

New research identifies additional species for use in marine and freshwater construction

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Angelim Vermelho

Cupiuba

Eveuss

Okan

Tali

Why we need to exploit lesser-used species

The construction industry has an unsustainable reliance on a few tropical hardwoods for use in marine and freshwater situations. The two commonly 'trusted' species are greenheart and ekki.

This historical reliance is understandable as often the material cost of timber in a construction scheme is dwarfed by the overall construction cost. Therefore, timbers with long established track records are favoured. However, increased focus on making businesses, environments and communities sustainable may push up the cost of the 'tried and tested' tropical hardwoods as demand for these species increases.

The industry's dilemma is how to exploit lesser-used species (LUS) when there is little evidence of their suitability for use in water. The main obstacles to using LUS are:

- Structural performance: There is limited information about the performance of these species in structural sizes. Information derived from laboratory tests on small, defect-free specimens is not a reliable indicator of structural performance.
- Resistance to attack by marine borers: Little is known about their resistance to marine borer attack. Natural resistance to attack by decay causing fungi does not necessarily guarantee robust marine performance.

For *freshwater applications*, the timber must be resistant to attack by wood-rotting fungi.

Timber in *marine applications* must also be resistant to attack by fungi but, below the high tide mark, it may be subject to attack by marine-boring animals that can cause severe damage to a timber structure over a comparatively short space of time.

Research by TRADA, carried out in the 1960s in coastal waters around the UK, identified two main groups of marine borers: shipworm (*Teredo* spp.) and gribble (*Limnoria* spp.). Gribble are ubiquitous whereas shipworms are thought to be limited to the south coast and isolated estuarine areas along the west coast of the UK.

Research summary

This document summarises the main findings of a collaborative research project funded by the Environment Agency and TRADA, and managed by H R Wallingford, which aimed to identify additional species for use in marine and freshwater construction. The research examined the performance of 18 LUS tropical hardwoods, benchmarked against greenheart and ekki. Five lesser-used species were found to be suitable alternatives for use where strength is critical, with another 13 considered appropriate for use where strength is not critical.

The full report ⁽¹⁾ on this work may be downloaded at www.trada.co.uk/techinfo/research.

The research was done in three stages:

1. Identify suitable LUS candidate timbers based on a desk study of previous research, existing literature and database reference sources. In order to qualify for selection, the candidate LUS had to meet the Environment Agency's procurement rules for timber ⁽²⁾. The candidate LUS are shown in *Table 1*.
2. Assess the potential marine borer resistance and abrasion resistance of the candidates using a range of novel, fast-track laboratory screening tests as well as a marine exposure trial.
3. Select five LUS (on the basis of the findings of Stage 2 and a range of commercial considerations) and determine their strength properties by testing structural sized specimens in accordance with the test method described in BS EN 408 ⁽³⁾.

Table 1: The 18 LUS that emerged from stage 1

Angelim vermelho	Garapa	Piquia
Basralocus	Massaranduba	Sapucaia
Cloeziana	Mora	Sougue
Cupiuba	Mukulungu	Tali
Dabema	Niove	Tatajuba
Eveuss	Okan	Timborana

Novel test methods

The logical standard that specifies test methods for determining resistance to marine borers is BS EN 275 ⁽⁴⁾. However, it specifies a five-year test period – too long a period for screening tests to be economically viable. Furthermore, this standard does not assess resistance to abrasion in service, nor does it address strength.

TRADA Technology and the University of Portsmouth devised cost-effective methods to assess marine borer (gribble only) ⁽⁵⁾ and abrasion resistance under laboratory conditions ⁽⁶⁾. The rationale behind these fast laboratory screening trials was that species that fail in the laboratory are likely to fail in the sea. Only species that performed well in these ‘filter’ trials progressed to the longer and more expensive marine exposure trials that tested resistance to shipworm infestation (no effective laboratory test for this has yet been devised).

Six further reference species were included in stage 2: yellow balau, Douglas fir, purpleheart, karri, oak and opepe. These have been used in marine and freshwater construction applications in the UK, and their performance in these environments is relatively well known.

The objective of stage 2 was to identify those timbers whose performance was *significantly*:

- better than ekki
- better than greenheart
- worse than ekki
- worse than greenheart.

Resistance to gribble (Limnoria spp.)

Gribble is the handsome marine creature shown in *Figure 1*.



Figure 1: Electron micrograph of Limnoria spp.
 Photo: University of Portsmouth

The data in *Figure 2* present average faecal pellet production rate per day over a 28-day period for candidate LUS, reference and benchmark timbers. Higher faecal production (pellets/d) by gribble means a higher feeding rate and hence a lower resistance of the timber to attack.

