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Research Article



# Variation in Inspection Efficacy by Member States of Wood Packaging Material Entering the European Union

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## Abstract

The use of wood packaging materials (WPMs) in international trade is recognized as a pathway for the movement of invasive pests and as the origin of most introductions of Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae) in Europe and North America. Following several pest interceptions on WPM associated with stone imports from China, the European Union (EU) agreed to survey certain categories of imports based on the EU Combined Nomenclature Codes for imports, which are based on the international Harmonized System. Between April 2013 and March 2015, 72,263 relevant consignments were received from China in the EU and 26,008 were inspected. Harmful organisms were detected in 0.9% of the consignments, and 1.1% of the imports did not have markings compliant with the international standard for treating WPM, ISPM 15. There were significant differences between the detection rates of harmful organisms among EU member states. In member states that inspected at least 500 consignments, the rate of detection ranged from 6.9% in Austria and France to 0.0% in Spain and Poland. If this difference in detection rate is the result of differences in the methods and intensity of inspection in different member states then an approximate sevenfold increase in the interception of harmful organisms may be achieved if all states were to achieve detection rates achieved by Austria and France. The EU data from 1999 to 2014 indicated an increasing number of interceptions of Bostrichidae and Cerambycidae since 2010. This study demonstrates that there is an ongoing threat of non-native forest pests being imported on WPM.

**Key words:** invasive species, commodity treatment, Cerambycidae, Scolytinae

Wood packaging material (WPM) is defined in the standards of the International Plant Protection Convention as 'wood or wood products (excluding paper products) used in supporting; protecting or carrying a commodity (includes dunnage)'. Dunnage is defined as 'wood packaging material used to secure or support a commodity but which does not remain associated with the commodity' (IPPC 2013), e.g., a piece of wood that is positioned to brace pallets or containers or stop them from contacting each other. In addition to dunnage, WPM can be in the form of pallets, crates, boxes, packing cases, cable drums, and spools; and WPM may be present in almost any imported consignment including those which would not normally be subject to phytosanitary inspections (IPPC 2016). The WPM is integral to global trade and used to contain and package a large proportion and variety of goods that are moved internationally. The U.S. Department of Agriculture (USDA 2003) estimated that up to 70 percent of all the goods traded internationally are accompanied by some type of WPM. The weight of goods traded internationally in containers increased from 102 million tons per year in 1980 to 1,687 million tons per year in 2015 (UNCTAD 2016), and by association, the use of WPM has been a significant factor in these increases (Bernhofen et al. 2013).

International Standards for Phytosanitary Measures (ISPMs) are guidelines and recommendations produced by the secretariat of the International Plant Protection Convention (IPPC). The standards are designed to achieve international harmonization of phytosanitary measures to facilitate world trade. ISPM No. 15 describes acceptable procedures for treating and labeling WPM as having been treated to reduce the risks of live quarantine organisms being present. The current core principles of ISPM 15 are that internationally traded WPM must be debarked and treated by a method that is feasible for operators and has been shown to be effective against an appropriate range of pests. The three currently approved treatments are 1) heat treatment to achieve a minimum temperature of 56°C throughout the entire profile of the wood (including at its core) for 30 continuous min; 2) dielectric (microwave) heating to achieve a minimum temperature of 60°C for 1 continuous min throughout the entire profile of the wood (including its surface); and 3) treatment with methyl bromide fumigant gas. ISPM 15 encourages National Plant

Protection Organizations (NPPOs) to promote the use of treatments other than methyl bromide because it is an ozone-depleting compound. In addition to the treatment requirements for newly manufactured WPM, each article must be marked with a code which is visible and legible to inspectors to show how, where, and by whom it had been treated (IPPC 2016). The code will include either HT for heat treatment, DH for dielectric heating or MB for methyl bromide treatment.

One of the reasons for pests being commonly found within WPM is that it can be constructed from low-value wood that is not of sufficient quality for other uses. The life span of most pallets is expected to be between 7 and 8 yr. There is an incentive to use higher grade wood for pallets that are used for food storage and for warehouse storage where specifications are more exacting. Pallets and pallet collars must stack safely at heights and must not jam. However, single use WPM that is used to transport heavy commodities such as stone and steel is often damaged during transport and is constructed from lower grade wood (personal communication John Morgan, Forestry Commission, UK). Second, there are generally lower profit margins on the low-value commodities such as stone and savings on the cost of packaging have a higher impact on the overall profitability of these consignments (personal communication, John Morgan, Forestry Commission, UK). Another explanation for the abundance of pests found in WPM used for heavy products is that thicker wood is needed with sufficient strength to support these goods. Thicker wood increases the likelihood of pests being present when WPM is constructed and for the pests to survive.

