NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

Environmentally friendly use of timber in harbour infrastructure

Miljøvennlig bruk av tre i havneinfrastruktur

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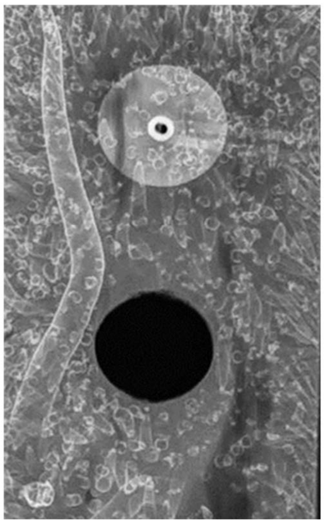

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SAMMENDRAG/SUMMARY:

Research activities in the field of wood protection in the marine environment in Europe have been limited and do not yet satisfy the need for new approaches to the problem of biodegradation of wood in seawater. Alternatives to creosote treatment were tested in the marine environment in Moss harbour. Most of the treated products showed high potential as a successful treatment in this use class in the short-term, such as acetylation of wood, treatment with sorbitol and citric acid and encapsulation of wood poles with a plastic envelope. Long-term studies need to determine the service life of these products.

LAND/COUNTRY:	Norway
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GODKJENT /APPROVED	PROSJEKTLEDER /PROJECT LEADER
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Preface

This report presents the results from the project "Environmentally friendly use of timber in harbour infrastructure", which has been financed by the Regionale Forskningsfond- Oslofjordfondet.

The aim was to investigate novel, environmentally friendly and biocide-free methods for the protection of wood-based material against wood borers in the marine environment.

We thank the partners for the collaboration and Oslofjordfondet for the financial support!

Ås, 04.03.20

Andreas Treu

Content

1 Introduction

1.1 Background

Moss Harbor is an environmentally certified and service-oriented port. The harbor is in the middle of the Oslofjord with a total of 670 meters of quay length and up to 11 meters depth. Moss harbor is one of the country's largest container ports. The ferry between Moss and Horten is the country's busiest connection at sea. The guest harbor is centrally located in the middle of the Moss canal. Moss port's strategic plan for the period 2011-2022 is based on a vision of being the preferred and most efficient hub of the Oslofjord. Moss harbor is environmentally certified and seeks environmentally friendly solutions in all development.

Innovation and regional relevance

Marine borers attack on wooden structures in the marine environment are often the cause of rehabilitation needs. Borer attacks can be difficult to detect with the naked eye. However, using a magnifying glass can uncover the shipworm (*Teredinidae*) larvae entrance holes in wood. Other wood-boring organisms such as gribbles (*Limnoriidae*) show a different attack pattern which is shaped by their tunnelling activities on the wood surface and is usually easier to detect with the naked eye compared with shipworm attack. In combination with wave action in the tidal zone, wooden piles attacked by gribbles will show an hour-glass shape.

Comprehensive studies of biogeography of both gribble (*Limnoriidae*) and shipworm (*Teredinidae*) have been conducted in European coastal areas. These studies demonstrated the diversity of established species and their past and present distribution (Borges *et al.* 2014a, 2014b). It is important to monitor the activity of such organisms in order to predict the lifetime of wood structures in the marine environment. However, to date only a few European coastal regions are included in the research on biogeography of wood borers.

Since the wood preservative CCA (Copper chromium arsenic) is generally banned in Norway, both for private and public use, only creosote treatment is permitted for public buildings in the marine environment. However, the use of creosote is only permitted due to the lack of alternatives. In relation to current standards, apart from creosote, there are no other wood preservatives in Europe, which are approved for use class 5 (marine) (EN 335 2013). A possible scenario for the future is a full replacement of timber in marine infrastructure with steel and concrete. New solutions, such as treatment of wood with furfuryl alcohol (Kebony) or acetic anhydride (Accoya), have been tested with positive results in seawater (Westin *et al.* 2016). However, none of the new wood modification methods have been approved or used commercially in use class 5 (marine use). In NIBIO's field trials in Drøbak and Nesset (Oslofjorden and Bunnefjorden) we have tested various treatments that have a potential for use in marine environments. NIBIO has achieved good results on its own invention, which is based on the treatment of wood with polyols. Such a wood modification is biocide-free, which means that there is no leaching of toxic substances into the seawater (Pilgård *et al.* 2010; de Vetter *et al.* 2009).

Research activities in the field of wood protection in the marine environment in Europe have been limited and do not yet satisfy the need for new approaches to the problem of biodegradation of wood in seawater. In addition to durability of modified wood products in seawater, it is equally important to evaluate strength properties, such as resistance to impact by e.g. boats and abrasion. Boat traffic, both larger boats and leisure boats affect the wood infrastructure. In addition, there is a need to understand more about how and why these organisms attack wood and focus more on the different species and behavior.

2 Project idea and goal of the project

2.1 Project idea

Timber has been extensively utilized in a variety of marine applications in the past. However, in Europe, the use of wood in marine environments has diminished during recent decades, mainly due to restrictions linked to the use of effective wood preservatives against attack by marine wood borers, such as shipworm and gribble. Although there is a strong need for developing new protection systems for timber in marine applications, the research in this field has been scarce for many years. New attempts to protect timber used in marine environments in Europe have mainly focused on wood modification, which are biocidal-free treatments, and the use of mechanical barriers to prevent colonization of marine wood borers. The evaluation of new wood protection systems in the marine environment are depending on active test sites, where different wood borers species are present. It was assumed prior to the start of the project, that Moss harbour was an ideal test site, since experience from other test sites further north in the Oslofjord showed heavy wood borer attack.

2.2 Goal

The main goal of the project was to improve the environmental profile of Moss harbour by increasing the amount of wood in marine constructions and to reduce costs for maintanence by using wood products with long service life. The specific goals were:

- to inspect and analyse already existing constructions
- to expose new wood treatments based on wood modification and encapsulated untreated wood in seawater in the harbour area and analyse the attack and degredation pattern
- to inform the public about the use of wood in the marine environment

3 Project organization

The project owner, Moss Harbour, collaborated with several industry partners and one research organisation within this project. A detailed description of the partners can be seen in Table 1

Table 1. Project consortium

Partner	Description	Contact person
Moss Havn KF	Moss harbour is an environmentally certified and service-oriented main harbor. The harbor is located in the middle of the Oslofjord with a total length of 670 meters and is up to 11 meters deep. The ferry connection between Moss and Horten is the country's busiest national road connection at sea. Skjærgårdstjenesten is a part of Moss municipality and have given Moss Harbour substantial support in this project.	Øystein Høsteland Sundby
Norwegian Institute of Bioeconomy Research (NIBIO)	NIBIO is a governmental research institute which contributes to sustainable resource management, innovation and value creation through research and knowledge production. NIBIO is owned by the Ministry of Agriculture and Food as an administrative agency with special authorization and its own supervisory board. The department of Wood Technology has strong expertise in wood protection in particular, and wood science in general.	Andreas Treu
WOPAS AS	WOPAS AS is an international start-up business based in ÅL in Hallingdal, Norway. The company is targeting the opportunities of combining the characteristics of wood, polyethylene and wood plastic composite into Wood Plastic Systems. The primary market segments are the energy utility, rail and marine markets. Their concept of using natural spruce and Scots pine wood and make it durable by encapsulating it in polyethylene has been tested in this project. The mother company of WOPAS AS is Hallingplast AS, a family company founded in 1969.	Vemund Gudbrandsgard
Kebony AS	Kebony AS is a Norwegian company which produces modified wood. Kebony products are not used commercially in the marine environment (use class 5). However, the products could be adapted to this use class by changing process parameters.	Stig Lande
Accsys Group (Accoya)	The Accsys group produces modified wood (Accoya) in the Netherlands. The product properties have the potential to be used in the marine environment.	Ferry Bongers
Larvik impregneringskompani AS	Larvik Impregneringskompani AS is treating wood (boards and poles) using different wood preservatives.	Lars Henriksen

4 Evaluation of existing creosote treated poles

4.1 Test sites and material

Three creosote-treated poles which were installed in Moss harbour in the 1940s were removed and analysed for attack by wood borers. The locations of the poles in Moss harbour are marked in Figure 1. One pole at Hesselbergbrygga was significantly longer than the other two poles.

