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DD 04: Wooden and Bamboo Commodities Intended for Indoor and Outdoor Use

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Contents

Introduction

North America's forests have been affected by introduced pests and diseases for several hundred years. Since the early 1900's, many exotic species have contributed directly in altering rural and urban landscapes forever. Among the numerous diseases that have had a negative effect on forests, some of the most notorious are chestnut blight, Dutch elm disease, butternut canker and more recently, *Phytophthora ramorum*. Chestnut blight wiped out chestnut trees, previously a very important component of eastern North American forests, whereas Dutch elm disease decimated the American elm throughout most of its natural range. Butternut canker devastated many populations of butternut, a highly valuable hardwood tree native to eastern North America, and *P. ramorum* destroyed numerous stands of coast live oak, California black oak and tanoak in California.

Many introduced insect pests have also compromised the health of North American trees and the welfare of industries that depend on them. Gypsy moth, *Lymantria dispar dispar*, introduced in Massachusetts more than two hundred years ago is still a pest of quarantine significance, having spread through much of the north-eastern U.S. States and adjacent Canadian provinces where it causes frequent defoliation of oaks and other broad-leaved trees over vast areas. The hemlock woolly adelgid, *Adelges tsugae*, first reported in eastern North America in the early 1950s, has since spread relatively rapidly and eliminated a large proportion of eastern hemlock stands from the eastern U.S. despite efforts to implement promising biological control programs. The pine shoot beetle *Tomicus piniperda* is another introduced exotic pest whose impacts in eastern North America have been significant, both in terms of its environmental and economic impacts (Haack and Lawrence 1995).

Among the exotic insect species that were introduced into Canada and the United States over the last 200 years or so, an estimated 368 species feed on woody plants (Mattson et al. 1994; Liebhold et al. 1995). A recent study by Koch et al. (2010) predicts that every year, about two exotic forest insect species will become established in some area of the U.S., with a significant forest insect pest causing economic impacts ranging in the order of tens of millions (or even billions) US dollars appearing every 5 to 6 years.

Exotic forest pests and diseases may be introduced into North America via a number of conveyances (for e.g., Asian gypsy moth eggs laid and transported on ships' hulls and cargo containers) and a multitude of man-made pathways, including nursery stock, Christmas trees, logs, lumber, firewood and wood packaging materials. The latter is believed to be the means by which two of the most destructive exotic pests currently infesting urban forests in eastern U.S. and Canada gained entry to North America: the Asian longhorned beetle, *Anoplophora glabripennis*, a serious pest of deciduous hardwood tree species under eradication in Ontario, New York, Massachusetts, New Jersey and Ohio; the brown spruce longhorned beetle, *Tetropium fuscum,* and emerald ash borer, *Agrilus planipennis*, a killing pest of ash trees currently expanding its range in several eastern U.S. states and in two Canadian provinces, threatening the very existence of *Fraxinus* species in North America.

Recognizing the serious risks posed particularly by untreated wood packaging materials at a global scale, the Commission on Phytosanitary Measures that governs the International Plant Protection Convention (IPPC) developed and adopted an international standard for the regulation of wood packaging material in international trade (International Standard on Phytosanitary Measures or ISPM 15), aimed at reducing the risk of pest introduction and spread via such material.

One pathway of introduction and spread of potential quarantine forest pests which is not currently regulated under international standards is wooden handicrafts and similar articles used for household purposes, even though it is reasonable to believe that at least some of these wood articles pose a similar risk to wood packaging materials. Other than ISPM 15, there are currently no adopted ISPMs that provide guidance specifically on reducing the risks of forest pests moving by any human-mediated means. There is an approved specification (No. 46) under the IPPC for the management of phytosanitary risks in the international movement of wood other than wood packaging material but until an international standard is developed, no guidelines are available on the phytosanitary certification approaches for the international movement of wood products and handicrafts made from wood.

Purpose

This discussion paper considers the phytosanitary risks that wooden and bamboo articles (hereafter referred to only as wooden articles) intended for indoor and outdoor use may pose if imported into the NAPPO region. We discuss the importance of the article size, intended end-use, and the relevance of the type of treatment or the level of processing that the wood components of the articles may have undergone. The interception data in Annexes 1 to 3 and the assessment of these commodities as possible pathways for quarantine pests lay the ground work for greater consideration by NAPPO of the phytosanitary risks associated with the wooden articles entering the region, through the development of guidelines considered effective in reducing the risk of pest introduction and spread.

Scope

The focus of this paper is to document the pest risk associated with the importation of wooden articles intended for indoor and outdoor use that can serve as a pathway for the introduction and spread of quarantine pests in the NAPPO region. It does not consider the risks associated with wood packaging, logs, and lumber.

