

Tree species used in historical shipbuilding and their risk of being attacked by Teredinidae

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Abstract - This paper gives an idea of the range, biodiversity and mechanism of the bore-worm, whose fast work of destruction could especially be observed at an artificial shipwreck. Conclusions as for archaeology are drawn (see also summary at the end of the paper).

Inhalt - Der Beitrag gibt einen Einblick in Verbreitung, Artenvielfalt und Wirkungsweise der Bohrmuschel, deren schnelles Zerstörungswerk besonders an einem künstlichen Wrack beobachtet werden konnte. Folgerungen für die Archäologie werden gezogen.

Tree species used for boat- and shipbuilding

In historical naval architecture and construction the tree species used (number of kinds unknown) varied, depending on availability and suitability. Usually the timber for ship- and boatbuilding was taken from regional forests nearby. Larger vessels for the high seas were generally built at places near the coast, using rivers for transporting the wood from inland areas to the coast. If the required kinds of wood were unavailable in their own homeland, the shipbuilders of the sea powers procured the timber from countries far away, usually transporting it by sea. The selective demand for special kinds of wood led to karst formation in entire regions as there was no controlled forestry taking care of replanting of trees. A typical example is the Lebanon Cedar (*Cedrus libani*) whose wood was used as early 5 000 years ago. As a result of overcutting, the formerly numerous cedar stands one to two thousand meters high-up in the mountain regions of Lebanon vanished¹. Cedar timber from Lebanon was shipped particularly to Egypt². There are reports on wood shortage dating back to the age of the Hanseatic League that have also been explained in terms of a great demand for special kinds of wood for shipbuilding³. Shipbuilding also strongly contributed to deforestation in Spain in the 16th century as the construction of merchant vessels and the Armada to support the Spanish hegemony brought about an enormous demand for wood⁴.

A comprehensive overview on the use of wood in naval architecture around the Eastern Mediterranean is given by Liphshitz and Pulak⁵. Their dendrochronological studies show that in this region the Lebanon Cedar (*Cedrus libani*), which is also found naturally in Turkey, was mostly used during the Bronze Age. Among the wood remnants of the Uluburun wreck, a ship that had sunk in the late 14th century B.C. according to their dating, the researchers also found *Pinus nigra*, *Cupressus sempervirens*, several kinds of oak, of which *Quercus cerris* and *Q. coccifera* could be identified with certainty, and furthermore the poplar species *Populus alba* and *P. nigra* and the pine species *Pinus nigra*. Additionally, in the Cape Gelidonya shipwreck, assumed to belong to a ship of the late Bronze Age about 1200 B.C., *Pinus brutia* and other, not exactly identifiable conifer species were found. The

¹ Beyse, R. 2001: Die Libanonzeder – ein ganz besonderer, geschichtsträchtiger Nadelbaum, Forstliche Mitteilungen 54, 224-225.

² Historisches Museum der Pfalz, Speyer 2008: Das Alte Ägypten mit allen Sinnen. Handreichung zur Ausstellung September-Mai 2008.

³ Förster, T. 2009: Große Handelsschiffe des Spätmittelalters (Deutsches Schiffahrtsmuseum Bremerhaven) 277 mit weitere Literatur.

⁴ Bauer, E. 1997: Wie es zu den großen Waldverlusten in Spanien kam, Forst und Holz 52, 379-383.

⁵ Liphshitz, N. – Pulak, C. 2008: Wood species used in ancient shipbuilding in Turkey – Evidence from dendroarchaeological studies, SKYLLIS 8. 2007/08, 73-82.

Pabuc Burnu shipwreck of the 6th century B.C. also contained *Nerium oleander*, and in the remains of the ship at Tektaş Burnu, dated to the 5th century B.C., *Quercus pubescens* was discovered.

In several cases it was impossible to ascribe a structural component the determined tree species. However, Liphschitz and Pulak assume that in the Bronze Age planking was usually made from Lebanon Cedar. In wrecks dated to a later period they found mostly pine species, which were also mainly used for planking, for example the species *Pinus brutia* and *P. nigra* that are found in the Eastern Mediterranean. Between the Bronze Age and the age of the Ottoman Empire, these kinds of wood were supplemented by oak species (*Quercus cerris* and *Q. coccifera*). Other wrecks discovered later confirm the frequent use of oak and pine wood around the Mediterranean⁶.



Fig. 1: Shipworm at three maturity stages.