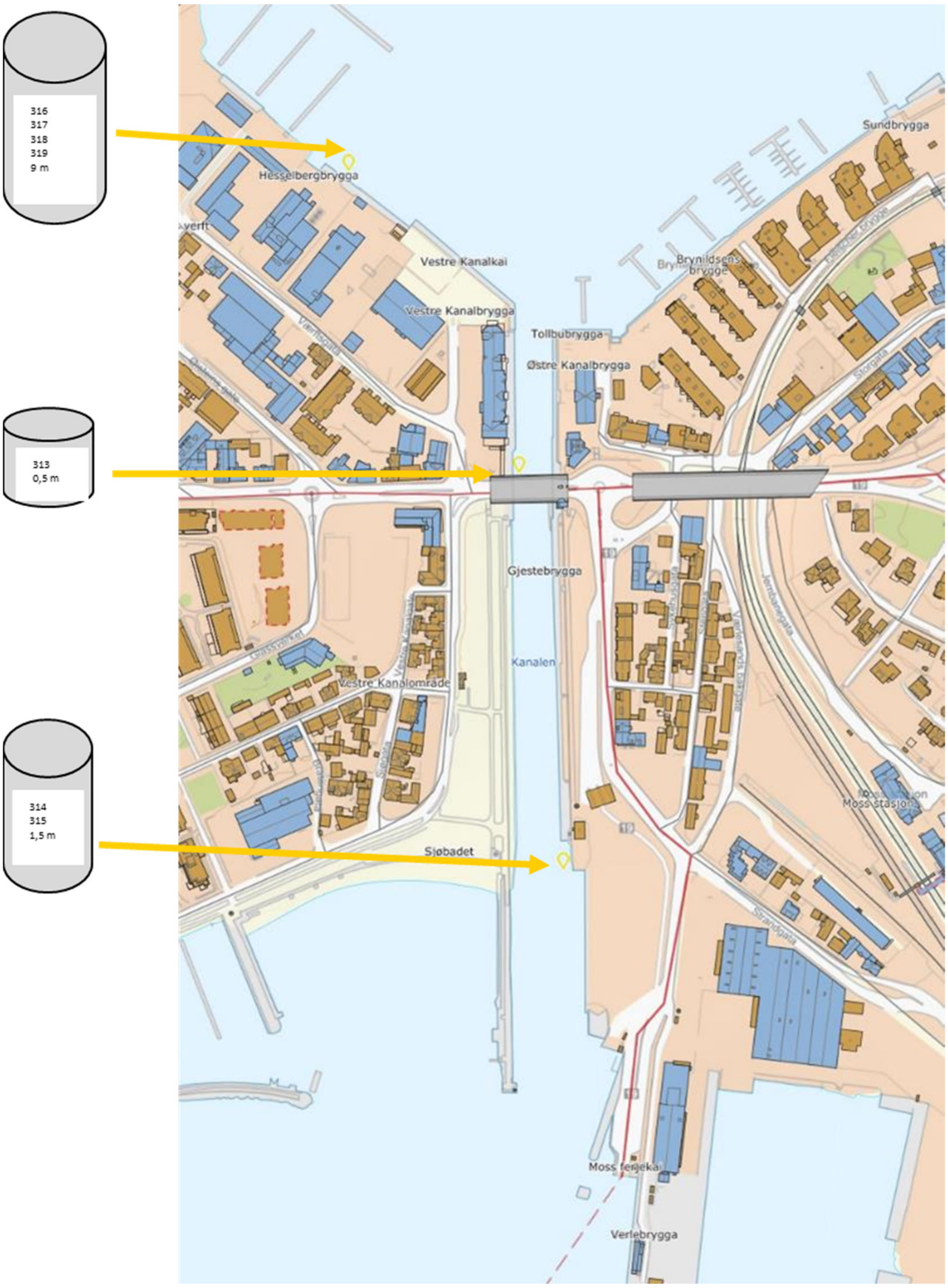


Figure 1. Overview of areas in Moss harbour where creosote-treated poles were removed and inspected

Figure 2. Suberficial degradation of creosote treated wood pole (left) and borer attack (right). The 9 m long pole was removed from Hesselbergbrygga/Moss

Only one pole could be removed in full length, due to practical difficulties, and an extensive analysis of the condition of the other two poles could not be performed. The pole which has been removed from Hesselbergbrygga (see Figure 1 and Figure 2) showed erosion on the surface and only slight growth of fouling organisms. Dividing the pole into four sections and cutting the sections in longitudinal direction revealed shipworm attack in all sections except for the upper section, which was partly, about 50 cm, above the water level or in the tidal zone. All boreholes appeared to be recently created because the calcareous layer of the tube walls was still present in most of the tunnels. However, no living organisms could be found in the wood. Interestingly, the boreholes are found mainly in the sapwood zone (see Figure 3), where usually most of the creosote is distributed. Although significant migration of creosote from the treated poles is not expected for short term exposure (Lebow 1987). 80 years of exposure could have changed the composition of the creosote-treated envelope. The amount and composition of creosote in the sapwood has not been analysed. An explanation, why shipworm were able to attack the sapwood zone can therefore not be given.

Figure 3. **Borer attack of creosote treated wood pole removed from Hesselbergbrygga and close-up of borehole in creosote treated sapwood of Scots pine (right); drawing of position of pole segments in the water (left)**

4.2 Conclusions drawn from the analysed material

- One of three creosote-treated poles showed attack by shipworm
- Tunnels appear to be from recent attacks of shipworms
- The damage pattern will give great loss in strength properties in the next years
- Amount of both migrated and residual creosote content in the pole has not been analysed. The analysis of creosote in the sapwood zone could contribute to an explanation why shipworm was found in the treated sapwood area.

5 Exposure of new wood products

The treatments exposed within the scope of this project (Table 2) were either already commercialised for other use classes, except marine environment, or they were new solutions, which are not commercially available, such as Ca oxalate and satric. The satric treatments were performed in the pilot plant at NIBIO, while the other treatments were provided by the industry. Creosote-treated poles were used as a reference for a treatment since it is known to prolong the service life of wood in marine environment. Untreated wood samples are used as control samples.

Table 2. Overview over treatments tested in Moss harbour

Short name	Treatment	Wood species	Exposure type
Satric	Modification with citric acid and sorbitol, different concentrations	Spruce and Scots pine sapwood	Standard test method (EN 275), Wood poles, Floating platforms
Acetylation	Modification with acetic anhydride	Radiata pine	Standard test method (EN 275), Floating platforms
Furfurylation	Modification with furfuryl alcohol	Radiata pine	Standard test method (EN 275)
WOPAS	WOPAS, envelope treatment of wood poles	Scots pine	Wood poles
CA oxalat	Precipitation of CaOx in the wood and the reaction by-product potassium chloride (KCl). The treatment is initiated by the reactants potassium oxalate monohydrate (KOx) and calcium chloride hexahydrate (CaCl2)	Scots pine sapwood	Standard test method (EN 275)
Thermal modification	Thermal modification of ash wood	Ash	Standard test method (EN 275)
Creosote	Creosote-treatment	Scots pine	Wood poles

Treated and untreated wood samples were exposed in different dimensions and at different test sites in Moss harbour, see Figure 4. All treated and untreated wood samples were exposed in May and removed for inspection in September 2019.