Between 2001 and 2015, 19 outbreaks of Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae), were detected in the European Union (EU) and a further four outbreaks were detected in Switzerland (Eyre and Haack 2017). Many of these outbreaks were linked to WPM associated with imports from China. In 2013, the EU agreed on emergency measures to evaluate certain imports from China, including a survey. This paper, summarizes 2 yr of results (April 2013 to March 2015) of an EU-wide survey of WPM from China associated with categories of stone products, plus an examination of the long history of interceptions of harmful organisms with WPM and noncompliant WPM. There has been considerable evidence that WPM associated with stone products is at high risk of borer infestation, justifying the focus on stone commodities (Bulman 1992, 1998; Haack 2006; Eyre and Haack 2017). Haack et al. (2014) provided evidence that infestation rates of WPM entering the United States had declined between 36 and 52% following the adoption of ISPM 15 by the United States. Although there are a number of databases (such as Europhyt in the EU) that record plant health interception records, it is difficult to analyze much of these data due to the way in which the data were recorded. For example, limitations of pest interception databases include 1) they are seldom based on random sampling; 2) negative inspections are seldom recorded; 3) once the first quarantine pest has been discovered, consignments are often destroyed without further inspection for additional pests; 4) only a small percentage of imports are inspected; and 5) organisms are often not identified to species given that many are intercepted as larvae (Humble 2010). Some of these criticisms are applicable to the present EU survey of WPM associated with stone products from China; however, some have been overcome. The data from the EU survey include both interception data and the total number of inspections and represent a high proportion of each stone category inspected. It was possible to calculate interception rates from the EU survey data, and these rates could be compared with other published figures, as well as for comparisons among member states and among different product categories. In addition, historical interception data of harmful organisms in WPM were collated from Europhyt and analyzed.

## Materials and Methods

### WPM Inspection Measures in the EU

The legislation governing plant health pests is common across the EU. The current basis of this legislation is EU Council Directive 2000/29/EC (EU 2000). In addition to this directive, there are also a number of emergency measures that are introduced by the EU in response to the developing plant health threats. In February 2013, the EU Commission published decision 2013/92/EU, which is an emergency measure requiring member states to survey WPM associated with consignments designated as stone products imported into the EU from China. This decision was taken after intercepting several harmful organisms, notably *A. glabripennis*, in association with such consignments and outbreaks of *A. glabripennis* in a number of member states that were either proven or strongly suspected to be the result of such imports. This Asian beetle has been assessed as being a significant threat to hardwood forests in the EU (MacLeod et al. 2002), as well as in North America (Haack et al. 2010).

The decision 2013/92/EU included requirements for member states to inspect a stated percentage of consignments of these products from China as shown in Table 1, i.e., 90% of slate consignments (Combined Nomenclature [CN] 2514 00 00), 90% for marble (CN 2515), 90% for granite (codes starting with CN 2516), 15% for setts and curbstones (CN 6801 00 00), and 15% for worked monumental or building stone (codes starting with CN 6802). In the emergency decision, a consignment was defined as 'a quantity of goods being covered by a single document required for customs formalities or for other formalities'. The results reported in this paper are for a 2-yr period from 1 April 2013 to 31 March 2015. The designated stone product CN codes are a standard system used across the EU for classifying traded goods. CN codes consist of the six digits used in the Harmonized System with an additional two digits for subdivision. The Harmonized System is the international custom code system administered by the World Customs Organization (EC 2017). The inspections took place at the point of entry into the EU or at the final place of destination, provided that specific guarantees and documents relating to the transport of the consignment were provided in accordance with Commission Directive 2004/103/EC (EU 2004). If the WPM being inspected was found to contain pests or not marked in accordance with ISPM 15 then member states were required to carry out one or more of the following measures: refusal of entry, re-export under official supervision, removal of infected/infested produce from the consignment, destruction, or an imposition of a quarantine period during which official diagnosis could be carried out or in exceptional circumstances appropriate treatments. Member states were obliged to report the results of their surveys to the European Commission within 1 mo of the end of each 6-mo period that the survey took place. If any pallet in a consignment was found to have either harmful organisms present or lack markings in accordance with ISPM 15 then the whole consignment was considered to be noncompliant.

### The Inspection Method in Austria

The EU Decision 2013/92/EU does not include any detail on how member states should carry out inspections and so different methods are likely used across Europe. The requirements for inspection in Austria are described here for reference because Austria (together

**Table 1.** Summary data for the inspections of wood packaging material associated with stone imports from China by all EU member states during 2013–2015

| Combined nomenclature code | Description | Target frequency of plant health checks | No. of consignments received into EU (actual % inspected) | % of inspected consignments in which harmful organisms were detected | % of inspected consignments without a compliant ISPM mark |
|---|---|---|---|---|---|
| 2514 00 00 | Slate | 90 | 756 (91) | 0.3 | 0.9 |
| 2515 | Marble, travertine, ecaussine, and other calcareous monumental or building stone | 90 | 435 (65) | 0.4 | 3.5 |
| 2516 | Granite, porphyry, basalt, sandstone and other monumental or building stone | 90 | 3,423 (75) | 0.4 | 0.8 |
| 6801 00 00 | Setts, curbstones, and flagstones, of natural stone (except slate) | 15 | 18,481 (34) | 1.4 | 1.3 |
| 6802 | Worked monumental or building stone (except slate) and articles thereof, other than goods of heading 6801 | 15 | 49,168 (33) | 0.8 | 1.0 |
| | | | Total received = 72,263<br>Total inspected = 26,008 (36%) | Mean = 0.9% | Mean = 1.1% |

The 'target frequency' was the target percentage of consignments to be inspected as required in the EU emergency measures.

with France) had the highest levels of detecting harmful organisms in WPM (see Results). Austria is landlocked, it has no seaport and all inspections of WPM from China are carried out at the final place of destination. Austria has bilateral agreements with a number of other member states to allow it to carry out many phytosanitary inspections of regulated WPM from China at the place of final destination using a plant health movement document in accordance with Commission Directive 2004/103/EC.