Danger from shipworms

Shipworms (*Teredinidae*) live in sea water and feed essentially on wood. In the larval stage they settle on wooden surfaces and bore into the wood (fig. 1) in a wormlike fashion, thereby damaging it. Only a few kinds of wood are resistant to shipworms, other wood types must be protected against these vermins by some suitable method to make them long-term durable in seawater. Shipworms also pose a serious threat to archaeologically valuable underwater structures and shipwrecks, for they can virtually completely decompose the freely

accessible wood within a few years. As an example, the rebuilt Uluburun III shipwreck (fig. 2) in the Mediterranean Sea near the Turkish sea port Kas shows such a rapid destruction of unprotected wood. Further conclusions on the importance of the shipworm for historical underwater finds can be derived from the results of the studies on the original Uluburun wreck and other research.

Biology of the vermin

Currently, some 70 kinds of shipworms are known within the family of *Teredinidae*; they are found mostly in coastal regions at temperate and tropical latitudes. In German, the misleading term „Schiffsbohrwurm“ (literally „ship boring worm“) is quite common because of the worm-like elongation of their body and their frequent occurrence on sailing ships in the past; the English equivalent „shipworm“ may have contributed to the frequent use of „Schiffsbohrwurm“ even in scientific publications. As a matter of fact, *Teredinidae* are molluscs with a long, stretched body that bore into the wood and, depending on species and living conditions, can reach a length of up to 45 cm and a diameter of about 1.5 cm. In the German coastal regions the animals usually reach only 10 to 20 cm, at the most 30 cm.



Fig. 2: Partial view of the wreck Uluburun III.

⁶ Schultheis, W. 2008: Das römische Wrack am Perduto-Riff bei Korsika, SKYLLIS 8. 2007/08, 7.

Generally accepted data on the environmental requirements of the various species of the *Teredinidae* family are not available. *Teredo navalis*, for example, can survive at salt concentrations between 7‰ and 35‰ and at temperatures between 5° C and 27° C⁷.

In the case of *T. navalis* it takes only about five days from fertilization to hatching if the growing conditions are favorable. Initially, that is, during the free-swimming phase lasting about two to four weeks, the larvae feed on plankton; thereafter they attach themselves to nutrient-containing substrates and develop into mature adults within only eight weeks under ideal conditions. Thus, a single adult produces several generations and millions of larvae within one year, and it usually has a lifespan of two to three years.

Wood destruction proper begins when the young larvae settle on the wood and start boring into it. This happens in such a way that the rear end of the body remains fixed at the wood surface while the continuously elongating body advances with its front tip into the wood, destined to stay there for the entire life. The degenerated shells rasp and bore into the wood little by little, thereby lengthening and extending the burrow. The pulverized wood serves as food. Round timber of 30 cm in diameter can be destroyed within only one year, yet the damage behind the small entry opening at the wood surface will not be visible.

Distribution and occurrence in the eastern Mediterranean Sea

Teredinidae are found in all oceans as well as in many seas and estuaries. But in some cases the species abundance varies strongly⁸. Species currently discovered in waters may occur there naturally, but it is also possible that they have migrated into a particular region over the millennia. Consequently, science distinguishes between native kinds which have always populated the local waters and non-resident *Teredinidae* whose occurrence, by definition, is the result of human activities (tourism, canals etc.). In terms of the temporal succession of invading foreign species, it is distinguished between pre-Columbian and post-Columbian invaders to account for the intensified global ship traffic after Columbus' initial landing in 1492. Thus, pre-Columbian species originally invaded a region before 1492.

When considering the *Teredinidae* occurring in the Mediterranean Sea today, this differentiation is also interesting from an archaeological point of view, for it is possible that through the millennia new kinds of shipworms immigrated that had a higher destruction potential against the timber species used earlier in this region than their native counterparts⁹.

According to Nair and Saraswathy¹⁰, citing the studies of Turner¹¹, the species *Teredora malleolus*, *Teredo bartschi*, *Lyrodus pedicellatus*, and *Bankia carinata* were observed in the Mediterranean Sea up to that time. Subsequently researchers also reported the occurrence of *Teredo navalis*¹² and

⁷ Bavendamm, W. – Schmidt, H. 1960: Holzbohrmuscheln (*Teredinidae*), Holz als Roh- und Werkstoff 18, 229-232.

⁸ Nair, N.M. – Saraswathy, S.M. 1971: The Biology of Wood-Boring Teredinid Molluscs, Advances in Marine Biology 9, 335-509.

⁹ Regarding finds of fossil teredinids, see Tauber, A.F. 1954: Die fossilen Terediniden der burgenländischen und niederösterreichischen Tertiärablagerungen (Eisenstadt).

¹⁰ Nair – Saraswathy et al.