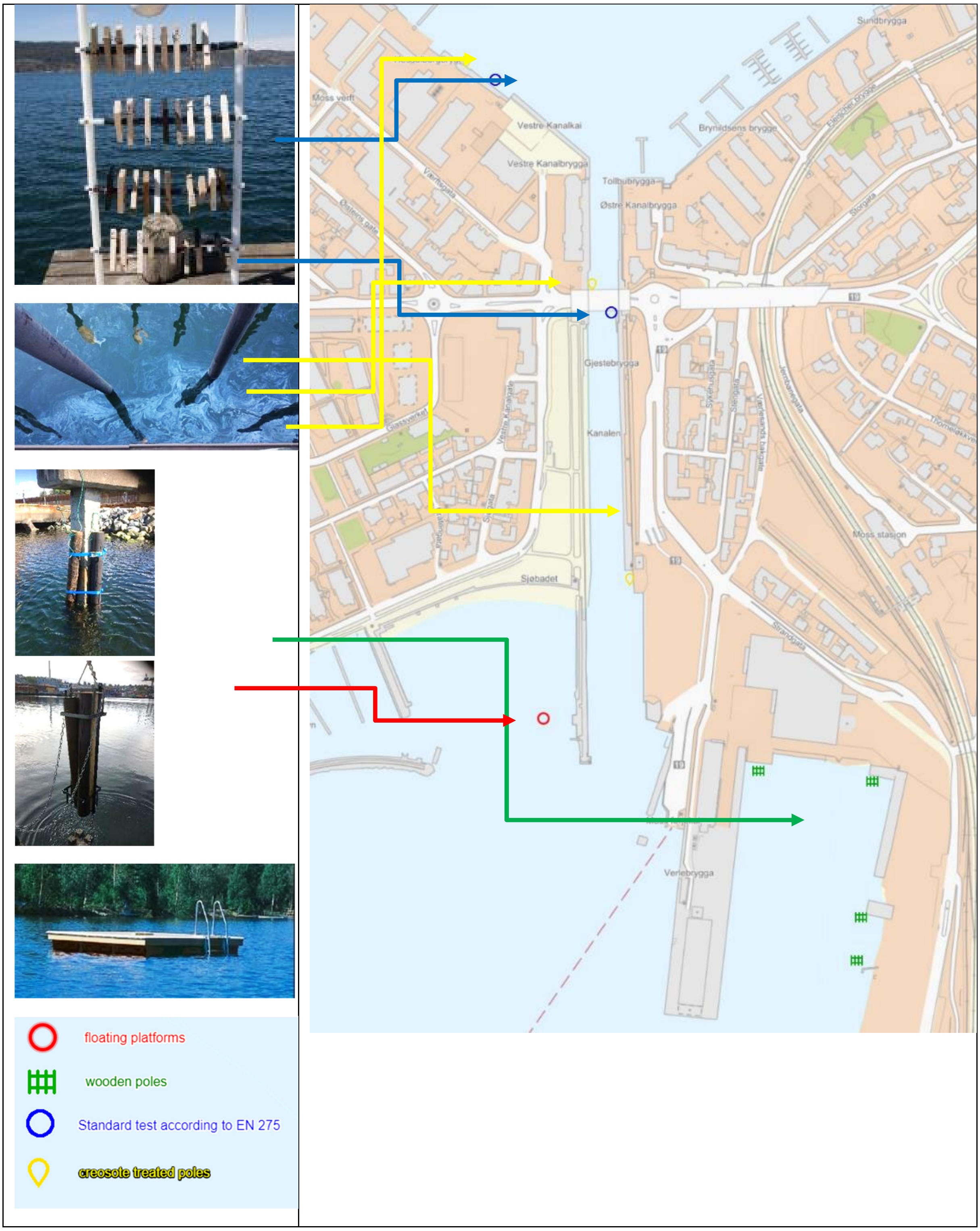


Figure 4. Overview of exposure sites of different wood structures in Moss harbour (test racks according to EN 275, creosote impregnated poles from 1940, treated poles, floating wooden platforms)

5.1 Wood borer activity in Moss harbour

The wood borer, in this case shipworm, activity was high during the exposure in Moss harbour from May to September 2019 and was even slightly higher compared with the activity at the Drøbak test site, where the same test setup was used. Both test sites are located in the Oslofjord. Their location is described in Figure 5.

The data from the Drøbak test site are used to compare and illustrate the activity of wood borers in Moss harbour. Untreated wood samples showed generally heavy attack and untreated radiata pine wood samples even failed during the exposure (see Figure 5). Experience from the Drøbak test site in 2018 revealed a slightly lower attack rate in 2019. A description of the different rating classifications can be seen in Figure 10.

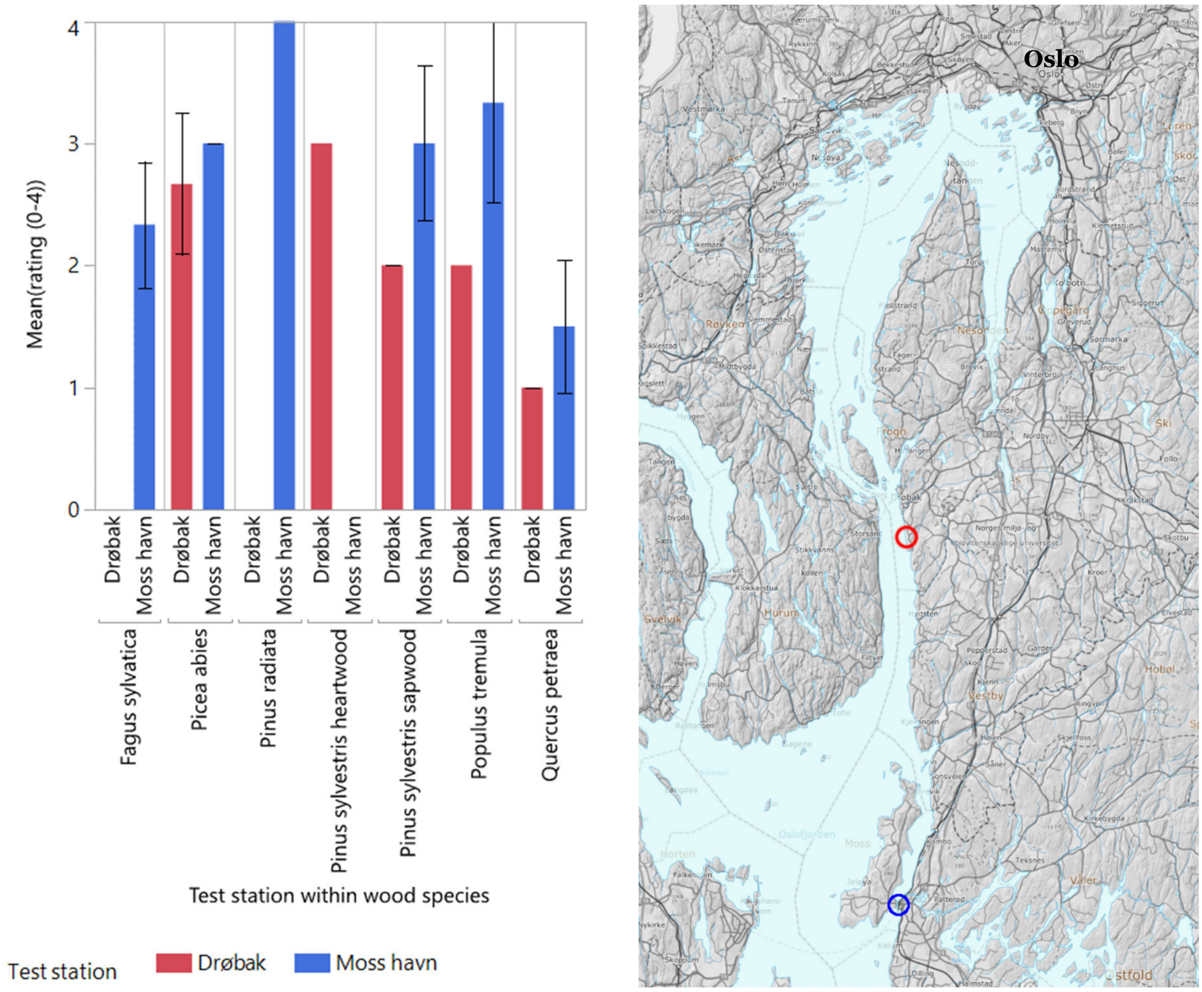


Figure 5. Attack rating after 4 months of wood borer attack (Shipworm) in untreated wood species in Moss harbour and Drøbak (left) and overview of the test site area (right); the exposed untreated wood material was beech (Fagus sylvatica), spruce (Picea abies), radiata pine (Pinus radiata), Scots pine heartwood and sapwood (Pinus sylvestris), aspen (Populus tremula), and sessile oak (Quercus petraea)

5.2 Wood borer species

The borer species have been identified mainly based on their burrows and size. An identification based on anatomical features has not been performed. Other studies have shown the abundance and distribution of marine borers in Europe (Borges *et al.* 2014a, b; Treu *et al.* 2019). The shipworm species *Teredo navalis* is by far the most abundant one in its appearance in Europe. Even though its size is smaller for a fully grown individual compared to many other shipworm species, the tolerance to low salinity and the large temperature area make *T. navalis* a threat to wood constructions in the marine environment. Other shipworm species in the Nordic countries are *Nototeredo norvagica* and *Psiloteredo megotara* and especially *N. norvagica* grows to much largers sizes compared with *T. navalis*.