Inspections of WPM in Austria can only be carried out at approved sites. Approved sites must have adequate light for inspection, a fork-lift truck with an experienced driver to unload and reload the shipping container, adequate space for storage of unloaded pallets and clear instructions for emergency measures to be taken if live pests are detected in the WPM. The NPPO in Austria uses an online registration system for regulated consignments including WPM from China. Every regulated consignment that needs a customs declaration in Austria is registered by the users (forwarders or importers) on the system along with the bill of lading. This allows inspectors to preselect consignments that are considered to be high risk for inspection. Before opening a container, a measurement of residual gas (fumigants) is carried out for safety purposes. Each pallet or crate is removed from the shipping container and lifted up with a fork lift truck. This provides inspectors with the opportunity to inspect all of the loaded pallets, including the lowest quality pallets that may have been placed deep inside the container and to inspect the thicker pieces of wood that are at the base of the pallets.

### Data Analysis

The data from all stone types and all countries were combined and analyzed with a quasi-binomial Generalized Linear Model (GLM) using the statistical analysis software R version 3.2.2 (R Foundation for Statistical Computing 2008). Throughout this assessment, we assumed that the WPM sent to each EU member state came from the same population in China; i.e., over the long term, we would expect each member state to receive an equal proportion of consignments that contained harmful organisms and a similar proportion of consignments would be noncompliant with ISPM 15. The significance level test value, alpha was set at 0.05.

Three models relating to the proportion of consignments containing harmful organisms were fitted to the data to test the relationship with 1) the member state of inspection plus the stone type; 2) just the member state inspecting, and 3) just the stone type. The survey results from each member state were used to estimate the proportion of consignments with harmful organisms present over the course of the survey. A second set of three models was also fitted, and these tested whether the number of consignments not complying with the requirement to mark WPM in line with ISPM 15 was related to 1) the member state conducting the inspection and stone type, 2) only the member state inspecting, or 3) only the stone type.

### Europhyt Data

Europhyt is the database of consignments received by the EU member states that violate in some way any of the EU's plant health requirements. In order to look at interceptions over a longer period and to compare interceptions from different sources, records of interceptions relating to WPM were downloaded for the entire EU for the period 1998–2014 and collated. This data set differs from the data collected in the EU survey of WPM related to known high-risk commodities from China in that 1) it covers WPM from all countries; 2) it covers WPM associated with any type of product; and 3) there is no accompanying data relating to the number of inspections or the number of consignments received, therefore it is not possible to evaluate the proportion of infested consignments.

## Results

### EU Survey of WPM From China

As summarized in Table 1, 72,263 consignments of stone from China were received in the EU from the five specified categories of stone

products during the 2-yr survey period, and 26,008 of these consignments were inspected for pests of quarantine significance. Looking at the EU results as a whole, the target inspection percentages were met for slate (CN code 2514 00 00, Table 1), setts, curbstones, and flagstones (CN 6801 00 00), and worked monumental or building stone (CN 6802), but not met for marble (CN 2515) or granite (CN 2516). The proportion of consignments on which harmful organisms were detected varied from a low of 0.3% for slate to a high of 1.4% for setts, curbstones, and flagstones, with a mean infestation rate for all consignments of 0.9%. The proportion of consignments without a compliant ISPM-15 mark on the associated WPM varied from 0.8% for granite to 3.5% for marble, with a mean for all consignments of 1.1%.

Table 2 shows the number of the relevant consignments received by EU member states, the number (and %) of consignments inspected, the proportions found with harmful organisms, and those without a compliant ISPM-15 mark. The greatest number of consignments was received in Germany (21,036), followed by the Netherlands (9,684), the United Kingdom (9,365), and Belgium (7,957). Of the consignments received in each member state, the highest proportion inspected was in Estonia, Latvia, Romania, and Lithuania (all 100%), followed by Italy (75%) and Finland (49%). Fourteen of the 28 EU member states did not detect harmful organisms in any of the consignments they inspected. Of the member states that did not detect any harmful organisms, Hungary (not listed in Table 2) did not report receiving any relevant consignments and others received and inspected relatively low numbers of consignments, e.g., three consignments inspected in Luxembourg. Two countries inspected more than 500 consignments but did not detect any with harmful organisms: Poland (1,611) and Spain (686). The countries detecting harmful organisms in the highest proportion of consignments were Austria (6.9%) and France (6.9%) followed by Finland (3.4%), the Netherlands (3.0%), and the Czech Republic (1.6%). These five countries detected harmful organisms in the highest proportion of consignments inspected for the two stone categories CN 6801 00 00 (setts etc.) and CN 6802 (worked monumental stone etc.). The analysis of variance based on the quasi-binomial GLM showed that there were significant differences between the number of consignments in which harmful organisms were detected among member states ($F = 20.83$; df = 78, 104; $P < 0.0001$), but no significant differences related to the different categories of imported stone products ($F = 0.8849$; df = 100, 104; $P = 0.4759$).

