NAPPO Science and Technology Document

ST 08

Contaminating organisms affecting trade of forestry commodities

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VIRTUAL APPROVAL OF NAPPO PRODUCTS

Given the current travel restrictions brought about by the COVID-19 pandemic, the NAPPO Management Team unanimously endorsed a temporary process for virtual approval of its products.

Beginning in January 2021 and until further notice, this statement will be included with each approved NAPPO product in lieu of the Executive Committee original signature page.

The Science and Technology Document 08 – ***Contaminating organisms affecting trade of forestry commodities*** - was approved by the North American Plant Protection Organization (NAPPO) Executive Committee – see approval dates below.

Approved by:

The NAPPO Science and Technology Document 08 "***Contaminating organisms affecting trade of forestry commodities"*** was electronically approved by the NAPPO Executive Committee members for Canada (Greg Wolff, CFIA) on March 8, 2022, the United States (Ibrahim M. Shaqir, APHIS PPQ) on March 8, 2022, and Mexico (Francisco Ramírez y Ramírez, SENASICA-DGSV) on March 4, 2022. Electronic copies of approval emails from each Executive Committee member have been archived by the NAPPO Secretariat.

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1. SCOPE AND PURPOSE

The objective of this NAPPO science and technology document is to provide scientific information on living contaminating organisms associated with the trade of forestry commodities, and their associated conveyances. It is intended to support regulatory decisions addressing potential phytosanitary risks in these pathways.

There are several pathways on which contaminating organisms may be transported. While the scope of this document is restricted to contaminating organisms found with forestry products (e.g.sawn wood, round wood, wood chips and Christmas trees), wood packaging materials (e.g., pallets, skids, crates, reels, drums, dunnage etc.), and conveyances (e.g., sea containers, maritime vessels, trucks, trailers, rail, planes etc.), the information could also be applicable to other commodities or packaging materials (e.g., cardboard, or plastic boxes). The scope of this document does not include inanimate contaminants, such as straw, soil, seed husks, nests etc. The scientific information contained herein will be useful to National Plant Protection Organizations (NPPOs) for the development of pest risk analyses (PRAs), deciding on the most appropriate phytosanitary measures given the identified risks as well as informing all stakeholders involved in the supply chain of these commodities in order to promote safe trade.

2. INTRODUCTION

Increased awareness and growing concern to the introduction and spread of contaminating organisms, some of which may be pests, has generated the need for more guidance on the topic. The interception of contaminating organisms on wood commodities and wood packaging materials is an issue that was raised at two NAPPO workshops on the implementation of International Standard for Phytosanitary Measures 15 (ISPM 15) in China (2014) and Costa Rica (2016). During those workshops, clarification was requested by countries to help distinguish among contaminating organisms, contaminating pests and regulated pests (quarantine or regulated non-quarantine) to minimize trade disruptions that might occur because of regulatory actions at ports of entry.

Differentiating among contaminating organisms, pests and contaminating pests

The biology online dictionary defines an ***organism*** as "*a living thing that has an organized structure, can react to stimuli, reproduce, grow, adapt and maintain homeostasis. An organism would therefore be any animal, plant, fungus, protist, bacterium or archaeon on earth*" (Biology Online, 2021). ISPM 5 defines a ***pest*** as "*any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products*". As such, pests are organisms that cause harm to traded commodities or other plants that are hosts of the pests in the importing country. To determine whether an organism is a potential pest, a pest risk analysis (PRA) is conducted using the guidance provided by ISPM 2 and ISPM 11. A PRA considers scientific, technical, and economic information to determine whether the organism is a pest if so, whether it should be regulated, and what, if any, phytosanitary measures might be utilized against it.