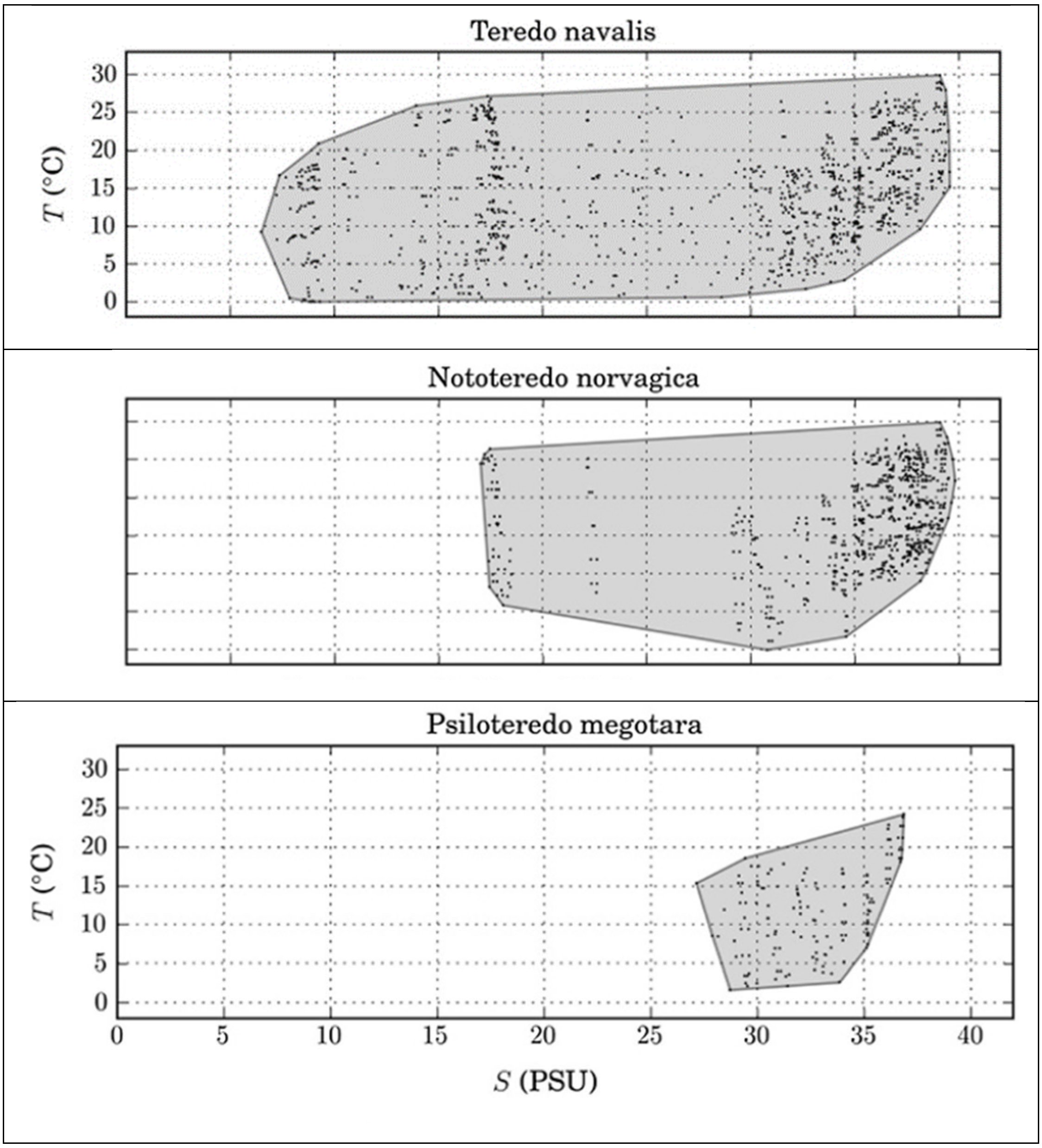


Figure 6. Distribution of teredinid species in salinity-temperature space (Borges et al. 2014b); PSU = Practical salinity unit

The identification of shipworms needs primarily to include the pallets, which are located near the base of the siphons at the end of the organism and can be extended from the small opening at the wood surface. Since pallet shape is important for identification, the species should include live animals or specimens preserved with soft parts intact. Pallets of *T. navalis* are forked at the tips, whereas the other two species occurring in Nordic waters have simple, paddle-shaped pallets.

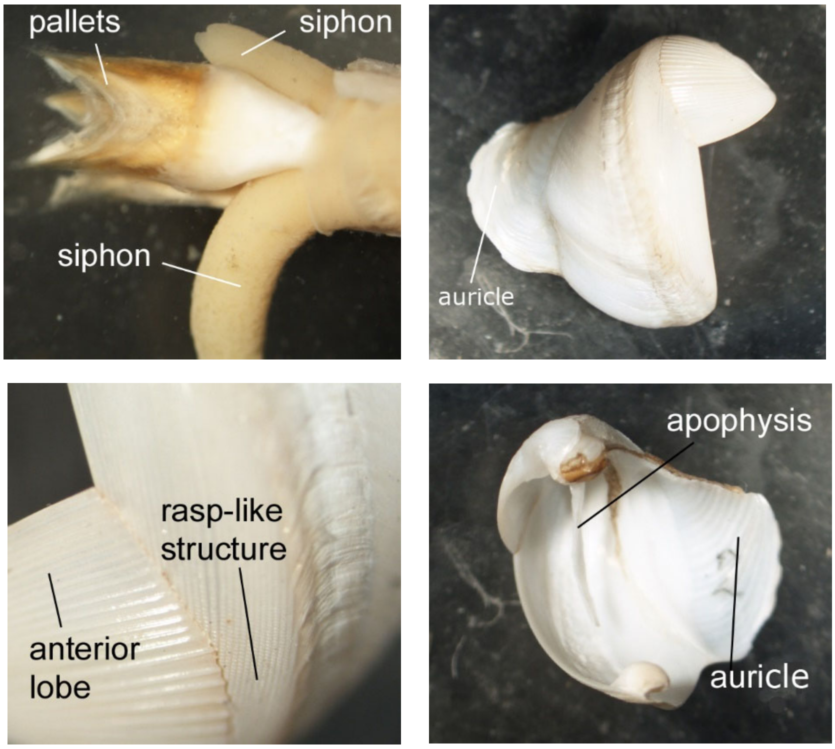


Figure 7. Identification features of pallets and shell valves on T. navalis; forked pallets and siphons (upper photo, left); interior shell with auricle (upper photo, right); exterior shell with rasp-like structure (lower photo, left); interior shell with apophysis (lower photo, right); Photo Kathe Rose Jensen (source: European Network on Invasive Alien species).

The shell valves of shipworms, which can also be used for species identification, are located at the bottom of the bore hole. Shell valves are relatively small and divided into 3 distinct sections (discs) plus anterior and posterior lobes with different ornamentation. In *T. navalis* the auricle (=posterior lobe) is about the same size as the anterior lobe and does not extend above the hinge line (see Figure 7). In one of the other Nordic species, *Psiloteredo megotara* (Hayward and Ryland 2017) the auricle projects above the hinge line. On the inside of the shell is a long apophysis used for muscle attachment. In *T. navalis* the apophysis is long and thin. In *Nototeredo norvagica*, the third species in Nordic waters, it is broad and only extends about half the height of the shell (Table 3).

