NOBANIS - Invasive Alien Species Fact Sheet

Teredo navalis

Author of this species fact sheet : Viktoras Didžiulis, Coastal Research and Planning Institute, Klaipeda University, Lithuania, H. Manto - 84, LT-91210, Klaipėda, phone: +370 46 380905, Viktoras@ekoinf.net http://ekoinf.net

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Species description

Scientific names: *Teredo navalis* Linnaeus, 1758 (Mollusca, Bivalvia, Teredinidae)
Synonyms: *Calmitas navium L.*, *Teredo novangliae* Bartsch, 1922 (see DAISIE fact-sheet (Gollasch 2006) for more synonyms)
Common names: Naval Shipworm (GB), sášeň lodní (CZ), Schiffsbohrwurm (DE), pæleorm (DK), harilik laevaoherd (EE), laivagraužis (LT), Skeppsmask (SE), Pelemark (NO), Świdrak okrętowiec (PL).

Fig. 1. and 2. Pieces of wood (groyne piles) heavily damaged by shipworm can reach as far as the Lithuanian sandy beaches, travelling 500 km northwards from the northernmost fringe of the species' area of distribution. No specimen survived. Photos by V. Didžiulis. Chunks of wood were found by Dr. J. Maksimov (Fishery Research Laboratory).

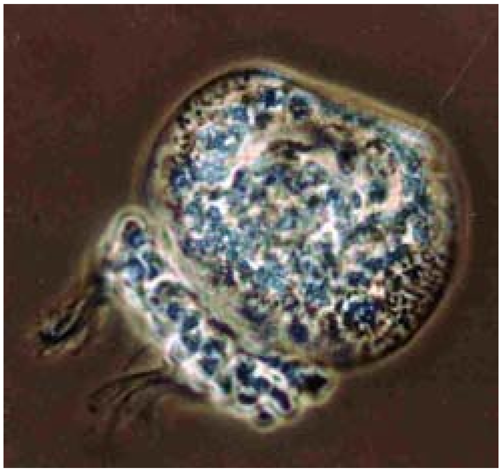

Fig. 3. (left) Shipworms veliger larva with characteristic ring of cilia.
Fig. 4. (right) Shipworm induced losses of groyne field piles built to protect sandy coasts from erosion cause substantial economic harm in Mecklenburg-Western Pomerania region of Germany. Photos by Dr. Jenz Gercken, Institute for Applied Ecology, Rostock.

Fig 5. Mature individual of *T. navalis* annually release as many as a million larvae to ensure successful spread. Photo by Dr. Jenz Gercken, Institute for Applied Ecology, Rostock.

Species identification
Since the appearance and habitat of this species is so special, it is not surprising that they were not even identified as molluscs until 1733 when they were first carefully studied by the Dutch zoologist Gotfren Snellius (Lambert 1971).

In the Baltic Sea, *Teredo navalis* usually grow as large as 20 – 25 cm. In tropical water, individuals may be as long as 60 cm (Kristensen 1979). The largest *Teredo navalis* in the Baltic reach 30 cm in length (Sordyl *et al.*1998).
The body of *Teredo navalis* is reddish and has a characteristic elongate worm-like shape with the anterior part covered by a small (up to 2 cm long) reduced helmet-like shell acting as a wood-boring instrument. The protective role of the shells is lost because the animal spends all its life surrounded by wood. Actually the shell consists of two parts (it is a bivalve mollusc!) with anterior and posterior lobes similar in size. Each shell is triangular in shape and is white with light brown periostracum (outermost layer). The valves of the shell are divided into regions with differing sculptures having breaks situated near the anterior end. The brownish soft worm-like body of the shipworm lies in a calcareous tube up to 60 cm long and 1 cm in diameter. The tube is divided by a dividing wall (septa) near the opening (Rowley 2005). Its only connection with the outer world is a tiny hole that the mollusc uses to protrude its two posterior siphons to keep the flow of water running through its mantle cavity (Lane 1959). The siphons can be rapidly withdrawn by the animal and closed off by a calcareous pair of white paddle shaped pallets 0.5 cm long. This makes *T. navalis* hardly detectable from outside of the wood and often the damage shows up only when the piling breaks.
The *Teredo* genus includes about 20 species inhabiting wooden material of logs, pilings, ships and nearly any other submerged wooden constructions from temperate to tropical zones of the world’s oceans (Turner 1966, ITIS 2007).