Overall, 24 of the 28 member states detected at least one consignment without a compliant ISPM-15 mark. The member states that detected the highest proportion of consignments without ISPM-15 marks were Portugal (12.5%), Cyprus (6.1%), Denmark (5.3%), and Bulgaria (4.5%). The second set of models showed that there were significant differences among member states in the proportion of consignments that were found with missing ISPM-15 marks ($F = 2.153$; df = 47, 60; $P = 0.0279$), but no significant differences were found among the different categories of stone products ($F = 0.3422$; df = 56, 60; $P = 0.8483$).

Figure 1 shows the number of pest interceptions on WPM for the six most frequently intercepted pest taxa by member state between April 2013 and March 2015. Interceptions that were recorded as 'Insecta' were not included in this figure. Most of the interceptions of these six taxa were made in Austria, Germany, and the Netherlands. Interceptions of certain taxa were concentrated in one or more member states, e.g., 27 of the 30 interceptions of *Apriona germari* (Hope) (Coleoptera: Cerambycidae) were made in the Netherlands. Not all the interception data were included in this figure, however, of note, there were also nine interceptions of pinewood nematode, *Bursaphelenchus xylophilus* (Steiner & Buhrer) Nickle (Aphelenchida: Parasitaphelenchidae), on WPM from China in France and one interception of a jewel beetle, Buprestidae (Coleoptera), in Austria. The 'Cerambycidae' category in this figure includes all longhorned beetles that were not identified further than family level.

### Inspections of WPM in Austria

Table 3 shows that of the 4 yr in which data were available (2013–2016), the proportion of consignments with WPM in which harmful wood-infesting organisms were detected was highest in 2016 at 19.6%. The proportion of consignments which did not comply with the marking requirements of ISPM 15 was low for all 4 yr and declined across the 4-yr period from 2.6% in 2013 to 1.5% in 2017.

### Noncompliance with ISPM 15 and Finds of Harmful Organisms on WPM in Europe Between 1998 and 2014

Figure 2 shows that China followed by India were the source countries for the highest number of interceptions of harmful wood-infesting organisms made in EU on WPM during 1998–2014. This figure also shows large differences in the types of pests that were intercepted for each of the four largest source countries. For example, most of the interceptions of harmful organisms from China were Cerambycidae, most were Bostrichidae from India, most were Aphelenchoidea (including pinewood nematode, a damaging North American pest of pine trees, see Discussion) from the United States and a mixture of Aphelenchoidea and Cerambycidae from Russia. The Aphelenchoidea from Russia were all *Bursaphelenchus mucronatus* (Mamiya & Enda) (Nematoda: Aphelenchoididae), a species that is present in a number of EU countries. The Cerambycidae from Russia that were identified below the family level were all *Monochamus* species and could have been European or Eurasian species that are not all considered quarantine species for the EU.

Figure 3 shows the annual number of interceptions of the four most numerous taxa that were intercepted on WPM between 1999 and 2014. Overall, there has been a noticeable increase in the number of interceptions of both Bostrichidae and Cerambycidae since 2010. The numbers of interceptions of Aphelenchoidea (including pinewood nematode) were higher in 2013 and 2014 than they had been during any year since 2001. Similarly, the number of interceptions of Scolytinae (8) in 2014 was higher than any other year between 1999 and 2013.

## Discussion

The results of this survey will help the EU and other parts of the world to understand the current risks relating to WPM used in international commerce and to help develop strategies to reduce these risks. The combination of member states recording and reporting interception data, negative inspection data and trade volumes makes it possible for a quantitative rather than qualitative assessment of the risks associated with particular trades and a comparison of the relative rates of interception in different member states.

Of the 26,008 consignments inspected, six consignments were without a compliant ISPM-15 mark and had harmful organisms, 232 consignments had a compliant mark and also had harmful organisms, and 269 did not have a compliant mark but no harmful organisms were detected. Therefore, of the 238 consignments in which harmful organisms were detected, 232 (97.5%) were consignments with marks indicating treatment compliant with ISPM 15. The proportion of the 275 consignments that did not have a

**Table 2.** Number of consignments of stone from China received by EU member states between 2013–2015 in which the associated WPM was inspected for the presence of harmful organisms and the markings on the WPM were checked for compliance with ISPM 15, ranked by the percentage of infested consignments detected (high to low)