Feeding rates that are significantly lower than those recorded on both benchmark timbers (greenheart and ekki) are shown in dark green and feeding rates that are significantly lower than ekki alone are shown in pale green. Feeding rates that are significantly higher than both benchmark timbers are shown in red and feeding rates that are significantly higher than greenheart alone are shown in pink. Scots pine was used to confirm the vigour of the test animals.

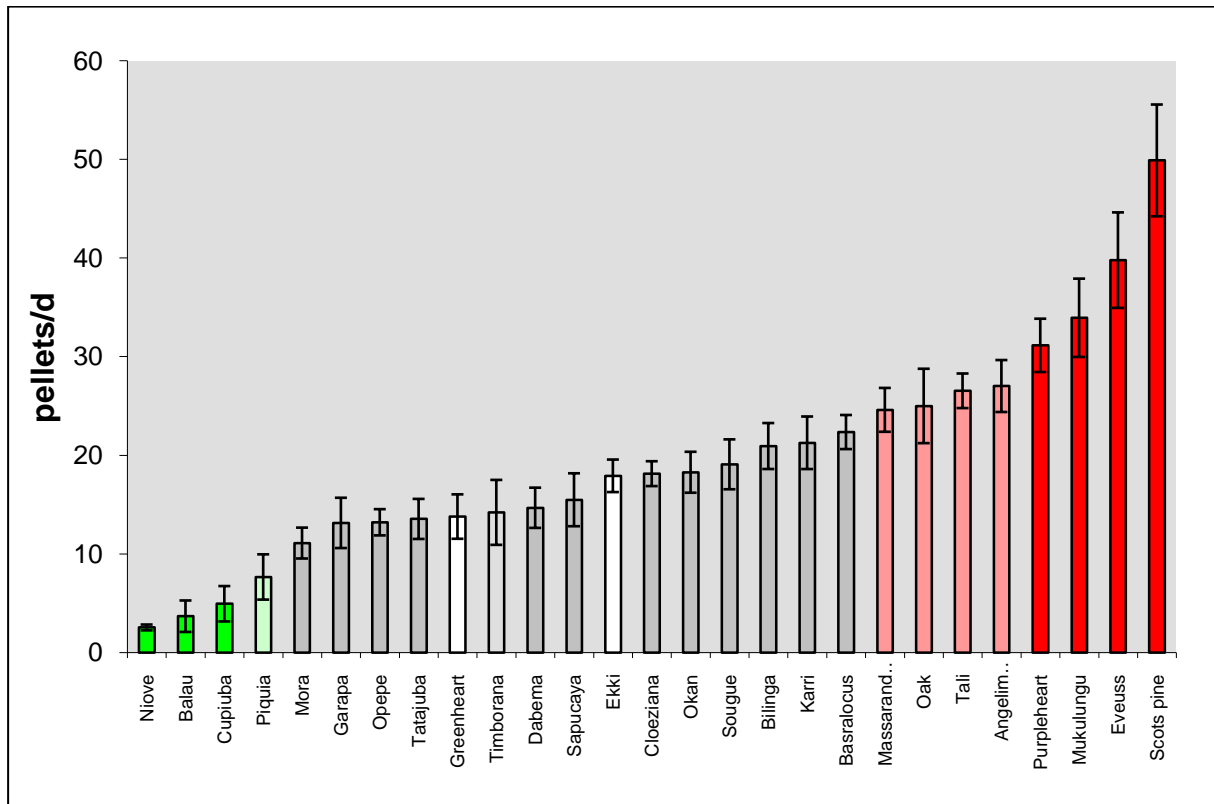


Figure 2: Comparison of daily feeding rates against greenheart and ekki

Resistance to abrasion

The effects of abrasion in marine trials are difficult to study owing to the extreme variability of weather and site conditions. The data in *Figure 3* present average volume loss after 160,000 cycles, or approximately 1350 tides, for the candidate LUS compared to ekki and greenheart. Volume losses (abrasion) that are significantly less than that recorded on greenheart are shown in pale green. Volume losses that are significantly higher than that recorded on both benchmark timbers are shown in red. Those higher than ekki alone are shown in pink.