A ***contaminating pest*** is defined in ISPM 5 as: "*a pest that is carried by a commodity, packaging, conveyance or container, or present in a storage place and that, in the case of (those particular) plants and plant products does not infest them*". Important to this definition is the concept of infestation, which is defined in ISPM 5 as "*presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection*." Infection refers to the invasion of tissues. Infestation implies an intimate biological interaction between the organism and its host whereby the organism derives nutrition or other necessary requirements to carry out its life cycle. In contrast, contaminating pests lack this physiological or physical relationship (MAF, 2008; Lemay and Meissner, 2008). Contaminating pests can be found on a wide range of articles, including plants, plant products, conveyances (e.g., airplanes, ships), shipping containers, machinery, vehicles etc. It is important to remember that a contaminating pest may be injurious to its specific host commodity if it is associated with that commodity.

This NAPPO science and technology document refers to organisms associated with commodities as ***contaminating organisms***, including as a subcategory, organisms that have undergone a PRA and that are determined to be injurious to specific commodities and are therefore identified as contaminating pests using the ISPM 5 definition given above.

For example, a housefly *Musca domestica* L. is an organism that could contaminate a commodity and is unlikely to be designated a pest through PRA and is therefore termed a ***contaminating organism***. Brown marmorated stink bug (BMSB) *Halyomorpha halys* Stål on fresh grapes is an example of an organism that has undergone PRA and is designated a ***pest***. BMSB on steel is an example of an organism which has undergone PRA and is identified as a pest but is not on its host and is therefore designated a ***contaminating pest***.

The IPPC is an intergovernmental treaty that aims to secure cooperation among nations in protecting global plant resources from the introduction and spread of pests to preserve food security and biodiversity and facilitate safe trade.

International trade is recognized as the primary pathway for introduction and spread of organisms such as plants, animals (including insects and nematodes), and microbes (including bacteria and fungi), many of which may be plant pests as defined in ISPM 5. When introduced into new environments, these organisms are referred to as "non-indigenous" and those that are pests may cause serious environmental, ecological, and economic damage (Liebhold *et al.,* 1995; Allen and Humble, 2002). Non-indigenous pests can move internationally in association with live plants and plant parts, including wood. In many cases, non-indigenous pests are unintentionally introduced on an article or surface they are not infesting. These pests are referred to as contaminating pests.

3. WHAT ARE CONSIDERED CONTAMINATING PESTS BY DIFFERENT COUNTRIES?

Canada, the United States, and Mexico each develops/maintains a list of regulated pests as part of meeting their international pest reporting obligations under the IPPC – Article VII.2.i – “contracting parties shall, to the best of their ability, establish and update lists of regulated pests, using scientific names, and make such lists available…” Lists of regulated pests as defined in ISPM 5 are established by an importing contracting party to specify all currently regulated pests for which phytosanitary measures may be taken (ISPM 19); intercepted organisms are checked against these lists.

Mexico’s list of regulated pests for forest products and by-products is maintained as part of the Official Mexican Standards (NOM, issued by the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) that regulate imports of raw forest materials, products and by-products, specifically natural Christmas trees; new sawn wood; and bamboo, wicker, vine, or rattan, as raw materials used in basketry or plaiting (SEMARNAT 2003, 2013, 2020).

The Official New Zealand Pest Register (ONZPR), formerly Biosecurity Organisms Register for Imported Commodities (BORIC) database, allows users to find the status of intercepted organisms (New Zealand Ministry for Primary Industries, 2021). New Zealand also employs more generalized “Contaminant Charts” for the benefit of biosecurity inspectors at ports of entry (New Zealand Ministry for Primary Industries, 2020). These databases assist inspectors in differentiating between contaminating organisms and regulated pests. When interception records are evaluated against these different databases a better understanding of contaminating organisms associated with trade of wood commodities, wood packaging material, and their associated conveyances can be obtained and used to inform regulatory decisions.

Depending on the structure of a country’s interception data collection format, interception data may differentiate regulated pests, contaminating pests and contaminating organisms. However, in some cases it may be challenging to clearly associate contaminating organisms with certain pathways due to their opportunistic nature (Toy and Newfield, 2010). While a country’s regulated pest list may aid inspectors in identifying pests associated with specific commodities, it is not always clear if the pest is infesting the commodity or is a contaminating pest. This is because interception databases often do not recognize “contaminating” as a distinct field. However, careful inspection of the data (e.g., pest species, commodity) may determine if an interception record should be considered that of a pest or a contaminating pest.

