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Tropical woods in hydraulic works and marine constructions

Photo 1.
Covered dock, made with wooden poles in radiata pine (*Pinus insignis*) treated with CCA (Chromated Copper Arsenate), Nouméa, New Caledonia, France.
Photo K. Candelier.

Photo 2.
Tropical woods tested in a marine environment, since 1999 and in agreement with the guidelines of EN 275 (1992), at the Kristineberg marine research station in Sweden (Westin and Brelid 2022).
Photo M. Westin & P. L. Brelid.

Photo 3.
Use of tropical woods in hydraulic works: installation of an Azobe lock gate.
Photo Wijma company (Deventer, Netherlands), from Gérard & Groutel (2020).

Wood structures used for marine applications are exposed to harsh environments in coastal areas (Tsinker 1995). These woods are often subjected to severe degradation conditions caused by significant mechanical loads (weight, waves, shock of fragments, etc.), abrasion, and especially by numerous biological agents that degrade wood (Treu et al. 2019). Whether in contact with saltwater, brackish water (estuaries, lagoons) or freshwater, and depending on their level of immersion, woods are subjected to many attacks from pathogens such as bacteria, fungi, insects, and marine borers (Oevering et al. 2001; Cragg et al. 2007; Can and Sivrikaya 2020). In salt or brackish waters, mollusks and marine borers are the main agents of degradation for wood used in submerged structures (Fouquet 2009). Despite its biodegradability, wood is a material of interest for marine construction due to its renewable nature, resilience, favourable strength-to-weight ratio, shock-absorbing ability, and flexibility in manufacturing, design and repair (Williams et al. 2005). In this sense, the use of wood in marine environments competes with other materials such as steel or concrete.

In the past, chemical treatments were applied to wood to obtain a product covering use class 5 (EN 335 2013; EN 350 2016), to protect it against biotic attacks and extend its lifespan in marine environments (photo 1). However, the negative impact of these biocidal treatments, based on creosote or chromated copper arsenate (CCA), on human health and the environment (Mercer and Frostick 2012, Martin et al. 2021) has led to their ban in Europe and their extended restriction in the United-States of America since 2003[1, 2]. Many research efforts have focused on alternative treatment solutions based on alkaline copper quaternary (ACQ) (Hellkamp 2012; Humar et al. 2013), 1,3-dimethylol-4,5-dihydroxyethylene urea (DMDHEU), methylated melamine resin (MMF), acetic anhydride, formaldehyde-based phenolic resin (PF), or furfuryl alcohol (Klüppel et al. 2014; Westin et al. 2016, Galore et al. 2023). However, currently available wood modification technologies mainly concern niche products that are costly, limiting their use to higher value-added products (Treu et al., 2019). As of now, no wood preservation product is approved in Europe for marine applications. New methods must meet efficiency requirements against degrading organisms while avoiding harmful side effects.

Some tropical species are traditionally used in port works in tropical and/or temperate areas, because they are considered resistant to marine borers, naturally covering use class 5 (wood regularly or permanently immersed in salt water, sea water or brackish water): Angelim Vermelho, Azobe, Greenheart, Okan, Wallaba[3]…. However, markets for some of these species appear strained with irregular supply that encourages turning to new species (photo 2) with at least

[1] Official Journal of the European Communities Commission, Directive 2003/2/EC of 6th January 2003, Clause (3).
[2] United States Environment Protection Agency, https://www.epa.gov/ingredients-used-pesticide-products/chromated-arsenicals-cca, consulted the 02/10/2024.
[3] Respectively *Dinizia excelsa*, *Lophira alata*, *Chlorocardium rodiei*, *Cylicodiscus gabunensis*, and *Eperua* p.p.

equivalent properties. The natural resistance of new species to marine borers must be validated through laboratory experiments or real-use conditions to positively contribute to the use of tropical woods in marine structures.

