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ISPM No. 15 and the Incidence of Wood Pests: Recent Findings, Policy Changes, and Current Knowledge Gaps

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ABSTRACT

Largely as a result of international trade, hundreds of species of bark- and wood-infesting insects have become established in countries outside their native range. Many of these exotic insects have caused severe economic and environmental impact to urban and forest trees in the receiving countries. Most bark- and wood-infesting insects have been transported to new countries by means of the wood packaging material (WPM) pathway, which includes products such as pallets and crating. The international community responded to the phytosanitary risk posed by untreated WPM by approving ISPM (International Standards for Phytosanitary Measures) No. 15 in 2002 that specifies treatments designed to kill wood pests in WPM used in international trade. In response to new research findings, ISPM 15 was revised in 2006 and 2009. The goal of ISPM 15, as stated in the 2009 revision, is to 'reduce significantly the risk of introduction and spread of most quarantine pests.' Since 2002, heat treatment and methyl bromide fumigation have been the only two approved phytosanitary treatments for WPM. New treatments are urgently needed given that the use of methyl bromide is being phased out worldwide. This paper presents background information on (a) ISPM 15, (b) changes that were made to ISPM 15 during each of the two revisions, (c) research highlights from projects that were used to support the revisions, (d) incidence of insects of quarantine significance that were found in WPM during surveys conducted before and after implementation of ISPM 15, and (e) research needs to further improve ISPM 15.

Keywords: fumigation, heat treatment**,** ISPM 15, quarantine pest, wood packaging material

1. INTRODUCTION

Hundreds of species of tree-infesting insects have been introduced to countries outside their native range during the past few centuries (Mattson *et al*. 1994, Brockerhoff and Bain 2000, Brockerhoff *et al*. 2003, Langor *et al*. 2009, DAISIE 2009, Aukema *et al*. 2010). Some of these exotic (= alien, nonnative) insects feed on the buds, foliage, or fruit of trees, while others invade the roots, trunks, or branches. For those insects that feed and develop within the trunk of a tree, some species develop primarily within the cambial region where they feed mostly on the inner bark (phloem) and outer sapwood, while others develop mostly in the sapwood, and still others develop deep within the heartwood (Haack and Slansky 1987, Hanks 1999, Lieutier *et al*. 2004, DAISIE 2009, Roques *et al*. 2010).

It is primarily the trunk-infesting insects that are most likely to be transported to new countries when trees are cut and processed into wood packaging material (WPM) such as crating, pallets, and dunnage. Historically, WPM has often been made from low-grade timber, including trees recently killed by bark- and wood-infesting insects (Allen and Humble 2002). Moreover, the

Table 1: Examples of wood-infesting insects and nematodes that were likely introduced to countries beyond their native range by means of wood packaging material. Note, in some cases eradication of the pest organism was declared following intensive area-wide control programs (e.g., Brockerhoff *et al*. 2010a, Haack *et al*. 2010).

Scientific name	**Common name**	**Native range**	**Countries where introduced** [a]
Agrilus planipennis	Emerald ash borer	Asia	CA RU US
Anoplophora glabripennis	Asian longhorned beetle	Asia	AT CA DE FR IT NL US
Bursaphelenchus xylophilus	Pinewood nematode	N. America	CN ES PT JP TW KR
Megaplatypus mutatus	None (ambrosia beetle)	S. America	IT
Sirex noctilio	Sirex woodwasp	Eurasia	AR AU BR CA CL NZ US UY ZA

[a] Country codes: AT = Austria, AU = Australia, BR = Brazil, CA = Canada, CL = Chile, CN = China, DE = Germany, ES = Spain, FR = France, IT = Italy, JP = Japan, KR = South Korea, NL = Netherlands, PT = Portugal, RU = Russia, TW = Taiwan, ZA = South Africa.

trunks and branches of trees are often colonized by insects such as bark beetles and wood borers when a tree is severely stressed, soon after it dies, or when it is cut, and many of these species are pests of quarantine concern. In addition, the time required from egg hatch to adult emergence can be as short as a few months for many species of bark beetles to 1-3 years for most wood borers (Haack and Slansky 1987). Given the above life-history data, it is understandable why such insects can easily be associated with and transported in WPM that has recently been manufactured from green wood.