| EU member state | No. of incoming consignments entering the EU via the reporting member state | No. of consignments inspected (% of all consignments) | No. of consignments in which the WPM was infested either with or (without) a compliant ISPM-15 mark | % of consignments with harmful organisms | 95% confidence intervals for proportion found with harmful organisms | No. of consignments without a compliant ISPM-15 mark only | % of consignments without a compliant ISPM-15 mark |
|---|---|---|---|---|---|---|---|
| Austria[a] | 2,726 | 812 (30) | 56 (0) | 6.9 | 5.1–9.3 | 19 | 2.3 |
| France | 1,657 | 448 (27) | 31 (0) | 6.9 | 4.6–10.4 | 4 | 0.9 |
| Finland | 774 | 381 (49) | 12 (1) | 3.4 | 1.8–6.4 | 3 | 1.0 |
| The Netherlands | 9,684 | 2,118 (22) | 63 (1) | 3.0 | 2.3–4.0 | 52 | 2.5 |
| Czech Republic | 806 | 304 (38) | 5 (0) | 1.6 | 0.57–4.6 | 2 | 0.7 |
| Sweden | 1,164 | 375 (32) | 3 (0) | 0.8 | 0.20–3.1 | 6 | 1.6 |
| Germany | 21,036 | 9,154 (44) | 49 (1) | 0.5 | 0.39–0.76 | 40 | 0.4 |
| Estonia | 229 | 229 (100) | 1 (0) | 0.4 | 0.04–4.5 | 5 | 2.2 |
| Ireland | 2,072 | 247 (12) | 1 (0) | 0.4 | 0.04–4.2 | 3 | 1.2 |
| Bulgaria | 748 | 269 (36) | 0 (1) | 0.4 | 0.03–3.8 | 11 | 4.5 |
| Lithuania | 591 | 591 (100) | 1 (1) | 0.3 | 0.06–1.8 | 15 | 2.7 |
| Belgium | 7,957 | 1,555 (20) | 4 (0) | 0.3 | 0.08–0.84 | 17 | 1.1 |
| United Kingdom | 9,365 | 4,305 (46) | 6 (0) | 0.1 | 0.05–0.37 | 32 | 0.7 |
| Italy | 2,746 | 2,068 (75) | 0 (1) | 0.0 | 0.00–0.51 | 32 | 1.6 |
| Cyprus | 276 | 82 (30) | 0 (0) | 0.0 | 0.00–3.6 | 5 | 6.1 |
| Denmark | 88 | 19 (22) | 0 (0) | 0.0 | 0.00–14.6 | 1 | 5.3 |
| Spain | 4,356 | 686 (16) | 0 (0) | 0.0 | 0.00–0.44 | 7 | 1.0 |
| Greece | 69 | 18 (26) | 0 (0) | 0.0 | 0.00–15.3 | 0 | 0.0 |
| Croatia | 392 | 95 (24) | 0 (0) | 0.0 | 0.00–3.1 | 2 | 2.1 |
| Latvia | 87 | 87 (100) | 0 (0) | 0.0 | 0.00–3.4 | 2 | 2.3 |
| Luxembourg | 9 | 3 (33) | 0 (0) | 0.0 | 0.00–63.2 | 0 | 0.0 |
| Malta | 110 | 40 (36) | 0 (0) | 0.0 | 0.00–7.2 | 1 | 2.5 |
| Poland | 3,540 | 1,611 (46) | 0 (0) | 0.0 | 0.00–0.19 | 2 | 0.1 |
| Portugal[b] | 92 | 24 (26) | 0 (0) | 0.0 | 0.00–11.7 | 3 | 12.5 |
| Romania[a] | 62 | 72 (100) | 0 (0) | 0.0 | 0.00–4.1 | 3 | 4.2 |
| Slovenia[b] | 1,627 | 264 (16) | 0 (0) | 0.0 | 0.00–1.1 | 0 | 0.0 |
| Slovakia[a] | NA | 151 (NA) | 0 (0) | 0.0 | 0.00–0.44 | 2 | 1.3 |
| Total | 72,263 | 26,008 | 232 (6) | 0.9 | NA | 269 | 1.1 |

[a]Some consignments that entered through another member state.

[b]Some consignments where the place of destination was in another member state.

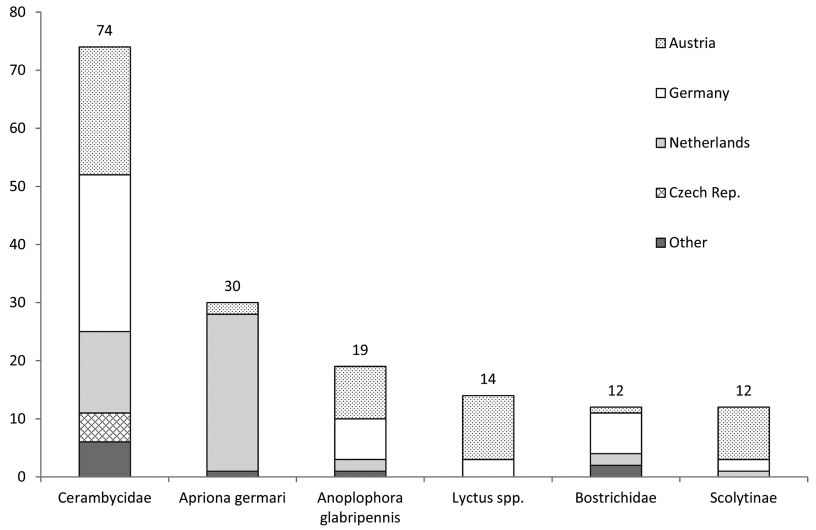


**Fig. 1.** The number of interceptions of harmful organisms of the six most frequently intercepted taxa in WPM associated with stone imports from China to the EU between 2013 and 2015, separated by the intercepting EU member state. The category 'Cerambycidae' excludes those identified as *Apriona germari* or *Anoplophora glabripennis,* which are shown separately and the category 'Bostrichidae' excludes *Lyctus* sp. which are shown separately.