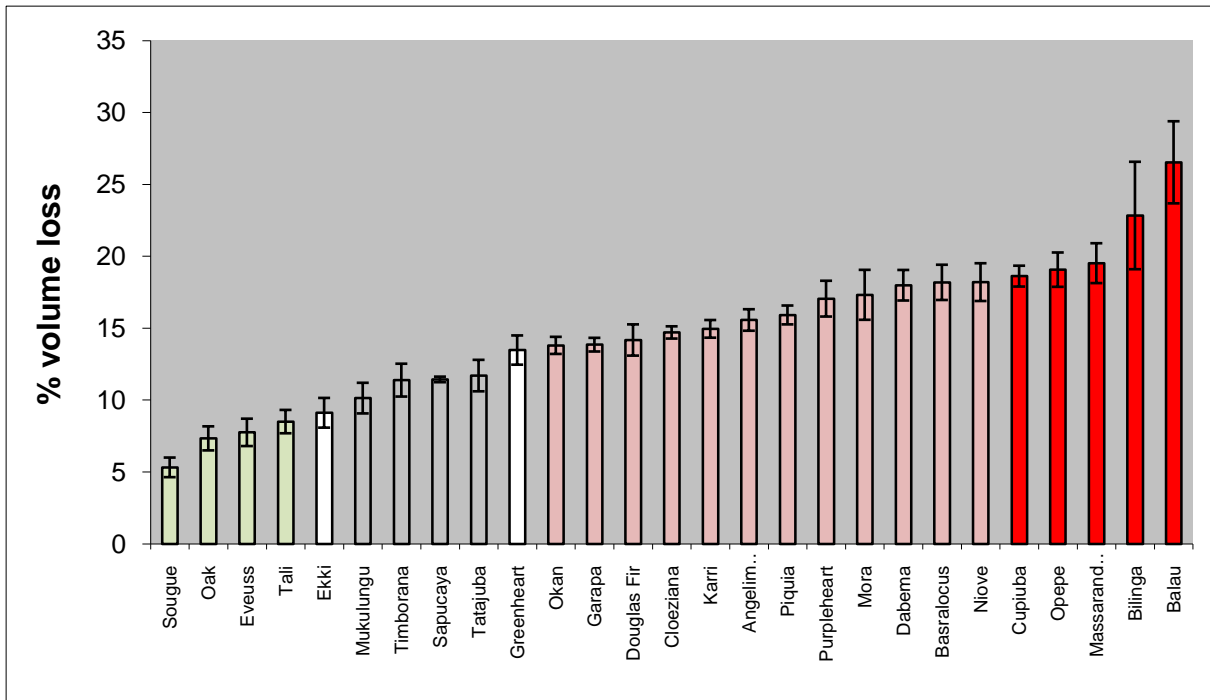


Figure 3: Average volume loss after 160,000 cycles for the candidate species compared to ekki and greenheart

Resistance to shipworm (*Teredo spp.*)

A marine exposure trial took place in Olhão harbour on the Ria Formosa lagoon, Portugal. Although the lagoon is on an Atlantic coast, the climatic conditions are essentially Mediterranean, with hot dry summers and warm wet winters. The lagoon is a known habitat for aggressive marine borer populations (*Figure 4*).



Figure 4: Example of *Teredo spp.* extracted from Barmouth viaduct
 Photo: TRADA Technology

The marine exposure trial ran over 18 months. Over this period, researchers made three assessment visits to monitor the performance of the candidate timbers. At each visit, the racks and samples were cleaned of all marine fouling and examined for signs of attack by marine borers. The racks were then wrapped in polyethylene bags to prevent stress to teredinid populations in the timber samples caused by drying out of the timber during transportation between the test site and a local X-ray clinic. The data in *Figure 5* present the comparative resistance to attack by shipworm in the trial, where 0 means no attack and 4 means severe attack.

