reach Hawaiian beaches the borers have completed extensive burrows and perished, leaving their shells and pallets as evidence of a long ocean voyage. The range of burrow sizes signifies that attacks have occurred at different times and places.

Since most of the logs that drift into the Hawaiian Archipelago are Douglas fir, it is assumed that their origin is the northwest coast of North America and that they are carried down the west coast of the United States by the south branch of the Japanese Current, later drifting westward with the northern equatorial current. The Japanese Current in its easterly course divides as it approaches the American coast, one branch flowing northward along the Alaskan shores, the other and larger branch moving southward off the coasts of Washington, Oregon, and California. According to McEwen (8), the southern branch of the Japanese Current flows slowly, a fraction of a mile an hour, whereas the northern equatorial current drifts westward at a rate of about 1 mile an hour.

The long, diagonal chain of islands from Kure on the north to Hawaii on the south constitutes the Hawaiian Archipelago, and forms the first barrier to the ocean-borne logs. Those which miss the Hawaiian Islands may float to Johnston or Wake Island or even to the shores of the far western side of the Pacific (fig. 3).

Though many of the drift logs which reach Hawaii are honeycombed by burrows of marine wood borers, the organisms have perished. However, the distinctive shells and pallets left in the burrows belong to *T. gregoryi*, described in 1938 by Dall, Bartsch, and Rehder (1). Some of the recovered shells are as much as 19 mm. in height, and the largest burrows, difficult to measure, doubtless exceed 2 feet in length, making this species of *Teredo* the largest seen in Hawaiian waters.

No living mature specimen of *T. gregoryi* has been seen in this area; nor has it ever been reported from any west American coast, where the drift logs presumably have their origin. (See figure 4.) However, occasional juveniles have been trapped in test panels in

Kaneohe Bay, at Waimanalo, and on Waikiki reef, Oahu; and a small floating board stranded in Hanauma Bay, Oahu, had been heavily attacked by juvenile specimens of *T. gregoryi*. Many of the burrows were only 2 mm. deep, indicating that larval contact with the board had occurred not many days earlier.

Shells and pallets of *T. gregoryi* have been recovered from drift timbers found on the shores of numerous islands west of Hawaii, including Wake, Eniwetok, Saipan, Alamagan, Yap, Koror, and Okinawa; but test panels installed at no fewer than 24 stations in the central and western Pacific after 1948 failed to trap the species.

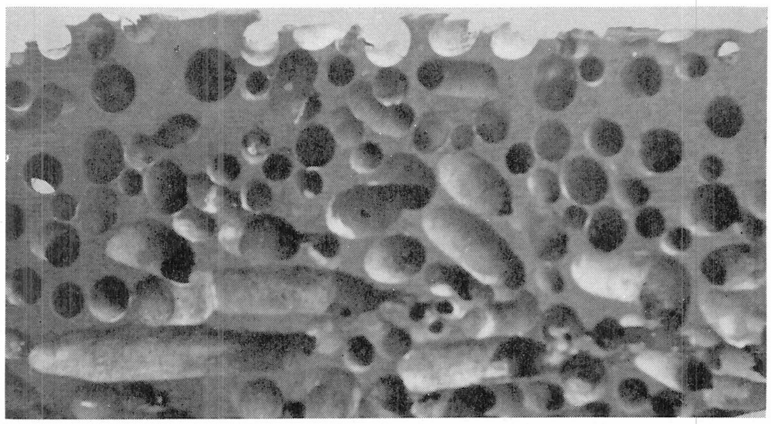

FIGURE 3.—Section of drift log attacked by *Teredo gregoryi* beached at Wake Island.

Although, in the Pacific, *T. gregoryi* has been recovered almost exclusively from northern latitudes, drift material on the shore of Canton Island has yielded shells and pallets of the species. Further evidence of the wide dispersal of *T. gregoryi* is supplied by investigators working on the south coast of India. R. Nagabhushanam (9) of Andhra University reports its recovery in that locality, and N. Balakrishnan Nair (10) of the University of Madras records *T. gregoryi* in considerable abundance in south Indian waters, where living specimens up to 29 cm. long were recovered from test panels and from drift material. Nair states that the ready appearance of the species in test panels suggests that *T. gregoryi* is well established in Madras waters.