1. Background

In recent years, increase in global trade of wooden articles constructed of unprocessed or primary processed plant parts and intended for both indoor and outdoor use has resulted in increased imports of these commodities into NAPPO member countries. Plant health officials in Canada, the U.S. and in Mexico have reported interceptions of many pests associated with wooden articles (Annexes 1-3 for more information on interceptions available upon request from the NAPPO Secretariat). An example of these interceptions is a collection of birdhouses constructed from the wood and bark of temperate trees, imported from Asia into Canada and the U.S. in the late 1990s, and found to be infested with bark beetles and bracket fungi. Another example is the discovery, in July 2004, of two unknown Cerambycidae, one belonging to the genus *Callidiellum* and the other to an unknown genus within the subfamily Lamiinae, on twig towers imported from Asia into the U.S.

Over the course of several years, U.S. authorities intercepted several adults of the brown fir longhorned beetle, *Callidiellum villosulum* (Fairmaire) (Coleoptera: Cerambycidae), from the wooden portion of numerous artificial Christmas trees. In response, APHIS issued a recall of four shipments of the trees. However, in December 2004, further interceptions of *C. villosulum* in artificial Christmas trees certified as kiln dried were reported from a number of U.S. states and additional recalls were issued by APHIS. Comparable cases of pest interceptions on manufactured wood products imported from China led the U.S. to issue a total of 304 Emergency Action Notifications over a 38-month period, from 2002 to 2005 (USDA APHIS 2011).

In January 2005, after intercepting multiple live wood boring beetles in artificial Christmas trees, APHIS suspended the importation from China of handicrafts and similar articles with intact bark, limbs, branches or twigs greater than 1 centimetre in diameter, pending further risk analysis and the development of regulations. A pest risk assessment and a risk management document both entitled “Pests and mitigations for manufactured wood décor and craft products from China for importation into the United States” were subsequently prepared. Based on their conclusions, APHIS determined that wooden handicrafts could be imported from China only if they met certain requirements.

In Canada, from 2000 to 2007, interceptions of 80 pests were recorded on bamboo products and wooden items ranging from furniture to handicrafts. Sixty-four (64) percent of the interceptions were from China. In July 2008, the inspection of wooden birdhouses imported from China revealed pest holes. Subsequent review identified the presence of the ambrosia beetle *Xylosandrus mutilatis* (Blanford) (Coleoptera: Curculionidae: Scolytinae) (S. Maccum, CFIA, pers. comm., Sept. 2009).

On June 2, 2009, 39 units in a shipment of birdhouses (constructed from wood and bark) from China were placed under detention because of the presence of numerous bark beetle larval feeding galleries, fragments of bark beetles (Scolytinae) and larger galleries from longhorned beetles (Cerambycidae) or wood boring beetles (Buprestidae). Also present were fragments of a parasitoid Bethylid wasp (*Scleroderma* spp.) and a live pupa (Hymenoptera) (S. Maccum, CFIA, pers. comm. Sept. 2009).

In response to these interceptions, Canada amended its Directive D-02-12 (”Import requirements for non-processed wood and other non-propagative wood products, except solid wood packaging material, from all areas other than the continental United States”) and currently specifies that decorative wood items that are not dried (i.e., with a moisture content of over 8%) or that contain untreated dry cones or either bark or wood exceeding 1.5 centimetres in thickness cannot be imported into Canada unless they are fumigated with methyl bromide at the prescribed rates and have achieved a moisture content of less than 20% (CFIA Directive D-02-12).

These examples demonstrate that the importation of home and garden décor, handicrafts and similar unregulated items containing unprocessed wood provides a pathway for the introduction of potentially harmful live plant pests and illustrates the need to assess and mitigate the risks associated with the importation of such articles into the NAPPO region.

This paper attempts to address the following questions:

Does the movement of wooden handicrafts represent a reasonable pathway for the introduction and spread of quarantine pests?
If these articles have an intended use that precludes pest spread or if the volume of infested articles in trade is small or negligible, is the application of sweeping phytosanitary measures for these commodities warranted?

2. Description of the Commodity

The wooden and bamboo articles under consideration in this discussion paper represent a wide diversity of products. They are either non-manufactured, constructed of untreated raw materials such as sawn timber, or commercially manufactured and highly processed, in some cases coated and packed commercially. They may be intended for either indoor or outdoor use, and may be with/without bark, seeds, cones and other plant components, with/without non-wood components of varied size (e.g., plastic, paper, metal parts). Generally, the degree of processing, the tree species, parts used, and the geographic origins of these articles and their components are unknown. Materials used to make such wooden articles do not necessarily originate from the same country as the one where the product is assembled and finished, increasing overall uncertainty about the product.