**Table 3:** Results from Austria of inspecting WPM from China for harmful organisms and the presence of compliant ISPM-15 markings between April 2013 and December 2016

| Inspection parameter | Time period | | | |
|---|---|---|---|---|
| | April–Dec 2013 | Jan–Dec 2014 | Jan–Dec 2015 | Jan–Dec 2016 |
| No. of consignments entering Austria | 1,120 | 1,343 | 923 | 873 |
| No. of consignments inspected (percentage) | 345 (30.8) | 356 (26.5) | 382 (41.4) | 337 (38.6) |
| No. of consignments with harmful organisms (% of inspected consignments) | 29 (8.4) | 18 (5.1) | 39 (10.2) | 66 (19.6) |
| No. of consignments with missing or incorrect ISPM 15 marking (% of inspected consignments) | 9 (2.6) | 8 (2.2) | 6 (1.7) | 5 (1.5) |

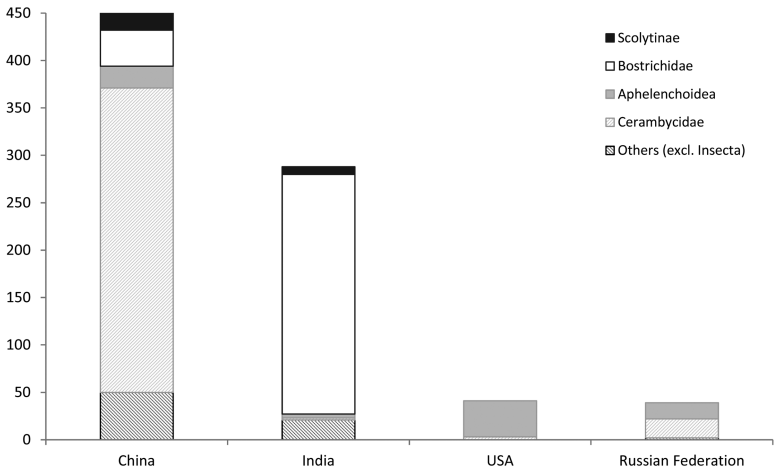


**Fig. 2.** Number of interceptions of harmful organisms found in association with wood packaging imported to the EU between 1999 and 2014 for the four source countries with the most interceptions divided by pest organism type.

compliant ISPM-15 mark but were infested was 2.2%. Therefore, although the proportion of consignments with harmful organisms was higher in those without a compliant ISPM marking (2.2%) than the level for all consignments (0.9%), the ISPM-15 mark was of little value in predicting whether harmful organisms were present. Overall, the above data suggest that most of the risk of pests being introduced into EU with WPM associated with stone products from China comes from consignments with ISPM-15 marks.

The efficacy and integrity of the measures taken by China to ensure that WPM exported to Europe meets EU requirements was the subject to an audit visit by the EU's Food and Veterinary Office (FVO) in June 2013 (EU 2013). The FVO (now called 'Health and Food Audits and Analysis') is an EU agency that carries out audits within and outside the EU to ensure that EU legislation on food safety, animal health and welfare, plant health, and in the area of medical devices is implemented and enforced. The FVO noted that

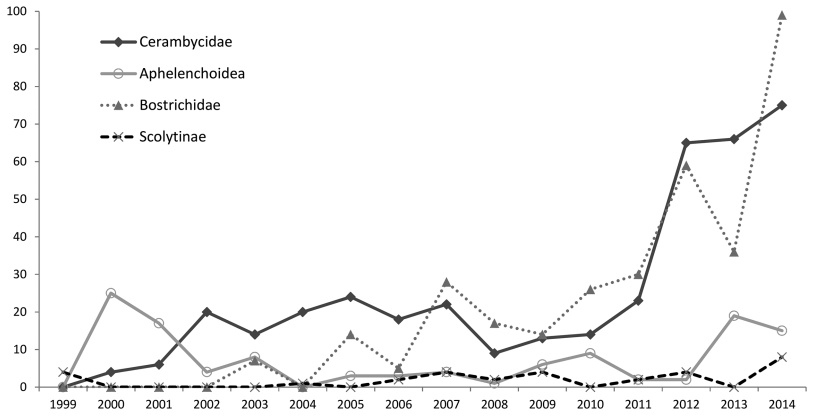


**Fig. 3.** Annual number of interceptions of the four most important groups of harmful organisms intercepted in the EU between 1999 and 2014 on WPM associated with worldwide imports.

WPM treatment companies in China were subject to official controls, and although there were some deficiencies, the controls were to a large extent in line with ISPM 15. However, there was some evidence that fraudulent marks were used at a few locations that were not approved treatment facilities and therefore were outside of official control. The FVO concluded that 'the current system of official controls in China does not adequately ensure that WPM which forms part of consignments of goods exported to the EU is marked and treated according to ISPM No. 15' (EU 2013). The FVO conclusions indicate that where treatments to comply with ISPM 15 have been carried out, they are likely to have been effective, but the risks to the EU stem from WPM that has not been treated at all and has been fraudulently marked.

Haack et al. (2014) reviewed studies into the efficacy of heat treatments as a means of eliminating *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) (emerald ash borer) from wood. In these studies (e.g., Myers et al. 2009) there was some survival of *A. planipennis* treated at temperatures of ≥60°C for ≥30 min. However, the studies did not replicate the heat regime required by ISPM 15 because the temperature was measured in locations other than the center of the wood, e.g., Myers et al. (2009) recorded the temperature at a depth of 3.5 cm from the outer bark surface, not necessarily in the center of the wood.