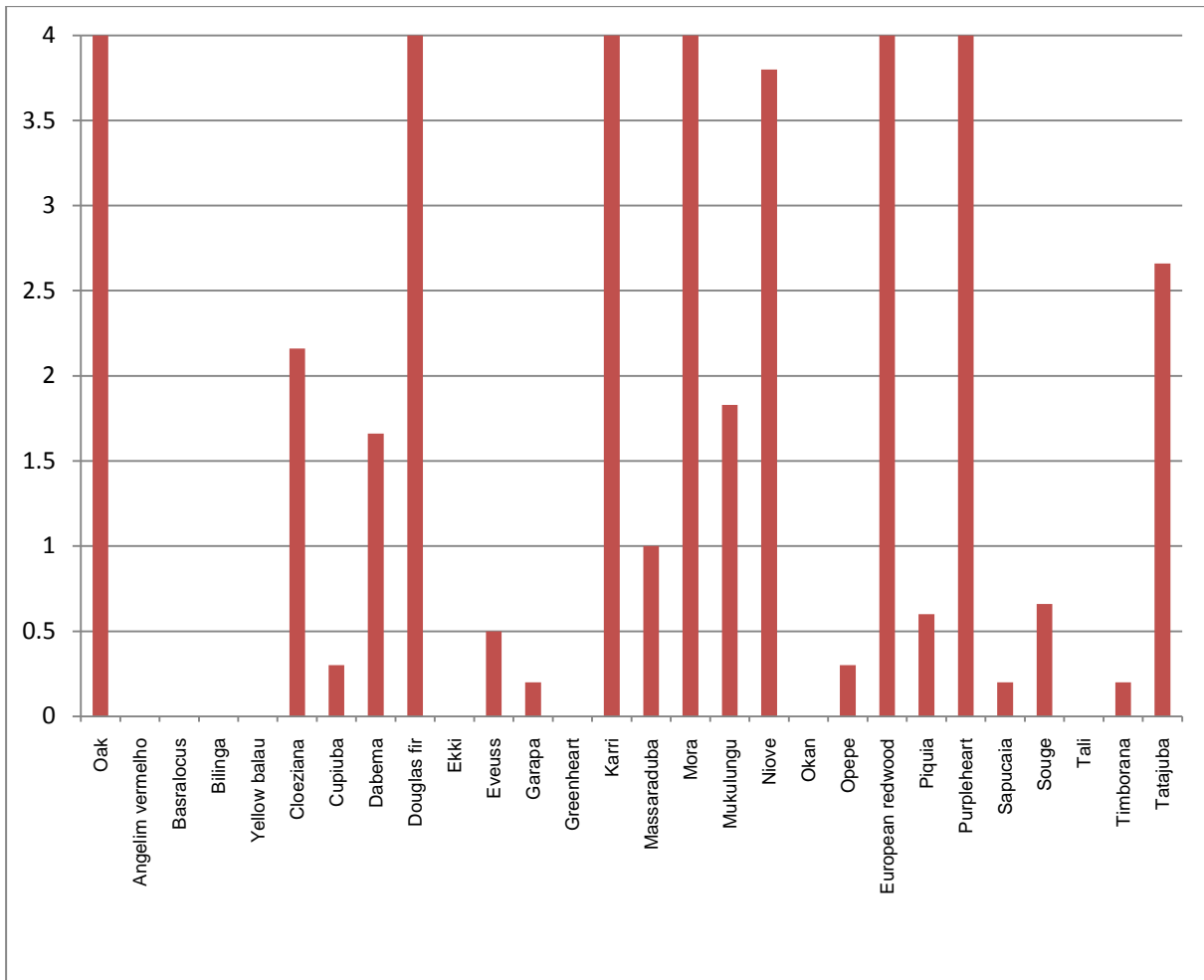


Figure 5: Performance of candidate LUS after 18 months' marine exposure.

LUS timbers with good strength

Mechanical tests in Stage 3 measured bending strength, bending stiffness and density.

Taking account of commercial factors, the research identified five LUS that performed well in both resistance and strength tests. These are listed in Table 2, together with their allocated strength classes. The strength classes provide values that may be used in design for all the necessary mechanical properties using *Eurocode 5*⁽⁸⁾.

Table 2: Allocation of five selected LUS to BS EN 338⁽⁷⁾ hardwood strength classes

Candidate timber	Strength Class #
Angelim vermelho	D60
Cupiuba	D50
Eveuss	D50
Okan	D40
Tali	D35

The strength class allocations for the five LUS detailed in Table 2 were derived from timber tested at a moisture content close to that likely to be found in Service Class 3 (SC3) where the average moisture content is greater than 20%. No correction was made for this high moisture content during the test programme. Therefore, structural engineers need not apply any of the strength reduction for SC3 in their designs when specifying angelim vermelho, cupiuba, eveuss, okan and tali. However, this must not be taken as advice that the strength values may be increased if the expected Service Class is SC1 or SC2.



Options for when strength is not critical

The research suggests a longer list of 13 LUS timbers that may be suitable for marine and freshwater construction where strength is not critical (Table 3). These exhibit varying levels of resistance to abrasion and marine borers, as well as variable commercial availability, so their suitability for use will depend on site and project specific requirements. *Figures 2, 3 and 5* are a guide to their likely resistance to gribble, abrasion and shipworm.

Table 3: LUS timbers for use when strength is not critical

Basralocus	Niove
Cloeziana	Piquia
Dabema	Sapucaia
Garapa	Sougue
Massaranduba	Tatajuba
Mora	Timborana
Mukulungu	

Need for trials

This research overcomes the two main reasons for a reluctance to use LUS: lack of knowledge about structural performance and resistance to attack. It provides information to inform decisions to specify timber that is resistant to significant hazards encountered in marine and freshwater situations. However, other factors such as price, section sizes, shrinkage, movement in service, workability and machinability characteristics, and delivery times may also influence choice.

There is no substitute for experience and, to paraphrase one of the researchers, in order to build up the necessary experience and track record of these LUS, the best time to have carried out this research would have been 25 years ago.

TRADA Technology recommends that a monitoring programme be established to assess and review the performance of these timbers over time, in live project applications. This includes LUS deployment in situations where strength is, and is not, critical.

The promotion of these lesser used species requires specifiers to identify the key risk parameters, that is the service requirements and service hazards, in order to ensure that these timbers are considered alongside the specifier's 'traditional' choices – greenheart and ekki.

Given the vast amount of wood used in water, the move towards LUS will have a significant impact on maintaining a sustainable supply of tropical hardwoods.

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