3. Assessment of Pest Risks Associated with Wooden Articles Intended for Indoor and Outdoor Use

The following evaluation provides a broad examination of the various factors that may affect the risks posed by the importation of these types of products. The diversity of products that fall under the definition of the commodity, the lack of information on many aspects related to these wooden articles and the resulting high uncertainty in the assessment of their risks render it difficult to single out the articles that constitute the highest risks for the introduction and spread of quarantine pests in the NAPPO region. Under these circumstances, the end use of such commodities - outdoors as opposed to indoors - and their size could prove as the only reliable factors contributing to their risk rating.

PROBABILITY OF ENTRY OF PESTS INTO THE NAPPO REGION

3.1 Probability of Pests Occurring in or on the Commodity at Origin

Pests can attack the wood used for the fabrication of handicrafts and other household or garden articles prior to harvest, between harvest and manufacture or after manufacture. The growth, development, and survival of wood-inhabiting insects, fungi and nematodes associated with wooden articles is dependent on three characteristics that change significantly following tree death, harvest, and/or milling: nutrient quality, temperature and moisture content of the wood (E. Allen, Canadian Forest Service, pers. comm., Sept. 2010). When wood dries in the air, it eventually reaches the equilibrium moisture content (EMC) of its ambient surroundings, generally considered to be 5-20% at a global level (Simpson 1998) over a period that may extend from several weeks up to a year, depending on the dimensions of the wood, the temperature, and moisture conditions that the wood is exposed to (Simpson and Hart 2000). Pests present in the wood at the time of tree harvest or tree death will generally be successful in completing their development to the adult stage despite reductions in tree moisture content, unless the drying process is accelerated (e.g. kiln drying), and occurs during the feeding stage of the pest (i.e., insect) when it is most dependent on tree moisture.

Wood-inhabiting insects like termites (order Isoptera), powder post beetles (Lyctidae), false powder post beetles (Bostrichidae) and deathwatch beetles (Anobiidae) are commonly found in dry, seasoned wood with different optimal moisture requirements for growth and minimum levels for survival (E. Allen, Canadian Forest Service, pers. comm., Sept. 2010). For example, *Lyctus* shows greatest activity between 10 and 20 % but can survive in wood with moisture content as low as 6%, (Parkin 1943, Brammer 2008). *Prostephanus truncatus* (Horn), a Bostrichid beetle, was reported to breed most successfully at 10-12% moisture (Nang'ayo et al. 1993). Low moisture conditions in wood can prolong development of insect larvae and subsequent emergence of adults; there are anecdotal reports of Buprestid beetles emerging from seasoned wood inside buildings 30 years after infestation could have occurred (Beer 1949).

For most decay fungi, optimum moisture conditions for growth are above wood fiber saturation (usually around 25 to 30% mc,) but well below the waterlogged condition (Carl and Highley 1999). Fungal development below fiber saturation is greatly retarded and is completely inhibited below 20% wood moisture content (Hunt and Garratt 1938, Panshin and deZeeuw 1964, Findlay 1967, Scheffer and Verrall 1979, Zabel and Morrell 1992). Many wood-inhabiting fungi are capable of becoming dormant if moisture conditions fall much below the range of fiber saturation, surviving in a dormant vegetative state, and reviving once moisture conditions again reach levels around fiber saturation (Griffith & Boddy 1991, Carl and Highley 1999). This phenomenon is well documented. For example, Hubert (1924) revived the blue stain fungus *Ceratostomella* sp. and the decay fungus *Trametes serialis* Fr. after 7 years of drying. Theden (1972) reported survival of decay fungi in dry wood up to 10 years.

Tainter et al. (1984) reported variable survival of *Ceratocystis fagacearum* (Bretz) Hunt up to 140 days depending on location and season. More recently Uzunovic and Khadempour (2007) tested the survival of both stain and decay fungi (*Ophiostoma clavigerum* (Robinson-Jeffrey & Davidson) Harrington, *Ophiostoma montium* (Rumbold) Arx, *Leptographium longiclavatum* Lee, Kim & Breuil, *Leptographium tenebrantis* Barras & Perry, Ambrosiella sp. Arx & Hennebert, *Trichaptum abietinum* (Dicks) Ryvarden and *Phellinus chrysoloma* (Fr.) Donk) in laboratory- and naturally-infested pine wood maintained under the same conditions (*Sporothrix*, *Leptographium* sp. yeasts/bacteria, Zygomycetes, *Aspergillus* sp. *Paecilomyces* sp., *Penicillium* sp., and *Trichoderma* sp.) at 15% mc for up to 4 months. All species tested were readily re-isolated at 4 months and remained infectious.