Native range
The species may be native to the Atlantic Ocean and is initially known as the Atlantic shipworm, but its actual origin remains uncertain (Främmande arter 2006, Gollasch 2006). *Teredo navalis* currently is a cosmopolitan species found both in Atlantic and Pacific oceans.

Alien distribution

History of introduction and geographical spread
The first confirmed occurrence in northern European waters is in pieces of wood from a Dutch dike that broke down in 1731 (Kramp, 1945). During the1930s and 1950s several periodical mass occurrences took place in the Baltic Sea near Germany, Denmark and Southernmost Sweden, lasting for a few years. Quite possibly there have always been minor populations of *Teredo navalis* in the south-western Baltic, waiting for a combination of environmental factors to trigger new mass occurrences. It is well known that *Teredo navalis* is able to reproduce in the southwestern part of the Baltic with the northernmost point at the Ruegen Island. Since 1993 an outbreak of shipworms has been observed along the shore of Mecklenburg-Western Pomerania (Bönsch and Gosselck 1994, Sordyl *et al.*1998). Some anecdotal cases mention its occurrence in some spots along the southwestern Polish coast of the Baltic. This is likely to occur when broken wooden chunks with living *Teredo* inside are brought by drifting currents. These pieces of wood can travel as far as 500 km north and reach Lithuanian seaside (authors' personal observation). However, no living shipworms were found inside the burrows on arrival at the Lithuanian coast.

Pathways of introduction

It remains to be determined just how the shipworm has managed to gain a foothold in the Baltic. It may have been brought in with water of higher salinity that penetrated the Danish Belts, in connection with storms, for example. It may also be that shipworms from other marine areas has been carried onboard vessels into the Baltic and then released with ballast water.

Alien status in region

After introduction of the shipworm to the Baltic Sea, it has spread northwards up to Ruegen Island. However, at present its appearance in the Baltic is limited to Germany, Denmark and the southernmost part of Sweden (see table 1). Further spread of *Teredo* is not possible because the species cannot tolerate low salinity levels in the greater part of the Baltic. In many of the invaded regions the species has become common, although its distribution is restricted to very specific substrate types – submerged wood only and therefore it does not appear in other habitat types (See table 1).

Country	Not found	Not established	Rare	Local	Common	Very common	Not known
Austria	X						
Czech republic	X						
Denmark					X		
Estonia	X						
European part of Russia	X						
Finland	X						
Faroe Islands					X		
Germany					X		
Greenland		X					
Iceland					X		
Ireland							X
Latvia	X						
Lithuania	X						
Norway					X		
Poland		X					
Sweden				X			

Table 1. The frequency and establishment of *Teredo navalis*, please refer also to the information provided for this species at www.nobanis.org/search.asp. Legend for this table: **Not found** –The species is not found in the country; **Not established** - The species has not formed self-reproducing populations (but is found as a casual or incidental species); **Rare** - Few sites where it is found in the country; **Local** - Locally abundant, many individuals in some areas of the country; **Common** - Many sites in the country; **Very common** - Many sites and many individuals; **Not known** – No information was available; **Native** – when a species is native in a country this is indicated in the table under the relevant frequency category.

Ecology

Habitat description
Teredo is a unique genus of marine mollusc species, able to feed solely on wood (Gallager *et al*. 1981). Symbiotic cellulolytic nitrogen-fixing bacteria are harboured within specialised epithelial cells (bacteriocytes) located within the gills (Distel *et al*. 1991) previously called the gland of Deshayes. However, more thorough examination of the gland proved that its structure is not a glandular tissue, but represents associations of symbiotic bacteria (Popham and Dikson 1973, Distel *et al.* 2002). Enzymes produced by this symbiont facilitate digestion of wood and provide an internal source of combined nitrogen. Shipworms play an important ecological role as the principle agents of mineralization of cellulosic plant materials in shallow (<150 m) marine and brackish environments.