We have few clues as to the rate of growth of *T. gregoryi* or the time required for a drift log to reach Hawaii from the northwest American coast. From our meager knowledge of the growth rate of *T. gregoryi* during the early period of its existence, the size it may attain in drift logs, and the probable speed of ocean currents, there is reason to believe that the floating time of a log, between the borer's first attack and when it reaches the shores of Hawaii, may exceed two years. Although we are ignorant of the time and place of the initial

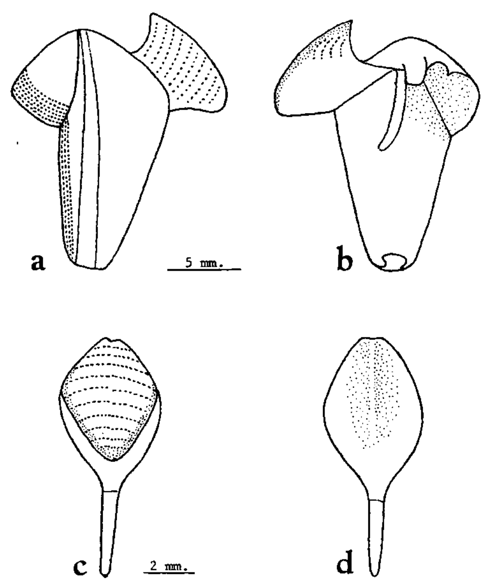

FIGURE 4.—Shell and pallets of *Teredo gregoryi* from a drift log at Midway Islands: **a**, outer surface of shell; **b**, inner surface of shell; **c**, outer surface of pallet; **d**, inner surface of pallet.

attack upon the drift log by the borer, indications of repeated contacts by larvae during the pelagic journey are sufficient to warrant the belief that *T. gregoryi* may be one of the few marine wood borers habitually adapted to the wide ocean spaces. The only firm information available comes from test sites, where intervals of time are known. A specimen penetrated a Douglas fir test panel in Kaneohe Bay, Oahu, to the extent of 75 mm. in 140 days, but the actual growth period may have been much less than the period of submergence. A maximum penetration of 70 mm. was made in koa wood at Waimanalo, Oahu, during a 180-day period, the shells attaining a height of 8 mm. in that time. Shells 14 mm. high were recovered from a floating raft of California redwood anchored on Waikiki reef for two years.

TEREDO (UPEROTUS) CLAVA

There are records of *Teredo clava* Gmelin from widely separated localities including the Moluccas, the east coast of South Africa, Mauritius, the east coast of southern India, Ceylon, Java, Amboina, Queensland, the Philippine Islands, and Canton Island.

T. clava is, in many ways, an even more remarkable ocean traveler than *T. gregoryi.* Although the species has been known to science since the latter part of the eighteenth century, considerable confusion has resulted from attempts to stabilize its taxonomy, for which no type exists. Numerous early diagnoses of *T. clava* omitted characteristics of the animal itself but clearly described the thick calcareous tubes in which the living organisms had been encased. Dillwyn (2), quoting other authors, accurately represents the gregarious manner of living of the species and discusses the clusters of calcareous tubes found in ocean-borne seeds of certain trees which serve as a means of dispersal. Obviously, few investigators have ever been fortunate enough to see living specimens of *T. clava.*

In 1936 Iredale (5) announced a new genus and species, *Glumebra elegans,* based on a shipworm found living gregariously in calcareous tubes in the husk of a coconut floating in sea water off south Queensland. The form described by Iredale was doubtless *Teredo clava* and agrees in all essential features with the clusters of calcareous tubes taken in the seed cases of *Xylocarpus moluccensis* on the shore of Canton Island by Otto and Isa Degener during February 1958 (fig. 5).

As *X. moluccensis* does not grow on Canton, the seeds collected there may have drifted from Samoa, Fiji, or some other Pacific island. The seed cases are roughly triangular in shape, the large ones slightly more than 3 inches long and about 1.5 inches thick, somewhat flattened on one surface and convex on the other. The seed case is tough, fibrous, and buoyant, normally enclosing a large kernel.

In its native habitat *Xylocarpus* grows close to the ocean, where seeds may fall into the water and be carried away by currents to be attacked in the open sea by drifting larvae of *Teredo clava.* When the solid substance of the seed is destroyed by the invading borers their cutting function ceases. In the meantime, calcareous deposits have been forming strong protective tubes about individual animals, tubes which fuse into compact clusters. Cavities of larger seed cases stranded on Canton Island were almost completely filled with calcareous tubes of *T. clava*. However, the living organisms once encased in these calcareous tubes had perished, leaving only their shells and pallets. When the cutting activity of the living *Teredo* is complete, the anterior end of the tube which has been its protection is closed permanently and the animal soon perishes.

FIGURE 5.—*Teredo clava* in seed of *Xylocarpus moluccensis,* normal size.

Commensurable with the animals which once occupied them, the calcareous tubes vary greatly in size; the larger ones, usually twisted and bent, may exceed 2 inches in length and reach a diameter of 15 to 18 mm. at the broader, closed end. The presence of well-developed calcareous tubes, and the recovery of shells of larval borers from the fibrous walls of the seed cases indicate that attacks occurred at various times during the ocean voyage.

Obviously there is a correlation between the character of the shell of *T. clava* and the environment in which the animal lives. The absence of well-defined teeth on the anterior lobe of the shell indicates that the substance through which the animal makes its way is relatively soft, offering little resistance. Apparently, the cutting function of the shell is greatly diminished and quite unnecessary through a considerable period of the animal's life. The development of the strong calcareous tube which encases the growing animal indicates that much of its energy is expressed in chemical, rather than physical, activity.