The examples provided above demonstrate that many insect and fungal organisms that attack trees used for the manufacture of various wooden articles in the area of origin are capable of surviving in air dried wood for prolonged periods of time and emerging from dry wood (insects) or producing spores upon rehydration (fungi). Given that the moisture content of wood used to produce wooden articles for indoor and outdoor use moving in international trade can range from fully hydrated or "green" (~30-200% moisture content) to air- or kiln-dried (~5-20% moisture content), there is a wide range of organisms that could be present on the pathway and be introduced into North America.

Other important factors that influence the probability of pests occurring in or on the commodity at origin are the prevalence of pests in the life stage associated with the tree species in question at the time of fabrication, the degree of processing and finishing of the wooden article and the types and efficacy of treatments applied to the product.

Pests associated with wooden articles are either present in the wood prior to the application of a surface treatment or may infest wood after treatments are applied. Surface treatments specifically designed to kill pests (e.g. fumigant or chemical pesticides) may be effective, depending on pest-specific efficacy, the depth of treatment penetration and whether the treatment is appropriately applied given the dimensions and physical characteristics of the wood (Schauwecker and Morrell 2008). Insects that do not ingest treated wood but rather simply chew through it, have been observed to emerge from chemically treated wood (Schauwecker 2006). Surface treatments such as paints, varnishes or oil finishes are generally not effective at killing pests present in wood prior to treatment (E. Allen, Canadian Forest Service, pers. comm., Sept. 2010).

The use of paints or varnishes on untreated woodware will generally prevent insects from laying eggs in cracks and crevices on the wood surface. For example, powder post (Lyctidae) beetles only lay eggs on bare, unfinished wood. These beetles will not infest wood that is painted, varnished, waxed, or similarly sealed. Adults emerging from painted or varnished wood will either have been in the wood before finishing or be a result of re-infestation by eggs that were laid in emergence holes of adult beetles (E. Allen, Canadian Forest Service, pers. comm., Sept. 2010). Sealing holes prevents re-infestation from eggs laid within the openings (Koehler and Oi 2011). However, beetles present in the wood before finishes are applied will not be stopped from emerging. Finishes will slow the drying of wood and could maintain conditions that favor insect development (E. Allen, Canadian Forest Service, pers. comm., Sept. 2010).

Similarly, latent fungi present in wood prior to the application of finishes may be “revived” if wood moisture contents increase to favorable levels. Although in general paint or varnish will present a barrier to fungal spores, even the smallest of cracks could provide an entry point to ubiquitous spores (E. Allen, Canadian Forest Service, pers. comm., Sept. 2010). Some species of fungi attack exterior surfaces of painted wood (Eveleigh 1961). Impervious coatings such as synthetic paint, resin, varnish, wax or lacquer, used before or after the manufacturing process can significantly reduce the efficacy of a methyl bromide treatment as reported in the “Impervious wrappings surfaces and coatings” section of the AQIS Methyl Bromide Fumigation Standard. This standard also stipulates that “Coatings may be applied before fumigation only if the product has at least one uncoated surface on each component and each component has a maximum thickness of 100 mm”.

The duration and conditions of storage of the finished product prior to its shipment and the use of appropriate packaging to prevent re-infestation or contamination of the finished product are also an important consideration. Wooden articles created by hand selecting high grades of wood or made of seasoned or aged wood products or produced over time with great care and attention should have a lower incidence of pest infestation than wooden articles that are mass produced or made of fresh material. Similarly, wood that has been subjected to chemical processes, heat or pressure treatment or that has been cut into small pieces (less than 6 mm in one direction) present negligible phytosanitary risk in comparison to untreated or unprocessed green wood (Leal et al. 2010).

Wooden handicrafts sometimes include woody stems with or without bark (e.g. bentwood chairs, twig screens, components of birdhouses). Canada currently exempts material that are less than 1.5 cm in diameter (CFIA Policy Directive D-02-12, Appendix 1) whereas the U.S. exemptions are for wooden handicrafts from China of 1 cm or less in diameter (US Code of Federal Regulations).

In the USDA Miscellaneous Product Manual, some of the requirements for handicrafts are:
"If the handicraft is from China:
and are bark or bark fragments (chips) – Prohibit entry
and are twigs with intact bark greater than 1 centimeter (0.39 inch) in diameter – Prohibit entry."
when the origin is other than China, then a special process is described in the Manual.

The infestation and persistence in small-diameter woody tissue by insects is influenced by a number of factors, primarily food resource availability, moisture content and physical space required to complete a life cycle. As a rule, larger insects do not utilize branches and twigs, or, if they do, will not stay or be able to complete their development. Woody tissues dry to ambient equilibrium moisture levels (globally ~4-20%, average ~10-15% depending on season and location) after being cut from living plants. Some insects are unable to survive or complete life cycles at these low moisture levels while others (e.g. Lyctids, Anobiids) can persist (E. Allen, Canadian Forest Service, pers. comm., Feb. 2011). The following summary reports and facts provide some evidence that small diameter wood can be a pathway of introduction for insects.