Table 3. **Features for identification of Nordic species of shipworm (Teredinidae), (Hayward and Ryland 2017)**

Character	*Teredo navalis*	*Psiloteredo megotara*	*Nototeredo norvagica*
Length (max)	59 cm	37 cm	60 cm
Diameter	9 mm	10-11 mm	17 mm
Shell auricle	same size as anterior lobe	Large, recurved; extending above hinge line	Much smaller than anterior lobe
Apophysis	Long, thin		Broad, half as long as shell height
Pallets	Bifurcate tips	Paddle-shaped; interior layer exposed at tip	Paddle-shaped

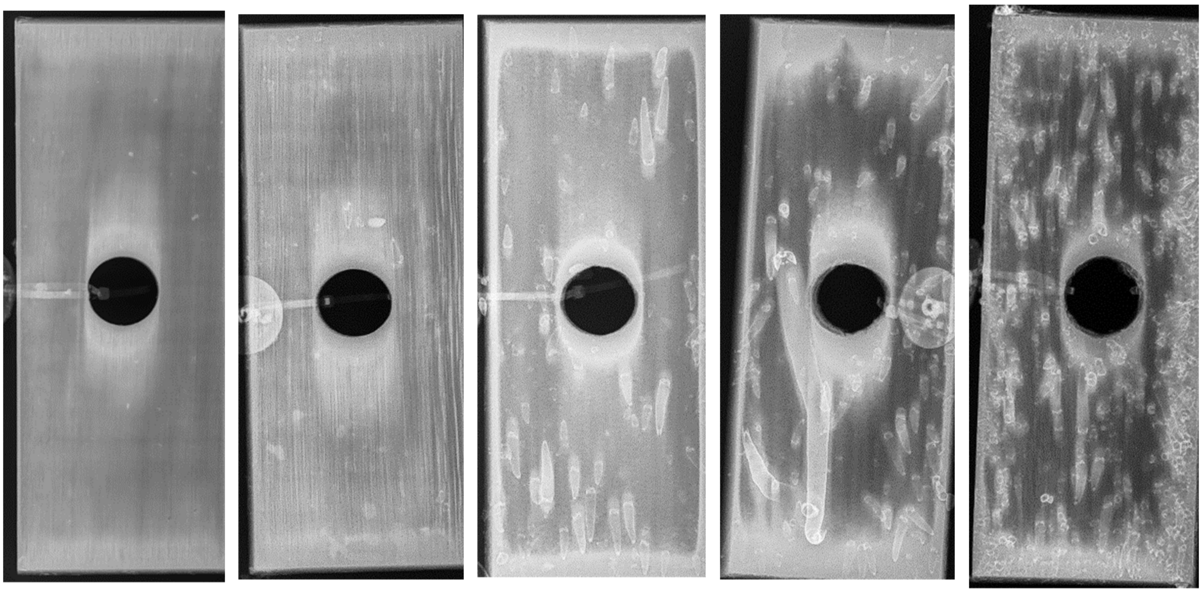
Figure 8. Shell valves from shipworm found in the heartwood zone of creosote treated Scots pine poles exposed in Moss harbour, the extending shell auricles could point to the species Psiloteredo megotara

Other wood borer species such as gribble (*Limnoria* ssp.) have not been found in Moss harbour. However, gribble attack was observed in the Drøbak test site 30 kilometres north of Moss (see Figure 9).

Figure 9. Gribble attack on spruce wood samples at the test site in Drøbak; tunnels are even visible in the x-ray image (right)

5.3 Standard test method EN 275

The standard EN 275 (1992) was used for the test setup and the rating system used for the evaluation of x-ray images from each wood sample. The attack rating according to the standard is described in Figure 10 and has been used to describe the damage done by marine borers on exposed treated and untreated wood samples.



Rating 0 Rating 1 Rating 2 Rating 3 Rating 4

Figure 10. Attack rating, according to EN275, of wood borer attack in wood samples; all images were taken from wood samples after 4 months in Moss harbour; the attack was caused by the shipworm Teredo navalis and assumingly Psiloteredo megotara (x-ray images)

Most of the treated wood samples showed no attack by wood borers after the exposure period. Two of the treatments, thermal modification and calcium oxalate treatment of wood, showed considerable shipworm attack. Untreated control sample made from different wood species showed attack ratings from 1-4. Sipo (*Entandrophragma utile*) showed no attack. However, results from other test sites after two years, e.g. the test site near Drøbak, showed a delay in attack for Sipo wood, but no long-term resistance.

Longer exposure is needed to evaluate the long-term effect of these treatments. Other test sites, e.g. Kristineberg, Sweden, have longer exposure series and have results that show sound samples of modified wood after 16 years (Westin *et al*. 2016).

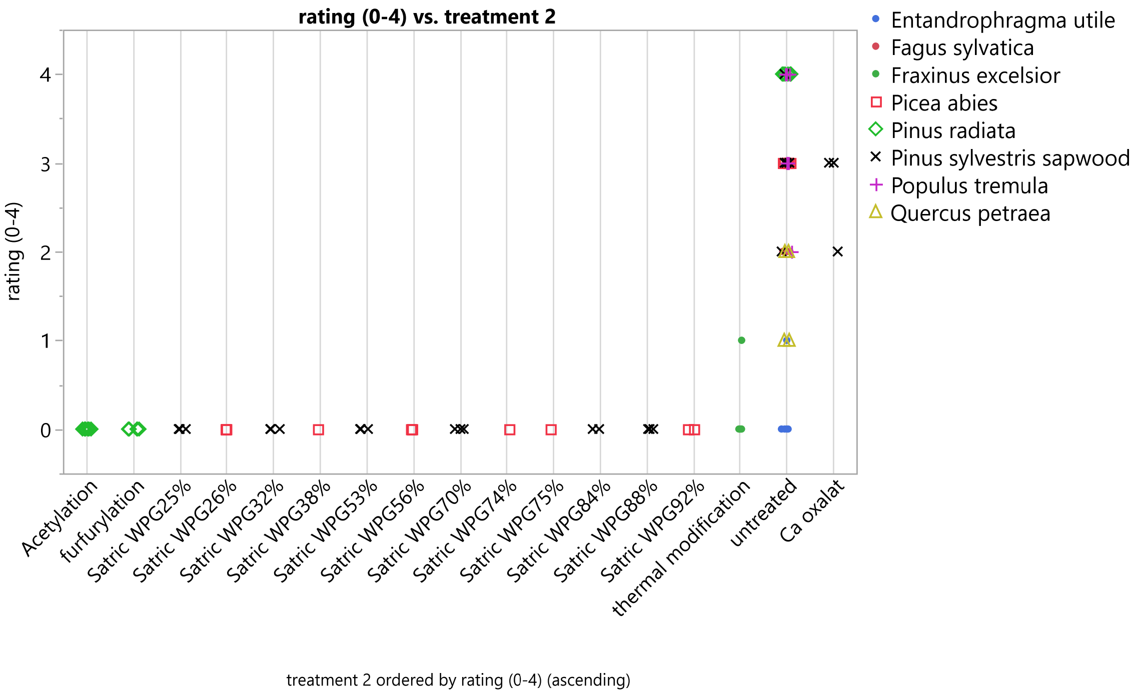


Figure 11. Attack rating, according to EN275, of different treated and untreated wood samples[1] after 4 months in Moss harbour

[1] *Entandrophragma utile* = Sipo, *Fagus sylvatica* = beech, *Fraxinus excelsior* = ash, *Picea abies* = Norway spruce, *Pinus radiata* = radiata pine, *Pinus sylvestris* = Scots pine, *Populus tremula* = aspen, *Quercus petraea* = sessile oak