NPPOs have record-keeping systems that centralize interception data for easy access and analysis. While interception databases can identify entry pathways for contaminating organisms, it is difficult to quantitatively analyze this type of data as different pathways have different levels of inspection, reporting, identification, and recording (Turner *et al.,* 2020). Examination of interception data gathered in the last twenty years for eight world regions (New Zealand, Australia, South Korea, Japan, United States, Canada, United Kingdom, and the greater Europe and Mediterranean) shows the lack of uniformity in data collection required for quantitative analysis

(Rebecca Turner personal communication). For example, the South Korean dataset includes only interception frequency by species, while other countries like the United States also record pathway, year, source country, and some interceptions are identified to higher taxonomic levels than those of the species. Most countries collect host or commodity data, but it is not always clear whether the intercepted organism was infesting the commodity or was a contaminating organism (Turner *et al.,* 2020). The U.S. Agriculture Risk Management (ARM) database, which includes the former Port Information Network (PIN) database, includes a host proximity column with in/on/with options, but other countries, structure their databases differently. In many cases, status as a contaminating pest is based on limited information. Interception databases are useful for identifying the types of organisms that are moving in international trade. Currently, inspecting and recording contaminating organisms presents challenges to different inspection protocols and designs. Countries such as New Zealand and Australia have focused inspections of the vehicle pathway on detecting invasive ants, Asian gypsy moth (AGM)[1] (*Lymantria dispar asiatica* Vnukovskij, *Lymantria dispar japonica* Motschulsky, *Lymantria albescens* Hori and Umeno, *Lymantria umbrosa* Butler, *Lymantria postalba* Inoue) and brown marmorated stink bug (BMSB, *Halyomorpha halys*).

Contaminating organisms and pests detected on imports to Australia were documented and summarized in a document drafted in 2018 and presented at the Commission on Phytosanitary Measures (CPM) in 2019 (FAO, 2018). Organisms listed as contaminating pests included insects, plant pathogens, weeds, seeds, reptiles, snails, and slugs. Additional analyses on the types of contaminated commodities coming into Australia have been conducted as part of a pest risk assessment for the contaminating pest BMSB (Australian Department of Agriculture, 2019).

The U.S. Agricultural Risk Management (ARM) system, which replaced the U.S. Agricultural Quarantine Activity System (AQAS) in April 2021, records data on inspections conducted by the Department of Homeland Security, Customs and Border Protection (DHS-CBP), and APHIS Plant Protection and Quarantine (PPQ) at the ports of entry into the United States (USDA, 2011). In Mexico, the Forest Health Analysis and Reference Laboratory from SEMARNAT General Directorate for Forestry and Soil Management has a database to record organisms intercepted on wood packaging materials, and forestry products and by-products. Canada's NPPO, the Canadian Food Inspection Agency (CFIA), in collaboration with the Canadian Border Services Agency (CBSA) collects data on interceptions on various commodities and records this information in an internal database.

[1] *Lymantria dispar* species common names are under review by the Entomological Society of America. New common names have not been formalized at the time of publication. We will refer to the *L. dispar* species originating in Asia as AGM in this document.

4. PATHWAYS: HOW CONTAMINATING ORGANISMS MOVE IN INTERNATIONAL TRADE

Nearly anything that moves in international trade - including all commodities (whether plant products or other commodities), packaging, and conveyances, provide pathways for movement of contaminating organisms. Furthermore, these can originate in the consignment's exporting country, in transit from a country through which the consignment transited, or after arrival in the importing country. As such, awareness and management of contaminating organisms and pests in trade should be a shared and global priority.

For the most part, data on contaminating organisms and on pest interceptions and pest introductions is tied to a pathway, not to a specific host or commodity, although there are some exceptions. Contaminating organisms are not necessarily associated with hosts or commodities, although certain predilections do exist. For example, terrestrial gastropods (snails and slugs) are commonly found on consignments of ceramic, marble, and cement tile (Robinson, 1999). The khapra beetle (*Trogoderma granarium* Everts), a NAPPO region regulated pest, is commonly associated with shipping (or sea) containers where larvae that undergo diapause can remain hidden in the container's cracks and crevices (NAPPO, 2019a).