Hespenheide (1976) reported 4 species of *Agrilus* and 2 unknown species of Cerambycidae in branches of *Celtis* and *Gleditsia* ranging in sizes from 2-16 mm in diameter. Different species were correlated with branch diameter.
The brood galleries of the walnut twig beetle *Pityophthorus juglandis*, frequently associated with the *Geosmithia* species that cause thousand canker disease, occur on branches 1.5 cm in diameter or greater (Seybold et al. 2009).
Many other species of *Pityophthorus* colonize small diameter branches of a variety of tree species (Wood 1982).
Lyctus planicollis has been found associated with picture frames and baskets. These beetles can tolerate low moisture 3-30% (commonly 10-20%) (E. Allen, NRCan, CFS, pers. comm. Feb. 2011).
Thirty three species from 16 families of Coleoptera were reared from Southern Red Oak *(Quercus falcata* Michx.) twigs (Ferro et al. 2007).

As for fungi, many canker-causing ascomycete fungi can be found on small-diameter twigs and branches of a wide range of species of trees and shrubs. As a rule, these fungi can survive desiccation for extended periods of time, reviving and forming spores upon rehydration. Where pathogens are spread by vectoring insects, the suitability of the dry wood for the insect may dictate the likelihood of spread (e.g. *Ceratocystis fagacearum* is (rarely) vectored by *Arrhenodes minutus*, *Pseudopityophthorus minutissimus* and *P. pruinosus* (E. Allen, NRCan, CFS, pers. comm. Feb. 2011)).

The following examples of fungi on small-diameter wood illustrate that size of wood pieces does not necessarily mitigate effectively against these pathogens:
Mycosphaerella populorum G.E. Thompson (Anamorph: *Septoria musiva* Peck) has been found on *Populus* twigs and branches in plantings in New York State and in Tennessee (Waterman 1946).
Cryphonectria parasitica mycelium can live for up to 10 months in dried bark (Hepting, 1974).
The insect-vectored *Sirococcus clavigignenti-juglandacearum* (Butternut canker) is known to survive desiccation (EPPO 2005).
Cryphonectria cubensis (Bruner) Hodges (= *Diaporthe cubensis* Bruner) kills coppice wood of Eucalyptus (Barnard et al. 1987)

Other pathogens of concern in wood include bacteria. *Erwinia amylovora* (Burrill) Winslow et al. (fireblight) infests woody tissues of hosts in the Rosaceae and can live in small diameter twigs and branches. While the most important pathway for spread is live plant material, the bacterium can survive for extended periods in dried ooze. Under dry conditions, the pathogen survived in ooze for more than 2 years (Beer 1979). *Carneocephala fulgida* Nottingham, *Draeculacephala minerva* Ball and *Graphocephala atropunctata* (Signoret) are known to be vectors of the bacterium *Xylella fastidiosa*, the causal agent of Pierce's disease. Although the bacterium may survive desiccation in cut grapevines, the vectors would not be attracted to the dry vines.

In addition to the examples provided above, there is an abundance of published data indicating that both insects and fungi of potential phytosanitary concern can infest branch and twigs of all diameters (including < 1.5 cm) and move internationally with untreated wooden articles for indoor and outdoor use. (E. Allen, Canadian Forest Service, pers. comm., Sept. 2010).

3.2 Survival during Transport

Most of the intercepted plant pests listed in Annexes 1 to 3 were alive when detected. This is not surprising given the shielded environment in which wood-inhabiting insects and fungi develop and thrive, protecting them against temperature and moisture fluctuations and extremes as well as from handling and packing procedures at origin. Pests that occur on the commodity inadvertently (i.e., 'hitchhikers') are much more prone to being negatively impacted by the speed and conditions of transport. Nonetheless, the three Annexes comprise a considerable number of organisms that neither feed on nor breed in wood or bamboo.

3.3 Probability of Pest Surviving Existing Pest Management Practices

As mentioned above, the U.S. and Canada have phytosanitary requirements in place to mitigate some of the risks associated with wooden articles intended for indoor and outdoor use. Mexico on the other hand has not yet developed a phytosanitary standard for the commodities under discussion. Notwithstanding existing mitigation measures, the diversity and magnitude of imported material manufactured through mass production make it very challenging to inspect articles at points of entry. The concealed life stages of many pests associated with the commodity, the occurrence of hidden wooden parts and/or other plant products, particularly in articles of a larger size (e.g., furniture, Christmas trees) add to the difficulty of detecting pests or signs of pests. An additional challenge faced by inspectors at points of entry is the unanticipated risks of the novel products that the handicraft industry seeks to market.