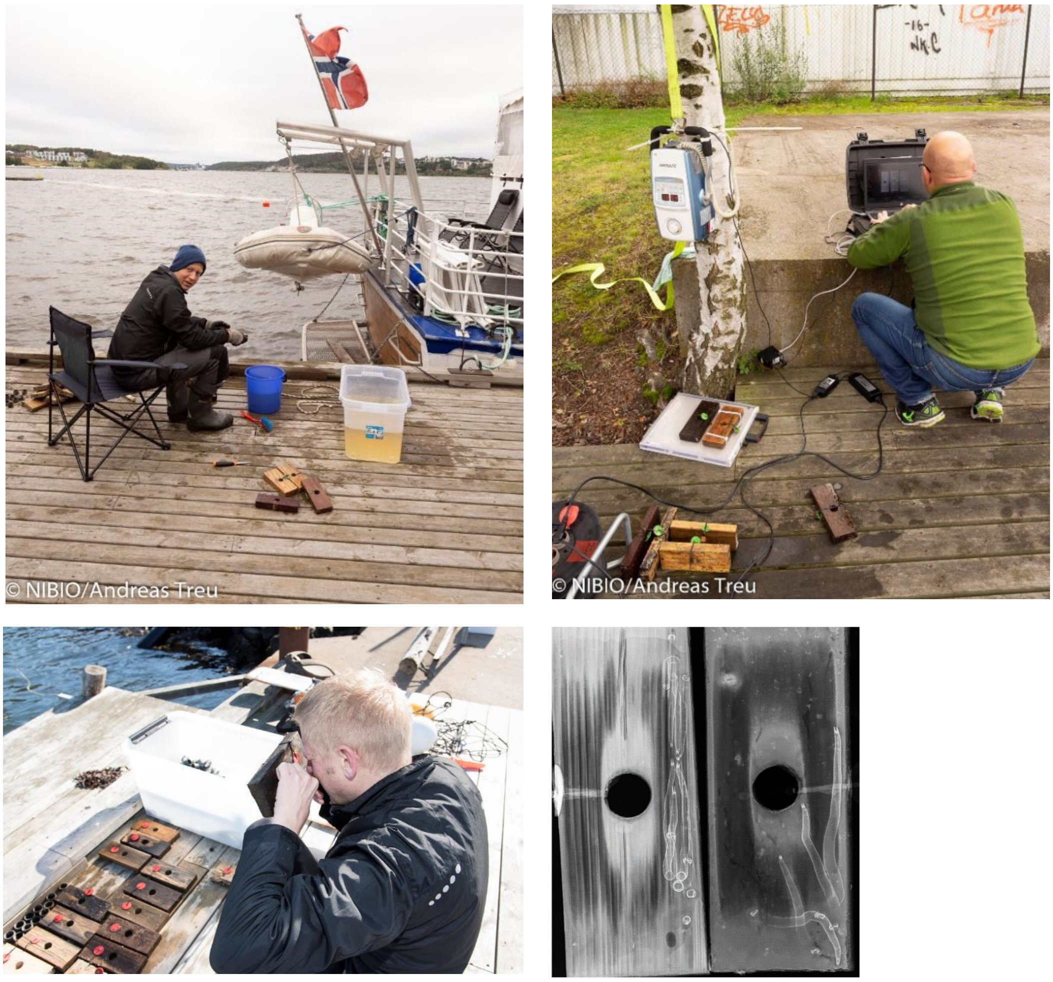


Figure 12. Work flow in wood samples evaluation: Cleaning of wood surface (upper left) , taking x-ray images (upper right), visual inspection (lower left) and resulting x-ray image (lower right)

5.4 Exposure of wood poles

A set consisting of wood poles from different treatments and with the length of 2 m and the diameter of 20-25 cm were exposed at four different test sites in Moss harbour, see Figure 4. The treatments of Scots pine were creosote, satric and WOPAS. Untreated Scots pine was used as reference as described in Table 2. The samples were tied to existing poles at two sites or exposed in retainers at two other test sites, see Figure 13. The samples were retrieved from the water and divided into four segments with 50 cm in length for further evaluation. The segmenst were cut in radial direction for the evaluation of borer attack, see Figure 14.

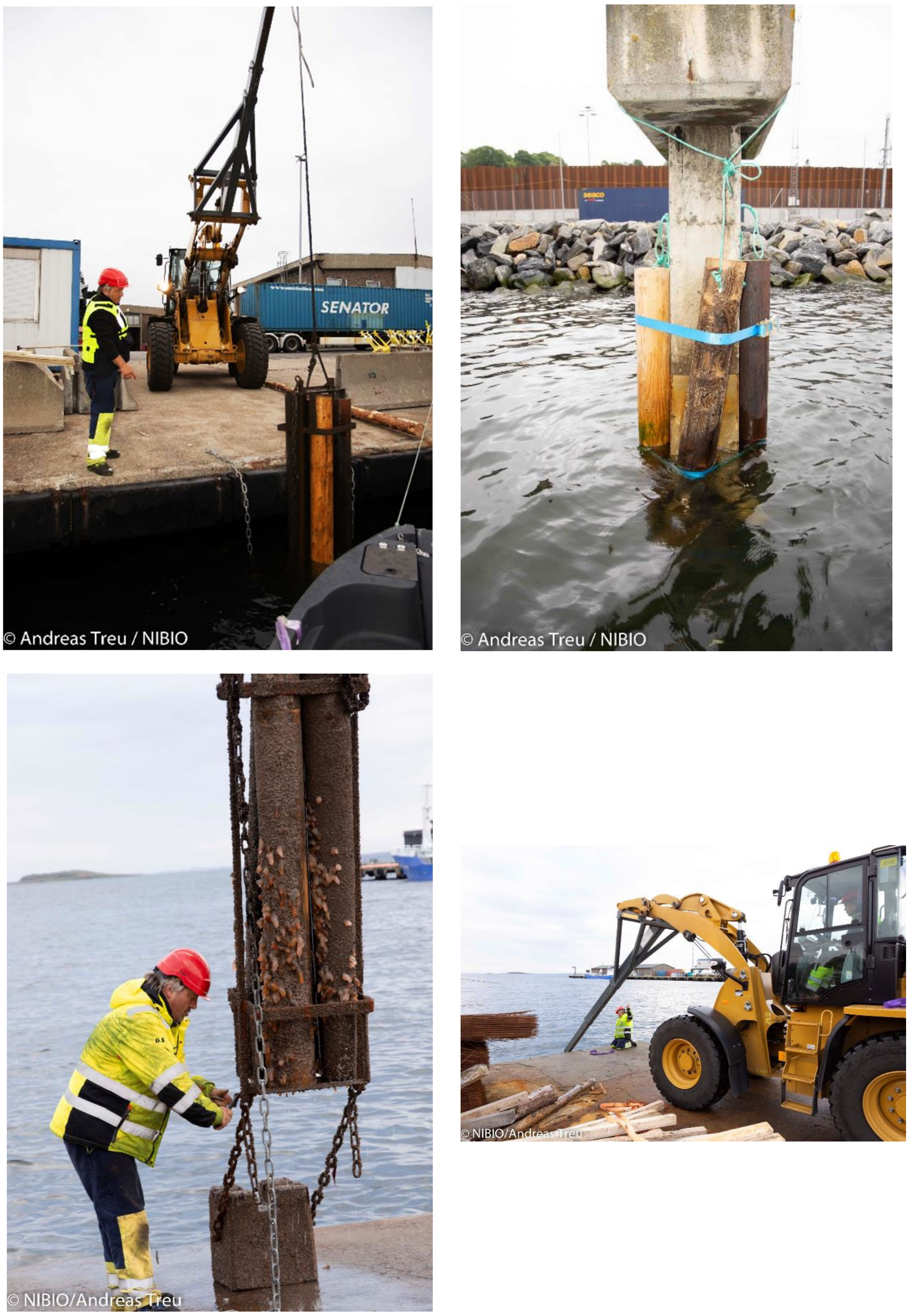


Figure 13. **Exposure of wood poles in Moss harbour at four test sites; Three treatments (creosote, satric, WOPAS) and one untreated pole were exposed per site. The samples were tied to existing poles (upper right) or exposed using retainers (left, upper and lower)**

The untreated poles showed heavy attack in the sapwood zone after four months of exposure, Figure 14. The treated poles perfomed well and showed no attack except for samples treated with creosote, where shipworm has entered the untreated heartwood zone from the lower unprotected transverse side of the pole (Figure 14).

Figure 14. Radial section of treated wood poles; satric (left), creosote (middle) and untreated (right)

5.5 Evaluation of wooden steps from floating platforms

Satric-treated and acetylated wood samples with the dimensions of 27 x 115 x 500 mm^3 were used for the steps of floating bathing platforms. Six different test sites were used, with one acetylated and two satric-treated wood samples per platform. Skjærgårdstjenesten transported the platforms after maintenance work to the different locations before and after the summer season. The six test sites were: Fiskerhytta Jeløya, Heyerdalsbukta Jeløya, Husebystranda Råde, Refsnes Jeløya, Sjøbadet Moss and Storesand Råde, see Figure 15.

