Institution: University of Portsmouth

Unit of Assessment: 7 Earth Systems and Environmental Sciences

Title of case study: Driving innovation in wood protection for the marine environment

1. Summary of the impact

Marine wood borers cause huge economic losses by damaging maritime structures. Research conducted by Cragg's team has driven the move from broad-spectrum, environmentally-hazardous wood protection methods towards environmentally-benign approaches tailored to target specific organisms. Their novel testing methods have accelerated evaluation of protection methods while reducing testing costs (impact 1). Their evaluations have been used to inform guidelines for selection of timbers for waterside construction issued by the UK Environment Agency (impact 2) and to market less well-known timber species (impact 3). Their information on invasive borers affects local and global decision making (impact 4).

2. Underpinning research

Research on the biodegradation of wood in the sea has been pursued at Portsmouth for over 40 years. In 1997, Dr S. Cragg (Reader in Zoology) joined the biodeterioration team, initially working with Dr. R. Eaton (Reader in Biodeterioration, University of Portsmouth 1970-2008). Since 2006, Cragg has led a team of Portsmouth-based researchers in this area to develop internationally-recognised expertise in the identification, biology and husbandry of marine wood borers.

At Portsmouth, Cragg developed quantitative methods for assessing the vulnerability of wood to crustacean wood-borer activity by measuring faecal pellet production rate. Method development involved research on the role of wood surface hardness in conferring resistance to *Limnoria* attack (***1***), resulting in the inclusion of a denser, non-durable wood species in routine testing, and the optimisation of environmental and animal-related conditions for the use of *L. quadripunctata* as a test organism (***2***). This protocol provided the first standardised laboratory test for the rapid and consistent assessment of the resistance of timbers to attack by *Limnoria* spp. It was used by the Portsmouth team to evaluate over 60 species of hardwoods from Ghana, Guyana, Guyane, Brazil, South Africa and Europe (***3***) and to assess a number of alternative wood preservation methods, including epoxy resin treatment, treatment with furfuryl alcohol (furfurylation) and chemical modification (***4***). Researchers at Portsmouth, under the direction of Cragg, developed an abrasion testing protocol which yielded performance data that complemented the borer resistance measurements. A protocol to test effects of furfurylation on settlement and growth of another category of marine wood borer (shipworm) was developed which demonstrated that furfurylation prevents shipworm growth. The work on marine borers at Portsmouth, and, in particular, the benefits of the protocol, prompted an invitation in 2013 for Cragg to join Technical Committee 38 of the European Standards Commission (CEN) charged with revision of current standards for testing resistance to biodegradation (*BS EN 350-1 and 2: 1994*). Cragg is giving guidance on predicting performance of wood in the sea for the provisional standard, *pEN 350*.

The research expertise of the Portsmouth team in the ecology and biogeography of wood borers has been used to link laboratory performance data with field assessments, and to predict borer hazard in different areas of the world. The team has demonstrated the importance of life history strategies in borer infestation (***5***) and the potential of tropical species to arrive in the Mediterranean from the Caribbean and the Red Sea (**5, 6**). One key crustacean wood-borer, *L. quadripunctata*, was found by Cragg to be invasive, with the potential to spread to further temperate areas (***CABI, 2011****; Section 4 Source 10*). A wood boring bivalve at the Mary Rose wreck site in the Solent was identified by Cragg as a species whose range was expanding northwards, with subsequent implications for conservation of this unique artefact. Another key bivalve borer species was shown to actually be two cryptic species (***6***), meaning that studies with this nominal species need to be re-evaluated.

3. References to the research: UoP contributors in bold;

1. **Cragg, S.M**., Danjon, C., Mansfield-Williams, H.D. (2007) Contribution of hardness to the natural resistance of a range of wood species to attack by the marine borer *Limnoria*. Holzforschung 61:201–206. DOI: 10.1515/HF.2007.035 IF 2.42, 2nd out of 22 in Materials Science, Paper and Wood.

2. **Borges, L. M. S., Cragg**, **S. M., Busch S**. (2009) A laboratory assay for measuring feeding and mortality of the marine wood-borer *Limnoria* under forced feeding conditions: a basis for a standard test method. Int. Biodeterioration and Biodegradation. 63: 289-296. DOI: 10.1016/j.ibiod.2008.10.007 IF 2.06 87th out of 210 in Environmental Science.