The number of bark- and wood-infesting insects that have become established beyond their native range has been increasing exponentially in recent decades (Aukema *et al*. 2010, Kirkendall and Faccoli 2010, Haack and Rabaglia 2011). A few of the high-profile, trunk-infesting insects and nematodes that were likely introduced to new countries via the WPM pathway are listed in Table 1. Among these is *Agrilus planipennis*, an Asian buprestid beetle, whose larvae develop in the cambial region of ash (*Fraxinus*) trees. As of early 2011, millions of ash trees have been killed by *A. planipennis* in North America (Haack 2006, Poland and McCullough 2006), and it is now established and killing ash trees near Moscow, Russia, as well (Baranchikov *et al*. 2008). The Asian cerambycid beetle, *Anoplophora glabripennis*, has established breeding populations in several countries in Europe and North America (Hérard *et al*. 2006, Haack *et al*. 2010). In each of these countries, area-wide control efforts are underway to eradicate *A. glabripennis* populations given that this beetle can infest and kill apparently healthy broadleaf trees in several genera. *Bursaphelenchus xylophilus*, a North American pine (*Pinus*)-infesting nematode, has caused the death of millions of pine trees in several Asian countries and now has entered Portugal and Spain as well where it threatens European pines (Mota *et al*. 1999, Mota and Vieira 2008, Mota *et al*. 2009, EPPO 2010, Kwon *et al*. 2011). The South American platypodid beetle *Megaplatypus mutatus* is an unusual ambrosia beetle in that it infests living broadleaf trees, and is especially damaging to poplar (*Populus*) plantations in South America, as well as in Italy where it was first reported in 2000 (Alfaro *et al*. 2007, Kirkendall and Faccoli 2010). And lastly, the Eurasian siricid woodwasp *Sirex noctilio*, along with its symbiotic microorganisms, has caused widespread pine mortality when introduced into countries in the southern hemisphere (Hurley *et al*. 2007), but so far has caused little damage in North America (Dodds *et al*. 2010).

Given the number of newly established exotic bark- and wood-infesting pests being reported worldwide during the 1990s, and their strong association with WPM (Haack 2001, 2006, Brockerhoff *et al*. 2006, Haack 2006, McCullough *et al*. 2006, Haack *et al*. 2010, Haack and Rabaglia 2011), there was a strong impetus for the world community to address the phytosanitary concerns with WPM. The culmination of these international efforts was the approval of ISPM 15 in 2002, which was entitled 'Guidelines for Regulating Wood Packaging Material in International Trade' (IPPC 2002). The abbreviation 'ISPM' stands for International Standards for Phytosanitary Measures, which is the name commonly used for such standards by the International Plant

Protection Convention (see https://www.ippc.int/index.php?id=13399). Note that although ISPM 15 was approved in 2002, each country selects when it will actually implement and enforce the new standard. For example, New Zealand was the first country to implement ISPM 15, doing so in 2003. Australia began enforcement of ISPM 15 in 2004, the European Union in 2005, and North America in 2006. As of early 2011, more than 70 countries require that imports meet the standards of ISPM 15 (http://www.ispm15.com/start.htm). The objectives of this paper are to briefly present the history of ISPM 15, the research efforts that supported the recent revisions to ISPM 15, the incidence of quarantine pests that were detected during international surveys of WPM pre and post-ISPM 15, and future research needs.

2. HISTORY AND CHANGES TO ISPM 15

As mentioned above, ISPM 15 was approved by the governing body of the International Plant Protection Convention (IPPC) in 2002 in response to the phytosanitary threat posed by untreated WPM used in international trade (IPPC 2002). By 2011, ISPM 15 had been revised twice: first in 2006 and again in 2009 (Table 2; IPPC 2006, 2009). The stated goal of ISPM 15 when first approved in 2002 and in the 2006 revision was to 'practically eliminate the risk for most quarantine pests and significantly reduce the risk from a number of other pests that may be associated' with wood packaging material (IPPC 2002, 2006). In the 2009 revision, the goal of ISPM 15 was changed slightly to 'reduce significantly the risk of introduction and spread of most quarantine pests' (IPPC 2009). It is important to remember that the goal of ISPM 15 has never been to completely eliminate all risk, but rather to significantly reduce the phytosanitary risk posed by untreated WPM. Many factors are considered when developing a treatment standard such as the desired level of efficacy (percent mortality), treatment costs, any environmental impacts of the treatment, and any physical changes to the integrity of the product as a result of the treatment. There are other phytosanitary treatments now under development for wood such as dielectric heating by means of microwave (MW) or radiofrequency (RF) irradiation (Hoover *et al*. 2009), and other fumigants like sulfuryl fluoride that are being tested as alternatives to methyl bromide (Barak *et al*. 2010, Buckley *et al*. 2010).