Lesser-known tropical wood species are difficult to promote due to the lack of reliable test data on their performance, particularly their natural durability. The resistance of these new species to marine borer attacks now needs to be checked in the laboratory or through experiments under real conditions of use, to contribute positively to the use of tropical woods in marine structures (photo 3).

There is also an observed evolution in the attacks on wood materials by marine borers migrating northward in relation to warming sea waters and an expansion of the natural area of these microorganisms (supposedly linked to global warming, Zarzyczny et al. 2023) (figure 1). This evolution impacts the behaviour of traditionally used woods in marine environments, some species considered highly durable are proving to be less resistant than others so far disregarded for this type of use (Palanti et al. 2015; Williams et al. 2018).

Current knowledge about wood resistance against biological attacks in marine context is therefore partially called into question. This natural resistance is thought to be linked to some characteristics (Gérard and Groutel 2020), such as (1) fine grain coupled with high specific gravity; (2) high silica content; (3) presence of repellent chemical compounds (= secondary metabolites) in wood.

In fact, most woods used for hydraulic structures in the marine environment have an average specific gravity of over 0.75, and this average specific gravity is most often over 0.85 (figure 2).

There is still a need (i) to better understand how and why marine woodborers attack wood, and (ii) to focus more closely on the different species of woodborer and their degradation ways in relation to the nature of the woods tested. Setting up permanent and temporary test sites would make it possible to monitor the pressure and distribution of marine species and the evolution of related risks for wood materials.

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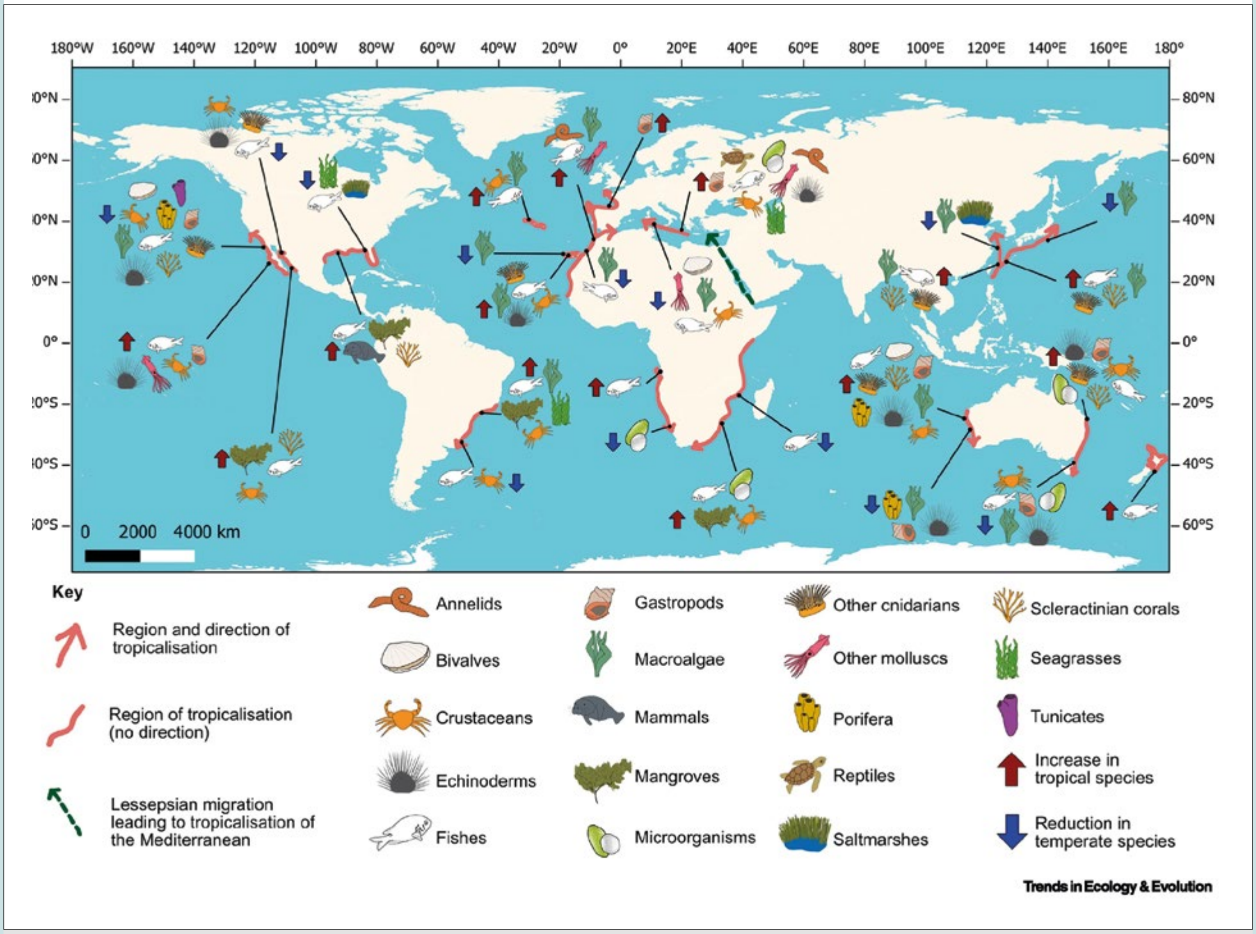