3.4 Probability of Transfer to a Suitable Host

The many potential destination points for wooden articles intended for indoor and outdoor use influence the likelihood that pests emerging from the articles will succeed in finding a suitable host. Wooden handicrafts, furniture, garden décor and related products may end up either in urban or rural areas, at retail stores, private homes or commercial properties, parks and playgrounds, garden centers, nurseries etc. Pests associated with articles that are used indoors, particularly where windows are screened and where a host is not available year-round are less likely to access and transfer to a suitable host than those associated with articles for outdoor use. Hence, wooden articles like kitchen utensils, musical instruments, carvings and picture frames pose a much lower risk than wooden bird houses, rustic patio/deck furniture, garden tools and garden ornaments, to name a few. However, regulators or inspectors should be careful as not to generalize or speculate on the intended use of wooden articles. Storage, disposal conditions, and the utilization of the articles intended for indoor use in the outdoors where the climate is favourable could increase the likelihood of pest transfer to suitable hosts.

PROBABILITY OF PEST ESTABLISHMENT IN THE NAPPO REGION

3.4.1 Availability of suitable hosts, alternate hosts and vectors in the PRA area

In North America and elsewhere, there are many cases of introduced pests succeeding in establishing reproducing populations that thrive and spread in their new environment. Organisms with broad host range have the greatest probability of encountering suitable hosts. Their success could be higher in mixed forests or in urban settings where the diversity of tree species may exceed that of nearby forests on account of non-native trees planted for ornamental purposes. In these environments, the pests may be able to persist on secondary host species when the preferred hosts are not available (Koch et al. 2010). Many of the more harmful invasive forest insects are indeed polyphagous (e.g., gypsy moth, Asian longhorned beetle).

A number of examples exist in the literature of pests that, once introduced into a new area, are able to infest or infect different tree species that are closely related to the host species in their native area (e.g., same genus, same family). Examples include: *Anoplophora glabripennis* (Haack et al. 2010), *Tetropium fuscum* (Flaherty et al. 2011), *Agrilus planipennis* (Anulewicz et al. 2008), *Callidiellum rufipenne* (Maier 2007). Situations where suitable hosts would not likely be available include the entry of tropical pests in temperate areas of North America and vice versa, the end point of an infested wooden article being in area devoid of potential host trees (e.g., in a grassland or prairie habitat, or for pests of deciduous trees, in an ecozone consisting predominantly of conifers, etc.), and the native host range of the pest in question being limited of one to a few species within the same genus, particularly in cases where the genus has a limited range in North America.

Suitability of the Environment

It is likely that many exotic pests that enter North America on various pathways never become established for various reasons including multiple physical or biotic factors. Based on the number of species that has been collected only once far beyond their native range, the local extinction rate of immigrants soon after their arrival must be enormous (Mack et al. 2000). Other examples illustrate the poor prospects for establishment and the extinction risks faced by small adventive populations:

In a study of the success of various groups of invading organisms, Williamson and Fitter (1996) found that no greater than one percent of insects introduced into a new region became established. Even in situations where insect introductions occurred under rather optimal conditions, rate of establishment was low.

Controlled studies of insects introduced for biological weed control showed that small founding populations (at densities likely to be greater than those typically infesting imported fruits and vegetables) tended to become extinct within three years of introduction (Memmott et al. 1998; Grevstad 1999).

A model developed by Bartell and Nair (2004) predicted that the probability of establishment of a persistent population of Asian longhorned beetle comprising 1000 individuals in the Eastern Deciduous region of the U.S. after one year is near zero for entry rates that are less than 10 adults per month, and that 20 adults per month with continued entry could assure establishment.

Among the factors in the environment that are critical to the survivorship and development of a pest, climatic suitability is probably the most straightforward to estimate for any given organism considering the wealth of information and data available on climate at a global and regional scale. Much like for host availability, it is probable that in many cases, pests escaping from wooden articles will not become established because of unfavourable climatic conditions at the time of emergence. Seasonality of emergence could be a limiting factor for species originating from the southern hemisphere that are introduced into North America, depending on their life stage at the time of entry and the specific triggers (e.g., temperature, moisture, degree-days, etc.) that influence their development, diapause, sporulation, etc., leading to infestation/infection and establishment. However, seasonality is less important for wood-borers than for other insects since they are usually capable of "waiting" indefinitely for cues such as cool or rainy periods.