The proportion of consignments with compliant ISPM-15 markings in the present study was 98.9% (noncompliance was 1.1%; Table 1). This is a slightly higher rate of compliance than the figure of 97.7% reported by Haack et al. (2014) for WPM worldwide inspected in the United States in 2009. In the United States, an increasing rate of compliance was noted annually after initial implementation of ISPM 15 by the United States in 2005 (72.4% compliant), to full implementation in 2006 (89.2%), and again later in 2009 (97.7%).

In the EU survey of WPM associated with stone products from China as reported in this paper, the average proportion of consignments in which harmful organisms were found for all member states combined was 0.9% and much higher in some individual countries (Austria, 6.9%; France, 6.9%; Finland 3.4%; and the Netherlands 3.0%). This is a much higher interception rate of live pests in WPM than the proportions reported by Haack et al. (2014) for inspections of worldwide WPM made in the United States between the implementation of ISPM 15 in the United States in 2005 and 2009 (0.11%). However, the EU survey of WPM from China used for transporting stone was designed to look at some of the pathways that were known to be high risk and therefore a relatively high proportion of infested consignments was not unexpected. In addition, in the United States, inspectors do not test for nematodes and do not consider Bostrichidae or Anobiidae to be quarantine pests.

The significant differences seen in the number of consignments in which harmful organisms were detected in the different EU member states could reflect 1) different survey techniques and the application of these techniques in different member states and 2) different levels of infestation in the consignments received by different member states. This second explanation could result from various member states using different exporters from the same region in China or importing stone products from different parts of China. Of these two explanations, the first scenario appears to be the most likely. One piece of supporting evidence is that the five member states finding harmful organisms in the highest proportion of consignments inspected is the same for both categories CN 6801 00 00 (setts etc.) and CN 6802 (worked monumental stone etc.), the two categories for which the most data are available. Therefore, it is likely that the methods or sampling effort applied in some member states is inadequate to effectively detect all harmful organisms. Consignments with harmful organisms would probably be intercepted more frequently if most member states adopted the same inspection methods as used in Austria and France. Experience in Austria has shown that it is necessary to totally unload consignments to effectively inspect any associated WPM. However, it may be more practical to carry out such inspections at the final destination point of the consignments due to the time and space constraints at points of entry.

The results of inspection of WPM imported from China to Austria (Table 3) show that the proportion of consignments in which harmful organisms were detected in 2016 (19.6%) was almost three times the rate reported in Table 2 for April 2013–March 2015 (6.7%). Such values suggest that the problem with harmful pests being introduced on WPM has not declined over this period and in fact could be increasing.

Figures 2 and 3 are both derived from Europhyt data, which is the EU database of plant health-related pest interceptions and outbreaks. Figure 2 shows the broad differences in the groups of invertebrates that have been intercepted on WPM from China, India, the United States, and Russia. Such differences likely reflect variation in both the invertebrate fauna present in each country and the type of wood that is generally used to construct WPM in each country. The figure shows that there has been an increase in the number of interceptions of Bostrichidae and Cerambycidae since 2010. However, given that there is no accompanying data on the number

of inspections, including negative inspections, the increase could be due to a number of causes such as an increasing number of inspections, improved inspection methods or intensity of inspections, or an increase in the level of infestation of the WPM. The increase in numbers of Bostrichidae and Cerambycidae intercepted in WPM during 2012–2014 compared with 1999–2011 (Fig. 3) may in part reflect the EU-wide survey of WPM associated with stone imports from China reported herein, although note that this EU survey did not start until April 2013.

One possible future alternative to inspection of wood packaging to detect harmful organisms and check for ISPM-15 markings could be to test wood to see if heat treatment leads to a change in the chemical profile of the wood. For example, Iline et al. (2014) demonstrated differences in the profile of enzyme activity and sugar concentration in *Pinus radiata* D.Don (Pinales: Pinaceae) wood that had been heated. However, a considerable amount of further work would be needed before such a test could be used in practice because it would need to be tested on a range of tropical and temperate softwood and hardwoods and take account of seasonal fluctuations in wood metabolites. One other complication of testing for heat treatment could be that the tests may be able to demonstrate that wood has been heat treated but not if the treatment was hot enough and long enough to be effective against harmful organisms.

## The Significance of Some of the Pests Found in Association With WPM

Asian longhorned beetle (*Anoplophora glabripennis* (Motschulsky) [Coleoptera: Cerambycidae]) is the prime example of a pest that is known to have been moved with WPM and establish invasive populations in the EU and North America (Haack et al. 2010, Eyre and Haack 2017, Haack 2017). A combination of the outbreaks of *A. glabripennis* in agricultural windbreaks, street trees, and highway greenbelts in China (Williams et al. 2004) and the exponential increase in exports from China that are often associated with WPM has created an effective pathway for the movement of this pest. This pathway has resulted in numerous outbreaks of *A. glabripennis* in both the EU and in North America (Eyre and Haack 2017). Eradication is the goal in all cases where *A. glabripennis* has been introduced (Eyre and Haack 2017, Haack 2017, Haack et al. 2010). In 2015, the EU agreed on emergency measures that member states must employ to eradicate *A. glabripennis* outbreaks (EU 2015).