Since 2002 there have only been two approved phytosanitary treatments for WPM: heat treatment and methyl bromide fumigation. Details on these two treatments and the major changes that took place in the revisions of 2006 and 2009 are presented in Table 2. The initial heat treatment standard as written in 2002 called for a minimum temperature of 56°C to be reached and held for 30 minutes as measured at the core. In practice, readings were taken from the largest piece of wood (as measured in cross-section) in the heating chamber. No changes were made to the heat treatment schedule in 2006 but in 2009 the language for the required time of heating was changed to 30 continuous minutes throughout the entire profile of the wood, including the core (Table 2). This change was made because other technologies were being developed for heating wood, such as microwave technology, where heating occurs throughout the profile of the wood simultaneously (Hoover *et al*. 2010). With respect to fumigation, the 2002 standard required an exposure time of at least 16 hrs, but this was extended to 24 hr in the 2006 revision (Table 2) based primarily on *Bursaphelenchus xylophilus* research (Soma *et al*. 2003).

The manner in which bark was considered has also changed between revisions of ISPM 15 (Table 2). In the original 2002 version and the 2006 revision of ISPM 15, no specific limitations were placed on bark (Table 2); however, with technical justification, countries could require that imported WPM be made from debarked wood (IPPC 2002). In the 2009 revision, tolerance

Table 2: Summary data for the wood packaging material (WPM) treatments as specified in ISPM 15 when first approved in 2002 and in the two subsequent revisions that were approved in 2006 and 2009.

Year	Treatments highlights [a]
2002	HT: minimum of 56°C for 30 min at the core. MB: various fumigation schedules were given but required air temperatures > 10°C and exposure for at least 16 hr. No restrictions on bark listed.
2006	As above except the minimum exposure time for MB was extended to 24 hr.
2009	HT redefined as 30 continuous min throughout the entire profile of the wood, including the core. MB schedule remained the same but many details were added on proper procedures, including that debarking had to precede fumigation. Repaired and remanufactured wood-packaging were defined and the need for retreatment was clarified. WPM should be made from debarked wood. Limits on size of individual bark patches were given. Clarity was given on the ISPM-15 mark and how and where it should be displayed.

[a] HT = heat treatment; MB = methyl bromide fumigation. Source: IPPC (2002, 2006, 2009).

limits were placed on the size of individual pieces of residual bark (Table 2). Specifically, WPM was to be made from debarked wood, but distinct pieces of bark could remain if they were either less than 3 cm in width (regardless of their length), as may occur along the edge of a board, or if they were greater than 3 cm wide, then the total surface area of the individual piece of bark had to be less than 50 square centimeters (IPPC 2009), which is a little larger than the typical credit card. The research basis for this decision is discussed below.

3. RESEARCH BASIS FOR CHANGES IN ISPM 15

Several studies, both published and unpublished, were used to support changes made in the 2006 and 2009 revisions of ISPM 15 (Table 2, IPPC 2006, 2009). The major change made in the 2006 revision was lengthening the exposure time of wood to methyl bromide from 16 to 24 hours. The need for this change came about primarily from studies with *Bursaphelenchus xylophilus* that showed that some nematodes were able to survive a 16 hr exposure period, but complete control was generally reported with exposure times of 24 hr. The work of Soma *et al*. (2003) was often cited in support of this change. In addition, research by Barak *et al*. (2005) indicated that a 24 hr exposure period to methyl bromide was also adequate to kill *Anoplophora glabripennis* in WPM.