Reproduction and life cycle
Reproduction occurs during warm summer months when salinity is not less than 12‰. In just eight weeks the larvae mature for reproduction. Several generations can be produced per year. The sexes are separate in the adults but cannot be distinguished externally. Young animals are potentially hermaphroditic and pass through alternating sexual phases during their development (Coe 1941, Grave 1942). The species is viviparous, able to release larvae at an advanced veliger stage. The early larvae are top-shaped and measure 59 by 60 microns. In older larva the cilia, which previously covered the entire body surface, are limited to the region of the velum. The appearance of the shell gland may slightly precede velum formation. The newly-formed shell is single, but it soon becomes bivalved. The velum in older veligers is well developed and the pre-trochal hemisphere is tipped with an apical tuft of cilia. During the free-swimming period, the larva develops siphons, gills and a well marked foot with byssus threads (Costello and Henley 1971). The free-swimming period of the larvae does not exceed fifteen days (Culliney 1975). After attachment to a wooden substrate, the young *Teredo* undergoes a remarkably rapid metamorphosis, during the course of which the velum is cast off and eaten. The young animal reaches sexual maturity in six weeks (Lane 1959). Life duration ranges from one to three years (Sordyl *et al.* 1998). Minimum reproductive temperature is 11-12-15 ^{O}C; duration of lifecycle – 1-3 years (NIMPIS 2002).

Dispersal and spread
The species occupies new habitats and spreads during a few days of free-living larval stage. Larvae are very sensitive to the presence of wood and exploit every chance to attach and penetrate into wooden constructions. One more well known way of spreading is drifting within floating wooden wrecks or hulls of vessels. In the Baltic, free drifting piles carved by shipworms can be found floating hundreds of kilometres away from the original wooden constructions. In both cases, the limiting factor for spread is salinity which has to be above 8 $^{o}/_{oo}$ for successful reproduction. Freshwater is deadly to these invertebrates (Lane 1959, Sordyl *et al.*1998).

Impact

Affected habitats and indigenous organisms
Shipworms destroy submerged wood. Some other species of crustaceans (*Idotea*) are known to reuse caves carved in the wood by *Teredo*.

Genetic effects
Not known.

Human health effects
No human health effects known.

Economic and societal effects (positive/negative)
The xylophagous bivalve *Teredo navalis* has a long record of being very destructive to any wooden constructions, should it be wooden ships or harbour buildings, everything is consumed quite rapidly. Pine tree poles are "eaten" as fast as within 16 weeks. It takes 32 weeks to destroy oak timber (ProSEA 2005), and about one year for the shipworms to completely warp a wooden trunk 30 cm in diameter in the Baltic (Gercken *et al.*1994, 1995, 1996). Its impact has been documented from numerous sites worldwide and the coasts of both the North and Baltic Seas since the 18th century and even earlier. It also destroys archaeologically valuable ancient wooden shipwrecks (Jöns 2003, Förster 2003).
Being notorious borers, shipworms have been known and dreaded since ancient times when they forced protective coatings to be applied on Egyptian navy and merchant ships, and destroyed the planking of Greek and Roman ships. Even their early name given by Linneaus, *Calmitas navium*, suggests their impact on maritime history. Shipworm appetites helped Britain sink the Spanish Armada in 1588, as their ships have been exposed to shipworms while waiting in Portuguese and French harbours. Anxiety of Columbus's sailors might well have been due to shipworm damage rather than to a fear of the unknown (Hubschman 1979).