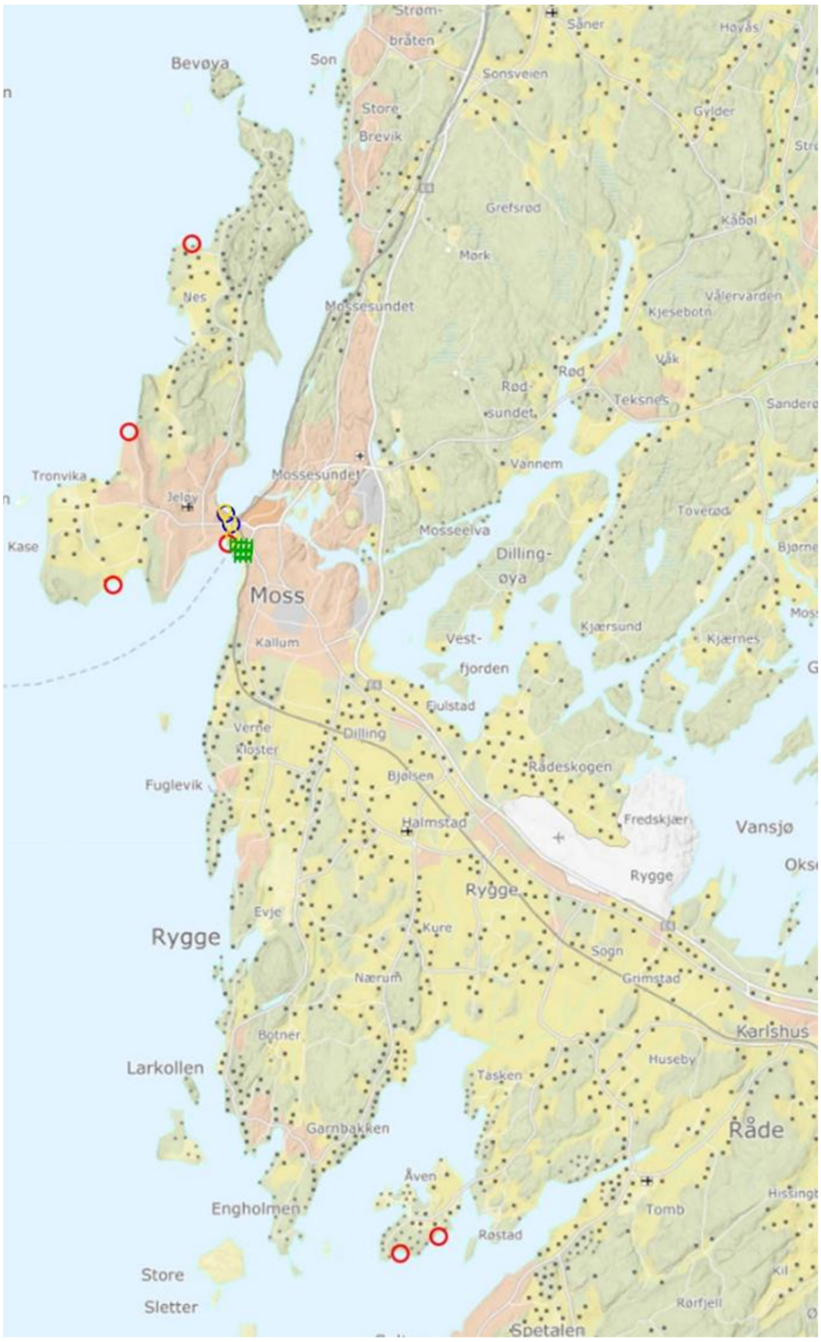


Figure 15. Overview of areas with floating wooden platforms in the Oslofjord (red circle)

Figure 16. Wooden steps after 4 month in the Oslofjord

The wood samples were removed from the platforms after 4 months of exposure and cleaned by removing the fouling organisms from the wood surface.

After splitting the samples in tangential longitudinal direction, the attack by wood borers was evalauated. A rating system according to EN 275 was used. Acetylated samples showed no attack after four months of exposure, while most of the satric-treated samples showed shipworm attack in the untreated heartwood zone, see Figure 17.

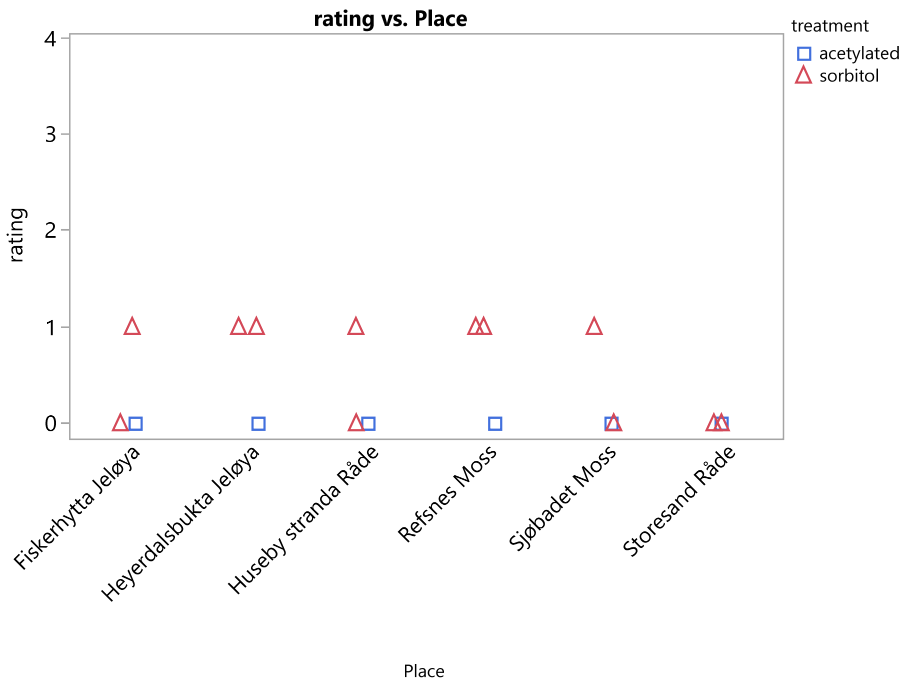


Figure 17. Attack rating of treated steps at floating platforms

Figure 18. Steps from floating platforms, acetylated (left) and sorbitol treated (middle and right)

5.6 Wear of the wood material

In addition to the wood samples exposed submerged in sea water, different treated wood samples were mounted as cladding at the pier of the canal in Moss harbour. The samples extended into the sea water level. Mostly physical damage done by boats, but also biological damage wil be evaluated. Results will be available next year.

Figure 19. Protective cladding at the pier of the canal in Moss harbour.

5.7 Protection of wood poles by plastic envelope

5.7.1 Performance in the marine environment

Wood poles encapsulated with plastic (polyethylene, PE 100 RC+) showed no damage after 4 months of exposure to the marine environment. No damage could be observed on the plastic coating.