The 'International Forestry Quarantine Research Group' or IFQRG was formed in 2003 and first met in 2004 at the FAO Headquarters in Rome, Italy. The IFQRG website is now housed by IPPC at <https://www.ippc.int/index.php?id=ifqrg&no_cache=1&L=0>. The mission of IFQRG is to address forestry quarantine issues through discussion and collaborative research, especially projects related to ISPM 15. The first research question addressed by IFQRG was to determine if wood treated to ISPM 15 standards could be colonized after treatment by pests of quarantine concern, especially when bark was present. Four studies were conducted by IFQRG members in four different countries to address this question (Table 3). In all studies, insects of quarantine significance colonized the wood after treatment, especially when bark was present. In addition, three of the studies evaluated colonization success by bark- and wood-infesting insects on treated boards with bark patches that varied in size (Haack and Petrice 2009, Humble unpublished data, Schröder unpublished data). In the study by Haack and Petrice (2009) it was noted that as bark patch size decreased fewer insects colonized the patches, and when colonization did occur on the smaller patches, fewer insects were able to complete development. In addition, for patches of similar surface area, bark beetles completed development more often in square patches than in rectangular patches. Findings from the above studies were used to support the tolerance limits for bark patch size that were adopted in the 2009 revision of ISPM 15 as discussed above (IPPC 2009).

Table 3: Summary data for field and laboratory studies that demonstrated that bark- and wood-infesting insects would infest and reproduce in recently cut logs and boards with bark after treatment to ISPM 15 specifications for hest treatment (HT) or methyl bromide fumigation (MB).

Country	Type of study	Genus of test trees	Families of insects that infested the treated wood	Reference
Canada	HT, MB -field	*Pinus*	Scolytidae [a]	L.M. Humble, unpublished data
Germany	HT - field, lab	*Picea*	Scolytidae	T. Schröder, unpublished data
United Kingdom	HT - field	*Pinus*	Scolytidae	Evans (2007)
United States	HT - field	*Acer, Carya Pinus, Quercus*	Cerambycidae and Scolytidae	Haack and Petrice (2009)

[a] Note that many taxonomists now treat the family Scolytidae as a sub-family (Scolytinae) of the weevil family Curculionidae.

4. INCIDENCE OF QUARANTINE PESTS IN WOOD BASED ON SURVEYS

Has ISPM 15 made a difference in the number or arrival rate of WPM-associated bark- and wood-infesting insects in world trade? This is a difficult question to answer because there have been very few accurate accounts of the incidence of such insects in WPM both pre- and post-implementation of ISPM 15. The authors of the present paper are members of a working group that is attempting to answer the above question. The working group is entitled 'Effects of Trade Policy on Management of Non-Native Forest Pests and Pathogens' and is sponsored by The Nature Conservancy and meets at the National Center for Ecological Analysis and Synthesis (NCEAS) at the University of California, Santa Barbara. Actual face-to-face meeting took place during 2008 to 2010 and now the group is actively preparing journal articles. Brockerhoff *et al*. (2010b) published an extended abstract that provided the overall objectives of this group effort.

We are aware of two detailed surveys that were conducted prior to implementation of ISPM 15 (Bulman 1992, 1998). Overall, inspections of 2547 'consignments' were reported in Bulman (1992), and 9001 'consignments' in Bulman (1998). It is important to note, however, that the term 'consignment' in these two surveys was used for all similar-type products within each container or partial container. Therefore one single consignment in the Bulman (1992) or (1998) studies likely represented multiple WPM items. By contrast, in the three post-ISPM 15 surveys discussed below, data were recorded for each distinct WPM item, e.g., a single pallet. Therefore the infestation rates reported in these two pre-ISPM 15 surveys (Bulman 1992, 1998) are not directly comparable to the three post-ISPM 15 studies that follow. We still hope to find additional datasets from anywhere in the world where the surveys were conducted prior to implementation of ISPM 15.

Since implementation of ISPM 15, surveys of WPM that were stamped with the ISPM 15 mark were conducted in Australia in 2005 (Zahid *et al.*, 2008), the European Union in 2005 (IFQRG 2006, European Union unpublished data), and the United States in 2006 (Haack and Petrice 2009). The results in each of these surveys were broadly similar (Table 4). Overall, live insects of quarantine concern were found on about 0.5% of the marked WPM items inspected in Australia, 0.3% in the European Union, and 0.1% in the United States (Table 4). In all three of these surveys, individual WPM items were inspected, such as a single pallet or a single piece of dunnage. In addition, for the surveys conducted in Australia and the United States it was also noted whether or not the live insects were found beneath patches of bark (Table 4). Overall, 78% of the interceptions of live insects were associated with bark in Australia (Zahid *et al.*, 2008), and 100% in the United States (Haack and Petrice 2009). This close association between the presence of bark and live insects was another important finding that was used to support the

Table 4: Summary data for the incidence of live insects found in association with wood packaging material during surveys of imports in various countries conducted after implementation of ISPM 15.