In the Netherlands until 1730, dikes of earth and wood served as the country's sea defence. In 1730 an outbreak of what they called "pileworm" infested the wood pilings of their dike system. By 1731 the shipworm had destroyed 50 km of the Westfrisian dike system and had seriously weakened another 20 km (Hubschman 1979). In 1731, when *Teredo* had eaten away wooden dyke gates, they crumbled in a huge storm and flooded the Netherlands (Hopkins 2001). It is thought (Hubschman 1979) that damage of the Dutch dikes was a consequence of several seasons of low rainfall that usually diluted the sea water near the coast. Increased salinity provided more hospitable habitat for these destructive invaders.

During 1919 – 1921, after its appearance in San-Francisco Bay (Pacific) it resulted in more than US$ 900 million damage to wooden pears and wharfs (Thompson *et al.*2005). Currently damage in this area is estimated to be approximately US$200 million per year (Cohen and Carlton 1995) and economic damage in the Baltic has already reached €50 million since 1993 (Wichman 2005).

Its arrival in the Pacific at the beginning of the 20th century has caused major damage because it tolerated lower level of salinity than its Pacific "cousin". Many wooden constructions in estuaries and brackish water at that time were built in respect to known salinity tolerance of the native shipworm (Cohen 2004) and thus susceptible to damage by *Teredo navalis*.

Management approaches

Prevention methods
Historically no effective prevention methods are known. After the dike collapse in 1731, the Dutch tried tropical hardwood, arsenical solutions and covering the dikes with iron plates, but the only real

answer was a major change in the dike construction. Dikes were reconstructed at a great expense (and increased taxes) of imported stone (Hubschman 1979).

Usage of biocides like creosote and chromated copper arsenate (CCA) may temporarily prevent wood from deterioration, but is harmful to the surrounding environment and humans as well. Some types of wood are also more resistant to the *Teredo* but usually they are much more expensive. To get rid of the shipworms, wooden ships would stay in freshwater rivers, estuaries or lagoons for several months.

Historically valuable shipwrecks can be protected by wrapping them into so called geotextiles and thus providing a physical barrier to prevent access by the organisms, without totally preventing water movement. This method proved to be cheap, easily applied and has a low environmental impact. By contrast biocides have been known to cause skin irritation in divers. Reburial of shipwrecks can also save them from woodborers as those usually do not penetrate beyond the sediment surface (ProSEA 2005).

Eradication, control and monitoring efforts
Abundance and impact of *Teredo navalis* is being monitored at least in Germany. Eradication is not possible. The only efficient way to avoid economical losses caused by *Teredo* and eradicate from regions where it is present is rebuilding coastal protection and submerged constructions using non-wooden materials (stone, concrete, plastic) in submerged parts.

Information and awareness
This species presents a serious economic threat, therefore it is always in focus in the most scientific and popular publications relating to general topic of invasive species and their spread.

Knowledge and research
Although there are many studies and publications on the subject of *T. navalis*, so far no effective management or protection means that can be extensively used in marine environment have been invented. The only efficient measure known so far is to stop using wood in submerged constructions.

Recommendations or comments from experts and local communities
No recommendations.

References and other resources

Contact persons
Dr. Jens Gercken (DE) Institut für Angewandte Ökologie, Alte Dorfstrasse 11, 18184 Neu Broderstorf. Tel.: 038204 / 6180, E-mail: gercken@ifaoe.de, http://www.ifaoe.de/

Kathe R. Jensen (DK) Zoological museum,Universitetsparken 15, DK 2100 København Ø, Denmark. E-mail: KRJensen@snm.ku.dk

Vadims Jermakovs (LV) Latvian Institute of Aquatic Ecology, Daugavgrivas 8, LV-1048, Riga, E-mail: vadims@monit.lu.lv

Melanie Josefsson (SE), Swedish Environmental Protection Agnecy, SE 106 48 Stockholm, Sweden.
E-mail: Melanie.Josefsson@snv.slu.se

Links

PROSEA - Shipwreck Conservation in situ and shipwreck protection issues

The History and Effects of Exotic Species in San Francisco Bay. San Francisco Bay Project, USGS Water Resources Division

MOSS Newsletter, Monitoring, Safeguarding and Visualizing North-European Shipwreck Sites: Common European Cultural Heritage - Challenges for Cultural Resource Management

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