Figure 1.
Geographical areas where "tropicalisation" has been identified. The red upward arrow indicates an increase in tropical marine species and the blue downward arrow means a reduction in temperate species (Zarzyczny et al. 2023).

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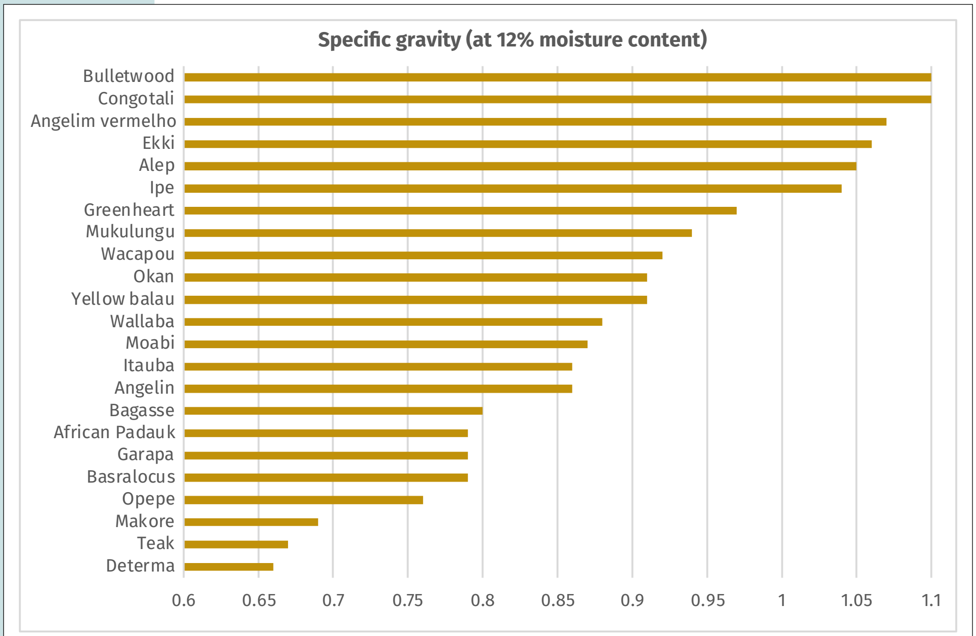

Figure 2.
Distribution of specific gravity of the main commercial woods naturally covering use class 5 (wood immersed in salt water on a regular or permanent basis), source: Tropix (Gérard & Groutel 2020).