Year ISPM-15 was imple-mented	**Year of survey**	**Country or region where survey was conducted**	**Quantity of wood items or consignments inspected**	**No. of wood items or consignments infested with live insects**	**Percent of live insects found in association with bark**	**Reference**
2004	2005	Australia	19,522	0.5%	78%	Zahid *et al*. (2008)
2005	2005	EU	15,042	0.3%	Not given	IFQRG (2006)
2006	2006	USA	5,945	0.1%	100%	Haack & Petrice 2009

need for bark tolerance limits for the maximum size of individual bark patches that could be allowed on WPM used in international trade.

The above discussion highlights the need for comparable data to be collected both before and after international regulations are approved and implemented. Without adequate information on infestation rates that reflect real-world conditions before a new phytosanitary policy is introduced will make it exceedingly difficult to verify the impact of the policy change and determine if it adequately addressed the pathway risk.

It is important to recognize that there are many possible explanations for the occurrence of live bark- and wood-infesting insects in WPM stamped with the ISPM 15 mark (Haack and Petrice 2009). As was noted above, it is possible for some insects to colonize WPM after treatment, especially when bark is present. Second, there may be some insects that are tolerant of the treatment and therefore 100% mortality is not attained. Third, at times treatments may be improperly applied because of defective equipment or facilities. And fourth, fraud is always possible in that the mark could be applied to untreated wood.

5. FUTURE RESEARCH NEEDS RELATED TO ISPM 15

Research is still needed in many areas so that ISPM 15 can continue to be improved. For example, additional phytosanitary treatments beyond conventional heat treatment and fumigation with methyl bromide are called for, especially considering the international efforts to phase out use of methyl bromide because of its role in depletion of the ozone layer. However, related to any new phytosanitary treatment that is submitted for consideration as a WPM treatment under ISPM 15 is the question of efficacy. That is, what percent mortality should a new treatment need to achieve to be considered for inclusion in ISPM 15? This question is currently being discussed among the signatory countries to IPPC (IPPC 2010) and has also stimulated preparation of two recent journal articles (Haack *et al*. 2011, Schortemeyer *et al*. 2011) in which background information on this topic was presented along with possible solutions.

There have been a few studies in recent years suggesting that the current heat treatment schedule (56°C for 30 min) is not adequate to kill all wood-infesting insects (McCullough *et al*. 2007, Myers *et al*. 2009, Goebel *et al*. 2010) and fungi (Ramsfield *et al*. 2010). However, upon close examination of many of these papers it is clear that ISPM 15 protocols were not followed specifically, i.e., wood temperatures were recorded at various depths in the wood but not at the core. Therefore, more studies are needed on the topic of heat tolerance in wood-infesting organisms, and the efficacy of other temperature-time combinations should be evaluated and compared to the standard of 56°C for 30 min. For example, based largely on the work by Myers *et al*. (2009) a heat-treatment schedule of 60°C for 60 min was adopted in 2011 by USDA APHIS (US Department of Agriculture, Animal and Plant Health Inspection Service) for domestic movement of firewood within the United States that could potentially be infested with *Agrilus planipennis* (USDA APHIS 2011). It should be noted that the current heat treatment schedule of

56°C for 30 min was based primarily on research conducted in Canada with *Bursaphelenchus xylophilus* during the 1990s, and was later adopted for basically all wood-infesting insects of quarantine concern when ISPM 15 was developed in the early 2000s (Smith 1991, 1992, Haack *et al*. 2011). Therefore, it should not be surprising that some wood-infesting organisms occasionally survive the temperature-time combination of 56°C for 30 min.

Another high-priority research need is the development of techniques by which inspectors can verify that WPM has been subjected to the phytosanitary treatment that is stated on the ISPM 15 mark. For example, if the mark reads HT (= heat treatment), how can the inspector verify that the wood was actually heat treated to ISPM 15 standards? Could, for example, a temperature-sensitive solution be applied to the wood or to the mark that changes to various colors depending on the temperature it is exposed to? Similarly, is there a comparable method by which fumigation can be verified? Answers to the above questions and others will help improve and strengthen ISPM 15 and thereby further reduce the phytosanitary risk of WPM in international trade.

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