3. **Borges, L. M. S., Cragg, S. M., Bergot, J**., Williams, J. R., **Shayler, B.** and Sawyer, G. S. (2008) Laboratory screening of tropical hardwoods for natural resistance to the marine borer *Limnoria quadripunctata* with an investigation of the role of leachable and non-leachable factors. Holzforschung 62: 99-111. DOI: 10.1515/HF.2008.015 IF 2.42, 2nd out of 22 in Materials Science, Paper and Wood. REF2 output: 7-SC-002

4. Papadopoulos, A. N., Duquesnoy, P., **Cragg, S. M.** and Pitman, A. J. (2008). The resistance of wood modified with linear chain carboxylic acid anhydrides to attack by the marine wood borer *Limnoria quadripunctata* Holthius. Int. Biodet. Biodeg. 61: 199-202. DOI: 10.1016/j.ibiod.2007.11.004 IF 2.06 87th out of 210 in Environmental Science.

5. **Cragg, S. M.,** Jumel, M-C., Al-Horani, F. A. and **Hendy, I. W.** (2009) The life history characteristics of the wood-boring bivalve *Teredo bartschi* are suited to the elevated salinity, oligotrophic circulation in the Gulf of Aqaba, Red Sea. J. Exp. Mar. Biol. Ecol. 375: 99-105. DOI: 10.1016/j.jembe.2009.05.014 IF 2.26 27th out of 100 in Marine and Freshwater Biology.

6. **Borges, L. M. S.**, Sivrikaya, H., le Roux, C. A., **Shipway, J. R.**, **Cragg, S. M**., Costa, F. O. (2012) Investigating the taxonomy and systematics of marine wood borers (Bivalvia: *Teredinidae*) combining evidence from morphology, DNA barcodes and nuclear locus sequences. Invert. Systemat. 26: 572-582. DOI: 10.1071/IS12028 IF 1.98 31st out of 151 in Zoology.

References 1, 3 and 5 should be used to assess the quality of the research.

4. Details of the impact

Degradation of wood by marine wood boring species causes major economic losses world-wide. For example, over £400K was spent recently to remedy damage by marine borers to Yarmouth Pier, Isle of Wight, while in Seattle, repairs of $290M have been required due to borer damage to timbers in the seawall. Traditional wood preservatives, such as chromated copper arsenate, are prohibited in Europe (Commission Directive 2003/2/EC) for use in marine construction due to risks to aquatic organisms, and established construction timbers, such as greenheart and ekki, are a diminishing resource. Lesser-utilised species (LUS) and novel treatments therefore need to be evaluated for their suitability in the marine environment.

Impact 1. Acceleration of evaluation of protection methods while reducing testing costs

The European standard for marine testing of natural durability of wood and the protective value of wood treatments (BS EN 275) requires the exposure and annual inspection of wooden panels in situ for five years. The cost of maintaining each field testing site can be as high as €12K p.a. (**S3**) and generation of results is slow. Standard rapid laboratory screening methods were previously available for testing resistance to fungi and wood boring insects, but not to marine wood borers.

Cragg's team developed a novel laboratory protocol that quantifies resistance to marine wood borers in naturally durable timbers and timbers with protective treatments. This method has been

validated against in situ testing (**S1**) and confers the ability to perform rapid, statistically-robust evaluations, reducing both the duration and the cost of testing. In 2008, the Timber Research and Development Association (TRADA), with Portsmouth, used this method to expand their portfolio of marine timber testing, generating over £200,000 additional income from contracts with the Forestry Commission of Ghana, the Guyana Forestry Commission and the Environment Agency (**S2**). Similarly, the method has been used to assess the efficacy of alternative timber modifications on behalf of commercial companies (Kebony ASA, Norway) and to perform rapid iterative evaluation of furfurylation methods on behalf of governmental organisations (Technical Research Institute, Sweden) (**S3**). The suite of methods developed at Portsmouth underpins a current, extensive evaluation programme of novel wood-polymer composites for use in marine construction by a Scandinavian consortium of government and commercial timber organisations.