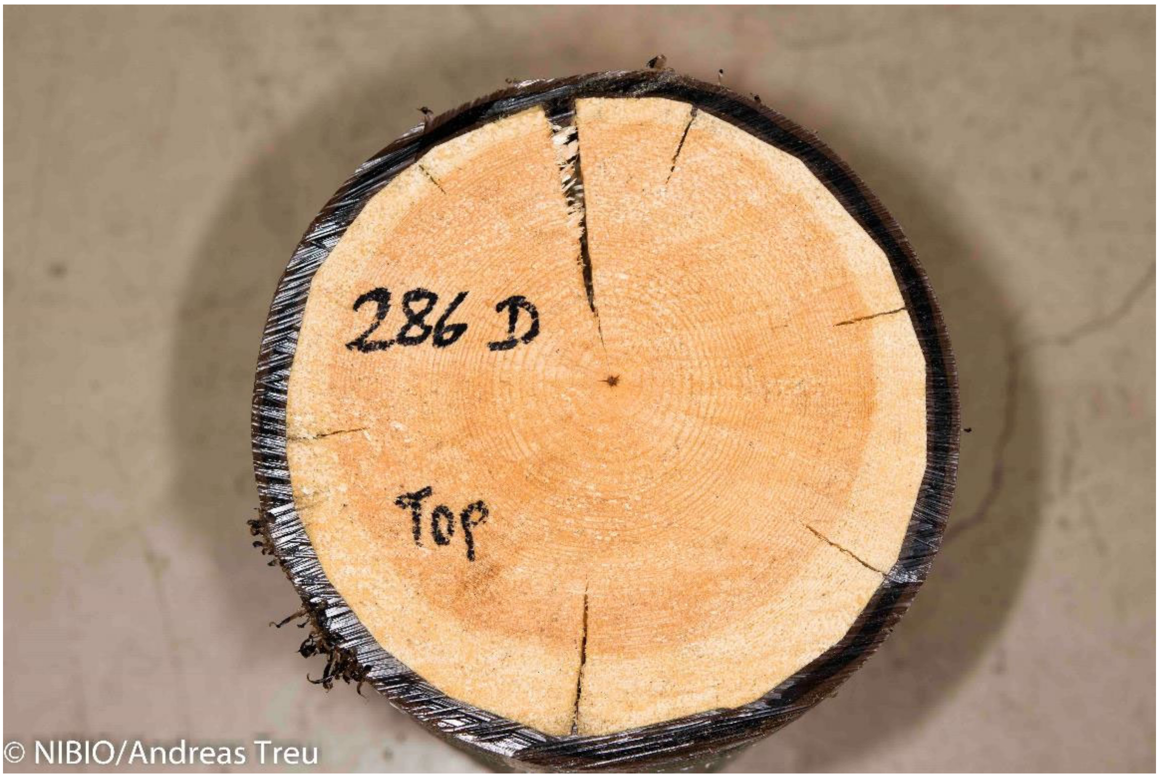


Figure 20. Transverse section of WOPAS pole made from encapsulated Scots pine

5.7.2 The influence of fasteners on water permeability

Water permeability tests have been performed, where test pieces were immersed in fresh water to examine the influence of various systems of bolts/screws/washers/sealings installed in WOPAS-treated wood poles on water uptake. In addition, test pieces of poles, where the plastic layer was damaged, and also a variant of end sealing by a top cap, were included in the test. The test was used to describe water penetration in a worst case scenario. However, the use of bolts below the water surface is not intended in practical applications.

Table 4: Test setup and results of water permeability tests

Type of installation			result
Shrinking plastic end cap			No water uptake
Galvanized nails **(2.5 mm x 65 mm, 8 nails per sample, no drilling or sealing)**			Low water uptake
Stainless steel screws (4.9 mm x 35 mm) with gasket (roof plate screws). No pre-drilling or other sealing			Low water uptake
Bolt (20 mm) with curved washer. Pre-drilled with 20 mm spiral drill. Threaded mastic between disc and plastic sheath.			No water uptake
French bolt (10 mm), fitted with round washer. Pre-drilled with 7 mm drill. Threaded mastic between disc and plastic sheath.			No water uptake

Bolt (20 mm) with curved washer. Pre-drilled with 20 mm spiral drill. No sealant			High water uptake
Bolt (20 mm) with curved washer. Pre-drilled with 20 mm spiral drill. Fitted EPDM gasket, 5 mm thickness, strength 30 Sh. Gasket of the same size as washer. An 11 mm hole was punched in the center of bolt gasket.			High water uptake of some samples
Removed plastic in an area of approx. 15 mm x 15 mm.			Medium water uptake

No water uptake was detected for test pieces including Mastic as sealant, test pieces with top cap and reference test pieces,. Other test pieces showed large variation in water uptake between the installation methods. Roof plate screws (without pre-drilling) and nails showed rather low water uptake, while test pieces with bolts and without sealings showed very high water uptake.

Samples with damaged plastic layer but undamaged wood showed only slight water uptake.

For the test pieces with EPDM-sealing, the water uptake was high in one of the test pieces. However, observations and measurments performed on the other test pieces in the same series indicated that the water uptake would have increased when prolonging the test period.

It is unlikely that bolts without sealant would lead to wood borer attack, when exposed to the marine environment, since the size of shipworm larvae would not enable them to enter the wood. However, removed or damaged plastic without bolts could easily create an entrance area for wood borers.

6 Dissemination

Project information on Moss harbour's and NIBIO's homepage:

- Mer miljøvennlige brygger og badeplasser, News article, NIBIO homepage (https://www.nibio.no/nyheter/mer-miljovennlige-brygger-og-badeplasser?locationfilter=true)
- Bruk av tre i maritimt miljø, News article, Moss harbour homepage (https://www.moss-havn.no/nb-NO/nyheter/bruk-av-tre-i-maritimt-miljo)

The following scientific publications are partly financed by this project:

- Treu A, Zimmer K, Brischke C, Larnoy E, Gobakken LR, Aloui F, *et al*. 2019. Durability and protection of timber structures in marine environments in Europe: an overview. *BioResources* 14(4), 10161-10184
- Treu A, Larnøy E, Beck G. 2019. Macrobiological degradation of wood modified with sorbitol and citric acid. 15th Annual Meeting of the Northern European Network for Wood Science and Engineering - WSE; 2019-10-09 - 2019-10-10.

6.1 Miljøfestival in Moss

A successful one day event was held at the environmental festival (Miljøfestival) in Moss 31st of August 2019, where one of the Sustainable Development Goals (SDGs): sustainable cities and communities was the main focus. Moss harbour informed about this project and the use of wood together with NIBIO. Other organisations informed about renewable energies, pollution, sustainable food, insects in the city, etc.

Figure 21. Miljøfestival in Moss, 31st of August 2019

7 Conclusion

- The test sites in Moss harbour showed severe attack ratings due to shipworm attack for untreated wood samples. Assumingly two shipworm species were found. Other wood borers such as gribble, *Limnoria* species, have been found 30 kilometres north of Moss harbour.
- Existing creosote-treated poles showed shipworm attack after 80 years of exposure. The attack was found in the treated sapwood zone. The starting year of the attack could not be determined.
- The tested treatment products showed no borer attack, except for thermal modified and Ca oxalate-treated wood.
- Exposed untreated wooden poles showed heavy infestation by shipworm. Creosote-treated poles were attacked from the unprotected transverse side of the pole in the untreated heartwood area.
- Wooden steps from floating platforms in six different sites in the Oslofjord showed shipworm attack for satric-treated samples, while acetylated samples showed no attack. Satric-treated samples were attacked in the untreated heartwood area and not in the treated sapwood.
- Encapsulated poles showed no attack by wood borers and a sound plastic layer after exposure to the marine environment. Dipping in fresh water revealed high water uptake when bolts were installed without sealant.
- The project was presented at the environmental festival in Moss end of August 2019.
- Project results were disseminated both in popular science and scientifically.
- Most of the tested wood treatments showed the potential to replace creosote-based treatments in short-term exposure. Longer exposure periods is necessary to determine their service life.

8 Outlook

- The use of wood in marine applications is threatened by the use of concrete and steel
- Changes in salinity and temperature of sea water can lead to spreading of wood degrading organisms
- No wood preservative is approved or suitable for marine applications in Europe
- Research on novel wood protection systems for sea water applications is shaped by the idea of preventing settlement on the wood surface
- The number of research articles in this field does not reflect the need for research on this topic
- Research needs to focus more on the different species of degrading organisms and the mode of action
- Further tests of the exposed products from this project are necessary. Especially, longer exposure periods in various areas would determine the long-term service life of the tested products.

9 Acknowledgement

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Figures

Tables

NIBIO
NORWEGIAN INSTITUTE OF
BIOECONOMY RESEARCH

NIBIO - Norwegian Institute of Bioeconomy Research was established July 1 2015 as a merger between the Norwegian Institute for Agricultural and Environmental Research, the Norwegian Agricultural Economics Research Institute and Norwegian Forest and Landscape Institute.

The basis of bioeconomics is the utilisation and management of fresh photosynthesis, rather than a fossile economy based on preserved photosynthesis (oil). NIBIO is to become the leading national centre for development of knowledge in bioeconomics. The goal of the Institute is to contribute to food security, sustainable resource management, innovation and value creation through research and knowledge production within food, forestry and other biobased industries. The Institute will deliver research, managerial support and knowledge for use in national preparedness, as well as for businesses and the society at large.
NIBIO is owned by the Ministry of Agriculture and Food as an administrative agency with special authorization and its own board. The main office is located at Ås. The Institute has several regional divisions and a branch office in Oslo.

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