Notwithstanding the above, given the large volume of wooden articles imported into and distributed all around North America throughout the year and the full gamut of climatic zones found across the NAPPO countries (see Köppen-Geiger climatic classification and map of climatic types, as in Peel et al. 2007), there is a high likelihood that at least some pests will find suitable climatic conditions upon emergence.

3.4.2 End use of the imported wooden article

As mentioned earlier in this document, establishment potential is largely contingent on end use. Infested wooden articles used or discarded outside could initiate pest establishment, particularly fungi; in an indoor environment, fungi would be highly unlikely to be exposed to rewetting which is an essential condition fungal growth and sporulation to occur (E. Allen, NRCan, CFS, pers. comm. March. 2011). Insects emerging indoors may have little likelihood of escaping outside and finding a mate or a suitable host for development, particularly in temperate regions of North America where synchrony between hosts and pests is a critical feature for survival and spread as well as in areas where windows are screened.

3.4.3 Other characteristics of the pest affecting the probability of establishment

The establishment rates of exotic pests associated with wooden articles will depend on whether or not the species is subject to strong Allee effects when there are relatively few individuals or propagules entering the NAPPO region, as is the case for most introductions. Populations of an introduced species may exhibit a critical size or density below which it declines and eventually becomes extinct unless there are recurrent introductions. The Allee effect is closely linked to propagule pressure or to the quality, quantity and frequency of invading organisms (Groom et al. 2006). Propagule pressure is a measure of number of individuals released into a new area, taking into consideration absolute number of individuals that enter the area (propagule size) and the number of discrete entry events (propagule number) (Lockwood et al. 2006). However, it is currently difficult to predict likelihood of establishment based on these two factors because the prevalence of Allee effects in invasive species is unknown and species-specific information on propagule pressure from various pathways has not been measured or in cases where it has, data is not currently available (Drake and Lodge 2006).

Dispersal capabilities of the life stages associated with the commodity at entry should also be considered in predicting possible pest introductions. Organisms with a limited dispersal potential (e.g. scales or mites) or needing assistance of a vector would have difficulties in making contact with a possible host if no vector were present, even if the host is available. In contrast, arthropods with strong flying abilities (i.e. adult beetles, moths or termites in a dispersing stage) can move actively towards their potential hosts. Passive dispersal on wind currents should also be noted as an important factor contributing to host finding and further spread. Some of the examples include lepidopteran larvae ballooning on silk threads (e.g. *Lymantria dispar*) or airborne pathogens like rusts.

4. Significance of Pest Interceptions on Wooden Articles

The intercepted pests lists in Annexes 1 to 3 provide a good, albeit incomplete picture of the range, diversity and abundance of pests that may be associated with wooden articles. One limitation of the lists is that many pests are not identified at the species level and the commodity on which they were collected is often not identified. In addition, the inspection process for wooden articles has certain biases, such as limited percentage of incoming materials being inspected and non-random sampling (Humble 2010). Nonetheless, it is apparent from the lists that a large number of the pests intercepted are ones that infest dry wood; they belong to the families Anobiidae, Bostrichidae, Lyctidae, Kalotermitidae and Termitidae. There are in addition a considerable number of organisms that belong to the insect groups comprising some of the most devastating forest pests: longhorned beetles (Cerambycidae), bark beetles (Scolytinae), jewel beetles (Buprestidae) and weevils (Curculioninae).

Many species are of concern as organisms of quarantine or potential quarantine significance and, for the U.S. and Canada, many of the intercepted pests identified at a supraspecific level are also actionable. The U.S. authorities intercepted for example many bark beetles such as a *Xyleborus* sp. in a wooden bowl from Ghana, six *Pityophthorus* species in various wooden articles from Mexico, *Ips typographus* on unidentified wooden product from Italy, etc., a few scarab beetles, including *Adoretus sinicus* on wooden trays from Honduras, diverse longhorned beetles such as six *Monochamus* species in carved wooden picture frames from China, *Chlorophorus strobilicola* in an unidentified wooden product from India, termites such as *Termes panamaensis* from furniture originating from Mexico, and numerous other actionable pests (L. Brown and M. Zlotina, USDA APHIS PERAL, pers. comm. Feb. 2011). Mexican authorities also intercepted many pests from imported wooden articles including a quarantine pest of concern, the termite C*optotermes formosanus*, from wooden furniture imported from China (G. Gonzalez Villalobos, SEMARNAT, Mexico, pers. comm., March 2011). As for Canada, in addition to the numerous pest interceptions listed in Annex 1, the interception of most concern aside from that of unidentified cerambycid beetles was *Trichoferus campestris*, a potential quarantine pest reared from a wooden bench imported from China (S. Maccum, CFIA, pers. comm., Sept. 2009).