¹¹ Turner, R.D. 1966: A Survey and Illustrated Catalogue of the Teredinidae. Museum of Comparative Zoology (Cambridge, Mass).

¹² Sivrikaya, H. 2003: The impregnability and durability characteristics of sapwood and heartwood, Ph.D. thesis, Zonguldak Karaelmas Univ., Bartın (Turkey) 187; Borges, L.M.S. 2007: Biogeography of Wood-Boring Organisms in European Coastal Waters and Evaluation of New Approaches to Controlling Borer Attack, unpubl. Ph.D. thesis, Univ. of Portsmouth.

Sivrikaya and Borges additionally identified *Nototeredo norvagica* and the (already earlier detected) species *Lyrodus pedicellatus* and *Bankia carinata*.

Sen et al.¹³ conducted further studies at Finike (about 50 km away from Kaş) and found *Teredo navalis* and *Lyrodus pedicellatus*. These two species were also detected farther northwest at the Alaçatı research station. Farther east at the İskenderun station, besides *Teredo navalis* and *Lyrodus pedicellatus* the species *Nototeredo norvagica* and *Bankia carinata* were also found in the wood specimen. Since *T. bartschi* and *B. carinata* usually occur farther south, in the Red Sea and the Indian Ocean for example, Sivrikaya et al.¹⁴ assume that the larvae had access via the Suez Canal finished in 1870.

After the NAS course wood samples infested by teredinids were taken from the wreck Uluburun III and sent to Dr. Hüseyin Sivrikaya (University of Bartın, Turkey) for species identification. After consultation with Dr. Simon Cragg (University of Portsmouth, UK) and Dr. Luisa Borges (University of Minho, Braga, Portugal) it was concluded that the wood was infested by *Nototeredo norvagica* and *Teredothyra dominicensis* (Bartsch). This is surprising because the occurrence *Teredothyra dominicensis* in the Mediterranean has never been reported in previous studies to our knowledge. Further samples collected later during dives in August 2010 confirmed the occurrence of *Teredothyra dominicensis*. As the animals were still alive when the samples were taken, the settlement must have occurred at the location of the find, according to Dr. Cragg¹⁵. Thus, this species can reproduce and presumably also survive in the eastern Mediterranean.

Preventive protection measures

Infestation of timber by shipworms can be prevented or at least be impeded by using shipworm-resistant timbers or effective wood protection – either on a chemical basis or by means of structural measures. According to DIN EN 350-2 (durability of wood and wood products – natural durability of solid wood), Basralocus and Greenheart are considered durable; Bilinga, Bongossi/Azobe, Sapeli, and Teak are seen as moderately durable. However, this standard is not meant to be exhaustive; there may be other durable or moderately durable timbers that have not been examined yet. Essentially because of the demanding requirements of the standard, no further durability tests on other kinds of wood have been presented in recent years. Nevertheless, practical observations and scientific studies have shown that several other timbers not mentioned in the standard can be at least moderately durable. For example, in Mecklenburg-Vorpommern (Germany) at the coast of the Baltic Sea the tropical timber species (botanical family in parentheses) Acariquara (*Olacaceae*), Abiurana (*Sapotaceae*), Castanharana (*Lecythydaceae*), Jarana (*Lecythydaceae*), and Mata Matá (*Lecythydaceae*) from South America have been used since 1997 although recognized certificates of their *Teredo* resistance were not available¹⁶.

In case of Castanharana, Jarana, and Mata Matá, rammed, sapwood-containing poles were only infested in the sapwood region after five years – the heartwood was still untouched. In Abiurana and Acariquara, not even the sapwood was infested with shipworms after six and eight years,

¹³ Sen, S. – Sivrikaya, H. – Yalçın, M. 2009: Natural Durability of Some Heartwood from European and Tropical African Trees against Marine Organisms, The International Research Group on Wood Protection, IRG/WP 09-10682.

¹⁴ Sivrikaya, H. – Cragg, S.M. – Borges, L.M.S. 2008: Variation of commercial timbers from Turkey in resistance to marine borers as assessed by marine trial and laboratory screening, The International Research Group on Wood Protection, IRG/WP 08-10668.

¹⁵ Personal communication.

¹⁶ Müller, J. 2004: Bohrmuschel verhindert Holzeinsatz im Küstenschutz, Holz-Zentralblatt 9, 111.

respectively¹⁷; continued monitoring revealed in 2008 still no infestation of these timbers, demonstrating that Acariquara sapwood can be shipworm-resistant for more than ten years.



Fig. 3: Destroyed parts of the wreck Uluburun III.