*A. germari*, another cerambycid beetle, was intercepted 30 times during the 2 yr of the survey of WPM from China. *A. germari* is present in China, South East Asia, the Korean Republic, and southern Asia (EPPO 2014). There have not been any reported establishments of this pest outside of Asia to date. *A. germari* has numerous deciduous larval hosts including species of *Morus*, *Malus*, *Populus*, and *Salix*. It is considered a serious pest of mulberry (*Morus*) trees used for silkworm production in China and northern India and also an important pest of apple (*Malus*), fig (*Ficus*), paper mulberry, walnut (*Juglans*), and poplar (*Populus*) trees (Wang 2017).

Other cerambycids that were identified to the genus or species level in the present survey were *Anoplophora chinensis* Forster (Coleoptera: Cerambycidae) (1 interception), *Anoplophora* sp. (2), *Aromia* sp. (1), *Batocera lineolata lineolata* (Chevrolat) (Coleoptera: Cerambycidae) (3), *Batocera* sp. (3), *Hesperophanes* sp. (2), *Monochamus alternatus* (Hope) (Coleoptera: Cerambycidae) (2), *Phoracantha semipunctata* Fabricus (Coleoptera: Cerambycidae) (1), *Purpuricenus temminickii* (Guérin-Méneville) (Coleoptera: Cerambycidae) (1), *Saperda* sp. (1), and *Xylotrechus* sp. (1).

Bostrichidae (powderpost beetles) have been one of the most commonly intercepted insect families in wood packaging, although none of the members of this family are listed as quarantine species for the EU. They can attack living, dead, or felled trees and cause considerable damage. Several species are highly polyphagous (Booth et al. 1990). Some wood boring beetles, including many bostrichids are secondary colonizers of treated wood and will infest WPM after treatment, thus, their presence on WPM may not always reflect treatment failure (Haack et al. 2014).

Bark and ambrosia beetles (Coleoptera: Curculionidae: Scolytinae and Platypodinae) are considered to be the most economically important borers of living trees in Europe (Sauvard 2004). One example of an invasive ambrosia beetle that has become established in the EU is *Xylosandrus crassiusculus* (Motschulsky) (Coleoptera: Curculionidae). This Asian species is a highly polyphagous pest of woody plants and was first discovered near Pisa in Italy in 2003 (EPPO 2015) and could have been introduced into the EU in WPM or on live plants. None of the Scolytinae or Platypodinae collected in the survey were identified to the generic or species level.

### Pinewood Nematode

There were nine interceptions of pinewood nematode on WPM from China in the present survey. This nematode is the causal agent of pine wilt disease and is native to North America but has become an invasive pest in Asia and Europe (Akbulut et al. 2017). Pines infected with *B. xylophilus* were first found in Europe near Lisbon, Portugal in 1999 and since then, has spread to central Portugal, Madeira, and Spain (Mallez et al. 2015). Human activities, including logging and internal trade that requires WPM have been proposed as possible causes of the rapid internal spread of pinewood nematode within China (Robinet et al. 2009, Hu et al. 2013). Soliman et al. (2012) estimated that in Europe, in the absence of regulatory controls, pinewood nematode could have a financial impact of €22 billion between 2008 and 2030. It is considered possible that pinewood nematode could extend as far north as Scandinavia in the future (Robinet et al. 2011), although pine wilt disease may not be expressed under such cool summer climatic conditions (Rutherford et al. 1990, Akbulut et al. 2017).

### Buprestids and Other Beetles

There was one interception of a buprestid (jewel beetle) during the present EU survey of Chinese WPM, but there is no information to indicate whether it could have been *A. planipennis* (Fairmaire). In the United States, there were 245 interceptions of buprestids on WPM imported from the entire world between 1985 and 2000 (Haack et al. 2002), of which, 38 were *Agrilus* sp. Most of these interceptions were on WPM.

## Conclusion

It is unlikely that the international movement of WPM can ever be without some phytosanitary risk. The evidence from the present 2-yr survey of WPM from China (2013–2015) supports the conclusion of Haack et al. (2014) that ISPM 15 has only been partially effective at reducing the risks associated with WPM. Without the impractical and improbable prospect of inspecting 100% of all risky consignments and the ability to detect 100% of harmful organisms within those consignments, inspection is best considered as a means of gathering evidence of risk and a deterrent rather than a means of completely preventing the movement of pests and pathogens. Such surveys can also generate the necessary evidence to review ISPM 15 as a control system and to investigate compliance at the source.

This study has shown significant differences between the proportions of consignments in which harmful organisms have been

detected in different EU member states. This is most likely the result of differences in sampling methodology and sampling effort (in terms of time spent inspecting each consignment). If the different rates are in fact driven by differences in methodology then harmonizing to the most effective methodology may lead to an approximate sevenfold increase in the number of interceptions across all member states. Despite the current deficiencies, a pathway-level economic risk assessment of the movement of WPM into the United States, Leung et al. (2014) found that even if ISPM 15 can only be partially effective it is still likely to have large economic benefits estimated as $11 billion for the United States by 2050.

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