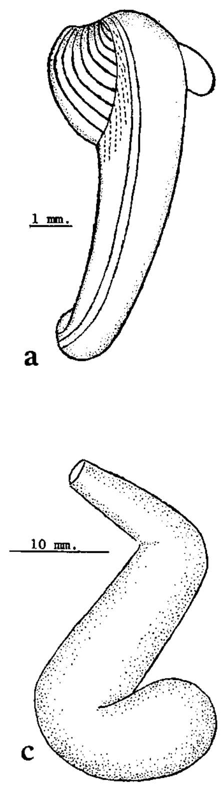

FIGURE 6.—*Teredo clava:* **a, b,** shell, outer and inner surfaces, respectively; **c,** calcareous tube removed from cluster; **d,** pallet, outer surface.

The valves of the shell are remarkably narrow (short) and strongly incurved. The anterior lobe of each valve bears few, often not more than 8 to 10, low ridges distantly separated from each other at the inner ends, each capped by a row of closely set, minute, blunt denticles. The ridges of the anterior median area are sculptured in zigzag fashion, the details of which are more or less obscured by calcareous deposits. The valves support the view of a slowing down or even a complete cessation of the cutting activities of the animal. The auricle of the shell is reduced to a rudimentary lobe, indicating a minimum of muscular activity. The physical aspect of the shell as a whole, with power and weight so near the fulcrum, points to a limited range in the rocking movement of the valves, thereby greatly reducing the cutting potential of the shell. (See figure 6.)

Pallets of *T. clava* show no special characteristics which can be ascribed to the mode of living of the animal. They have radiating ribs that mark the outer surface of the distal half of the blade; and they resemble, to a marked degree, the pallets of *T.* (*Teredora*) *vattanansis,* recently described by Nair and Gurumani (11) from the east coast of India. However, the shells of the two species are quite different.

TEREDO (TEREDOTHYRA) PALAUENSIS

The species from the Palau Island in the western Pacific that I have described as *Teredo* (*Teredothyra*) *palauensis* (Edmondson, 4) was first collected in 1948 by A. N. Nicol of the United States Geological Survey, who found it in driftwood on Koror. The following year Yoshio Kondo of Bishop Museum took it from drift timber on the shore of Babelthuap in the Palau Islands. The most recent appearance of the species was in February 1958, when specimens were recovered from sections of a drift log taken by botanists Otto and Isa Degener from the beach at Canton Island. In no instance were living specimens seen, but the pallets recovered indicated a wide range of infesting shipworms, probably from very young juveniles to adult forms.

Distinctive features of this species include the very fine and exceedingly numerous ridges borne on the anterior lobe of the shell, together with the broad shelf formed by the junction of the auricle and the median portion, as seen from an inner view of the valve. The blade of the pallet is hollow, the cavity being divided by a longitudinal septum with the distal apertures directed obliquely outward. The stalk of the pallet is seldom straight, but usually bent to one side or asymmetrical with respect to the blade. (See figure 7.)

There is considerable negative evidence that strongly suggests that this species is another shipworm that is highly adapted to an oceanic existence and rarely, if ever, accustomed to a life cycle in stationary structures. The abundance of the species in drift material in the Palau area in 1948 and 1949 led to the assumption that it was a rather common and permanent one in that region, but this was disproved when, during 1949-1951, the United States Navy conducted a survey to determine the incidence of marine wood borers throughout the central and western Pacific. Test panels failed to trap this species in the Koror area or at any of more than 25 other stations in the Pacific, including Canton Island. Later, in 1954, Jerome Schweitzer and his son were successful in trapping a variety of species of shipworms on Koror, but *Teredothyra* was not found on their test panels.

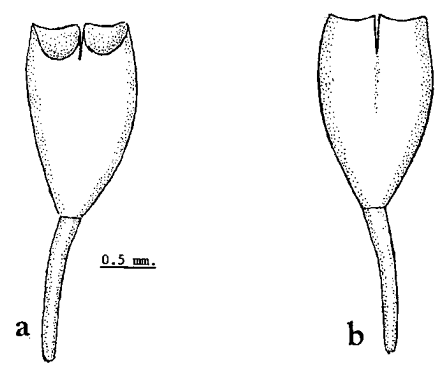

FIGURE 7.—Pallets of *Teredo palauensis:* **a**, outer surface; **b**, inner surface.

CONCLUSIONS

Careful examination of flotsam in the sea and drift material on the beaches may bring to light other shipworms with a preference for unstable conditions, a pelagic existence in the open ocean rather than one of comparative immobility in harbor piling. That this preference is a result of long adaptation is suggested by certain species, especially *Teredo gregoryi,* that still, with favorable opportunity, attack and infest a fixed timber. Without doubt, there are other shipworms, some of them as yet undetected, which are nicely adjusted to special means of ocean transportation.

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