Impact 2. Evidence of durability backs EA procurement policy

In 2009, the Environment Agency (EA) and TRADA jointly commissioned Portsmouth researchers to examine the performance of 18 LUS tropical hardwoods, benchmarked against greenheart and ekki. This enabled TRADA to make specific recommendations to its members on specific LUS species as suitable alternatives to greenheart (**S1**) and the EA to publish (2011) authoritative guidance aimed at structural and civil engineers, design consultants, building contractors, asset managers and procurement professionals (**S4**). Subsequently, the EA has changed its procurement procedures to include a mandatory requirement to consider LUS and to follow the methodology within the EA guidance. It has also set up a framework contract with two UK-based LUS timber suppliers (this contract is also open to other government agencies and public sector bodies) and has used LUS in a range of freshwater and marine applications that have delivered cost savings and sustained performance (**S5**).

Impact 3. Evaluations have been used to market less well-known timber species

Evaluations of the resistance to borer attack of Guyanese timbers conducted at Portsmouth indicated that several LUS performed as well as traditional marine construction species. This information was incorporated into recommendations by TRADA to the Guyana Forestry Commission (GFC) on ten timbers for longer-term marine testing (**S6**), and was included in a series of datasheets and booklets on relevant tropical timbers prepared by the GFC (**S7**). The International Tropical Timber Organisation (ITTO) included these studies and recommendations in guidance and training material delivered to over 80 forestry concession holders, saw millers, lumber yard holders, exporters, and other stakeholders in the three major counties of Guyana (**S8**).

Impact 4. Information on borer hazard changes affects decision-making locally and globally

In 2006, Cragg detected living specimens of destructive warm-water borers in timbers remaining at the wreck site of the Mary Rose ship. As a result, the Mary Rose Trust immediately introduced a number of physical methods of protection against borer attack at the site and initiated an enhanced programme of monitoring (**S9**). Cragg has provided all information and text for the borer, L. quadripunctata in the Invasive Species Compendium developed by the international, intergovernmental Centre for Agriculture and Biosciences International (CABI). The Compendium is an authoritative database that supports decision-making in the management of invasive species worldwide (**S10**).

5. Sources to corroborate the impact

1. *Assessment of the durability and engineering properties of lesser-known hardwood timber species for use in marine and freshwater construction* TRADA Technology Ltd Report (2010). TRADA recommendations on LUS species as suitable alternatives to greenheart.

2. Letter, Senior Technical Consultant, TRADA, confirming that novel testing methodology enabled TRADA to diversify its portfolio of testing projects, generating >£200K of additional contract income since 2008.

3. Letter, Research Manager, SP Traetek, confirming that novel testing methodology allowed

rapid iterative testing and evaluation of furfurylation methods for protection of wood.

4. *Delivering Benefits through Evidence Series 'Alternative hardwood timbers for use in marine and fresh water construction' Project: SC070083/R1 DEFRA Environment Agency (2011).* Environment Agency/DEFRA encourages the specification and use of lesser used species of hardwood timber in marine and freshwater construction.

5. Letter, Sustainable Procurement Advisor, Environment Agency, confirming that UoP research underpins the EA's policy of diversifying the range of timbers used for marine and freshwater construction.

6. *Assessment of the resistance of 15 lesser used timbers from Guyana to abrasion and attack by Limnoria quadripunctata* Holthuis. Report TC/F07096 Part 2 prepared for the Guyana Forestry Commission. TRADA Technology Ltd (2008). 10 species of timbers recommended to the Guyanan Forestry Commission for longer-term marine testing.

7. Promotional material for Guyanan timbers with marine borer resistance information.

8. International Tropical Timber Organisation Report (034405) on training and information campaign in Guyana disseminating findings contained in source 1.

9. Letter, Head of Conservation, Mary Rose Trust, confirming that Cragg's research directly influenced conservation practices at the wreck site

10. CABI, (2011). *Limnoria quadripunctata* [original text by S. M. Cragg]. In: Invasive Species Compendium. Wallingford, UK: CAB International. http://www.cabi.org/isc. Demonstrates world-wide invasiveness of *L. quadripunctata*