Sen et al.¹⁸ examined 33 kinds of timber, 18 of them belonging to European growing areas, in Turkish coastal waters at six different locations in accordance with EN 275. From an archaeological perspective, the results are interesting in terms of the timbers used for shipbuilding in ancient history. *Castanea sativa*, *Cedrus libani*, *Cupressus sempervirens*, *Fagus orientalis*, *Juglans nigra*, *Juniperus foetidissima*, *Olea europaea*, *Pinus nigra*, *Quercus petraea*, *Fraxinus excelsior*, and *Ulmus minor* – they all were more or less infested and destroyed by shipworms within one year when the experiments were carried out. Hence these timbers do not possess a sufficient natural protection against *Teredinidae*.

A case in point is the replica of the shipwreck Uluburun III, which was originally built as a part of an underwater archaeological park and accidentally has become a shipworm study object. Local investigations in Kas and information provided by the shipbuilder responsible for the project revealed that the ship was essentially made from *Pinus brutia* and that both heartwood and the particularly susceptible sapwood were used. The wood was not chemically treated against timber pests and had no surface protection. At the end of October 2006 the rebuilt shipwreck was originally sunk about 25 meters below the water surface near Kas, but later it slipped down to a depth of about 35 meters. Several dives at the end of October 2009 revealed severely damaged hull planks and frames due to shipworms. The mast and other wooden components with a larger diameter were less affected at that time (**fig. 3-4**).

As it is common practice in lumbermills to cut out thin parts from the sapwood-rich external region of roundwood, the particularly severe destruction of the planks may be explained in terms of smaller heartwood content. The thicker wooden components are assumed to contain more of the better shipworm-resistant heartwood. The degree of infestation noticed also on these structural components after three years of sea water exposure nevertheless shows that constructions on the basis of this kind of wood can be completely destroyed by shipworms within a few years.



Fig. 4: Planking remnants of the wreck Uluburun III.

Conclusions for archaeology

Experts believe that there are still many wooden shipwrecks from ancient times buried under the sea floor. Here the timbers are not infested by shipworms and are therefore in a relatively safe environment. However, strong water movements like currents and breaking of waves can expose the

¹⁷ Müller, J. – Gercken, J. 2006: Auch Tropenholz-Buhnen teilweise mit Teredo-Befall, Holz-Zentralblatt 5, 135.

¹⁸ Sen – Sivrikaya – Yalçın et al. (s. footnote 13).

wooden components so that they become accessible to those vermins. Then it would be only a matter of a few years until the timber would be irreversibly destroyed by the feeding activities of the shipworms. So it would make sense to routinely check the sea floor in areas used as sea routes in ancient times so as to be able to quickly employ protective measures when a new wreck is discovered. This way finds of cultural and historical importance could be preserved.

Summary

This paper describes the impact of shipworms (lat.: *Teredinidae*) on wooden ship constructions (recent as well as ancient ones) not properly protected. Ship hulls and other wooden parts are easily destroyed very quickly (e.g. Uluburun III). *Teredinidae* are bivalves (sea shells, misleadingly referred to as shipworms) with a long, slim body drilling into wooden structures growing up to 45 cm in length and 1.5 cm in diameter. A minimum of 1.2% salinity of ocean water is necessary for breeding larvae, adults survive at a salt content between 0.7% and 1.0%. They are hermaphrodites, the male germ cell being developed before the female. Their lifespan is about 2-3 years; an adult will procreate several million of larvae per year. *Teredinidae* can be found in every ocean with a water temperature of 5°-27° C. About 70 different species are known today. Rapid trade route development following the discoveries of Christopher Columbus in 1492 led to a massive migration of species. There are three kinds of protection measures: use of resistant species of wood (e.g. basralocus or greenheart) for critical parts, chemical treatment and construction measures.

Uluburun III was built of *Pinus brutia*, using heartwood as well as sapwood parts that where neither chemically pre-treated nor coated. In October 2009, several survey dives showed heavy damages of the hull, ribs and super structure, less damages of the mast and wooden ship parts of larger diameter (probably because they were made essentially from heartwood).

Most likely there are many other shipwrecks buried under the sea floor. Waves, underwater currents and tidal activities – to name a few influencing variables – may expose the wreck to infestation by teredinids. Close underwater surveys and early rescue activities are imperative to protect our cultural heritage under water.

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Sources of figures

Fig. 1: Jens Gerken IFAÖ (Institut für Angewandte Ökologie).

Fig. 2: Rupert Brandmeier.

Figs. 3-4: Gerd Knepel.

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