A few of the pests listed in Annexes 1-3 have become established in one or more NAPPO countries (e.g., *Halyomorpha halys*, *Heterobostrychus aequalis*, *Hylurgus ligniperda*, *Trichoferus campestris*, *Xylosandrus crassiusculus*). Other alien invasive species potentially associated with wooden articles, according to the New Zealand Ministry of Agriculture and Forestry (see its “Import Health Standard for Woodware from All Countries” at http://www.biosecurity.govt.nz/files/ihs/woodware.pdf), are also known from Canada, U.S. and/or Mexico (e.g., *Anoplophora glabripennis*, *Cryptotermes brevis, Orthotomicus erosus*, *Tetropium fuscum*, *Tomicus piniperda*). In all cases, the pathways of introduction of these particular species have never been conclusively determined. In a European study conducted by Roques (2007, cited by Humble 2010), of all reported interceptions related to trees and forests, wood packaging predominates, followed by sawn timber and logs. Wooden articles would be included in the remaining 3% of intercepted pests that is recovered from plants for planting, seeds or miscellaneous categories. Not surprisingly, wood packaging material is also considered as the most likely pathway for the introduction of many of the species mentioned above (CABI 2011; Humble 2010). Nonetheless, one cannot exclude the possibility of one or more of these pests having been introduced into North America in association with wooden articles for outdoor use.

The introduction of the red palm mite *Raoiella indica* into Florida in 2007 from one of the Caribbean islands is a case that exemplifies the potential of handicrafts to serve as a pathway for the entry and subsequent establishment of quarantine pests. In this particular instance however, the mite was intercepted on hats, bowls, baskets and other items fabricated with coconut leaves or palm fronds rather than wood. This mite species poses a significant threat to the ornamental palm, coconut and banana industries. Although the pest might also have entered continental U.S. with wind currents or movement of infested plants through nursery stock and cut branches of host plants, the untreated palm-leaf handicrafts were considered as a sufficiently risky pathway to warrant their regulation in the U.S. (CABI 2011; Hoy et al. 2006; USDA 2007; Welbourn 2009).

5. Conclusion

Ongoing pest interceptions on wooden articles intended for indoor and outdoor use demonstrate that this commodity can be a pathway for the entry of quarantine pests. However, current information is insufficient to provide solid evidence for the probability of establishment of quarantine pests potentially associated with wooden commodities. The entry of exotic invasive pests in the NAPPO region as a result of the importation of wooden articles hinges on various characteristics of the pest itself such as its prevalence in the area of origin and its ability to survive in transit. Establishment is largely dependent on abiotic and biotic features of the new environment and trade patterns. Although it is difficult to predict where new pest introductions into North America might occur, the increased volume of commodities combined with their speed of transportation and number of trading partners is expected to exacerbate the movement of exotic pests in international trade.

The level of risk of wooden articles is determined by the commodity type, its origin, the presence of bark, its intended use, the level of processing it has undergone and any treatment that has been applied to the product. The articles that present the greatest risk when traded internationally are those that are non-manufactured (e.g., natural stem of artificial Christmas trees) because their potential pest hazard includes a wide variety of forest pest types (Ormsby 2001). Commercially manufactured and highly processed, coated and packed solid both from wood (e.g. furniture, doors, musical instruments, picture frames, etc.) and bamboo, rattan, willow, pose a much smaller risk. Higher risk articles are manufactured in rural-based cottage industries (i.e. traditional carvings and ornaments) which use sawn timber and other untreated raw materials. Likewise, wooden articles intended for outdoor use present a higher risk for pest establishment than those intended for indoor use.

Many of the pests potentially associated with wooden articles are cryptic in nature. Good examples of pests difficult to detect with the naked eye include fungi, nematodes and wood borers. Consequently, visual inspection at ports of entry cannot mitigate effectively against the entry of these pests into North America.

As demonstrated above under “Probability of Pests Occurring in or on the Commodity at Origin”, surface treatments of wooden articles would not eliminate all pest risks. Until evidence is found in support of pest establishment, provisional use of treatments could be considered for adequately mitigating risks associated with wooden articles and could include fumigation, kiln drying, heat treatment and heat treatment with moisture reduction. Irradiation is perhaps an option that should be considered. The exemption of commodities based on size does not appear to be advisable as some pest risks remain even in wood pieces less than 1.5 cm in diameter.

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Annex 1: Canadian Pest Interceptions on Wooden Articles (Including Bamboo) Intended for Indoor and Outdoor Use

Annex 2: U.S. Pest Interceptions on Wooden Articles (Including Bamboo) Intended for Indoor and Outdoor Use

Annex 3: Mexican Pest Interceptions on Wooden Articles (Including Bamboo) Intended for Indoor and Outdoor Use

All three annexes are available upon request at the NAPPO Secretariat.