4.1 Conveyances

A conveyance is broadly defined as something that is used to transport goods or people. While any conveyance has the potential to carry a contaminating organism, this document will focus more specifically on conveyances that are used to transport forestry commodities in international trade. These conveyances are larger, typically travel longer distances, and thus represent the higher risk of transporting contaminating organisms from one area to another.

4.1.1 Sea containers

Approximately 60% of world trade travels inside sea containers (Statistica, 2021); they are an important pathway for contaminating organism movement. Sea containers are also known as shipping containers, twenty-foot equivalent units (TEUs) or freight containers. A freight container is defined in the Cargo Transport Code (CTU) as "*an article of transport equipment that is of permanent character and accordingly strong enough to be suitable for repeated use; specially designed to facilitate the transport of goods, by one or other modes of transport, without intermediate reloading: designed to be secured and/ or readily handled, having fittings for these purposes, and approved in accordance with the International Convention for Safe Containers (CSC), 1972, as amended. The term freight container includes neither vehicle nor packaging; however, a freight container that is carried on a chassis is included*" (IMO, 2014).

To reduce the risk of contaminating organisms moving on the sea container pathway, New Zealand designed and implemented the Sea Container Hygiene System, which includes certified best practices such as container depot and container cleaning and pest risk management (MAF, 2009). The system is now jointly operated by the NPPOs of New Zealand and Australia's and is approved across 6 Pacific Island countries. The program has reduced sea container contamination by 99.5% (Australian Department of Agriculture, 2020). A study evaluating interior and exterior contamination of empty sea containers in New Zealand indicated that the types of contaminants moving on sea containers included: soil and its associated pathogens, plant products (seeds), invertebrates (insects, spiders, snails), and reptiles in decreasing order of incidence (Brockerhoff, 2016).

Additional documentation on the risk of contaminating organisms moving on or in sea containers is widely available (Stanaway *et al.,* 2001; Gadgil *et al.,* 2002). A draft ISPM entitled *Minimizing pest movement by sea containers* was added to the List of Topics for IPPC standards at CPM 3 in 2008 (Draft ISPM 2008-01). The draft standard was put on hold for five years after some IPPC contracting parties expressed their concerns with the document. In order to continue working on this important topic, the Sea Container Task Force (SCTF), was established by the IPPC in 2017, to raise awareness on the importance of sea container cleanliness. The SCTF published guidance on the best practices to reduce pest contamination (FAO, 2020a).

The North American Sea Container Initiative (NASCI) has developed guidance on cleaning and inspecting sea containers (NAPPO, 2019b). NASCI complements the guidance provided by the International Maritime Organization's Code of Practice for Packing Cargo Transport Units (IMO, 2014). Since the CTU Code was updated in 2014, a supplementary document, *Prevention of Pest Contamination of Containers: Joint Industry Guidelines for Cleaning Containers,* was completed in 2016 (COA *et al.,* 2016).

4.1.2 Maritime vessels

Maritime vessels are similarly involved in the movement of contaminating organisms and offer a range of locations for contaminating organisms to hide (for example on decks, holds and stores) (Lemay and Meissner, 2008). AGM egg-masses are routinely intercepted on vessels travelling to North America from AGM regulated countries. The specified risk periods for AGM moth flight in regulated countries are used to trigger formal inspection programs which specifically target this pest (NAPPO, 2021b; see section 7.6).

4.1.3 Terrestrial transport – trucks, trailers, and rail

Contaminating organisms on terrestrial vehicles are generally less well documented (Meurisse *et al.*, 2019). A great number of trucks, trailers, and trains are used to transport sea containers overland. The transfer of sea containers to trucks, trailers, and trains is an important consideration in fully characterizing this domestic and cross-border pathway for spreading contaminating organisms.

Transport data from the Organization for Economic Cooperation and Development (OECD) demonstrate that road and rail are predominant modes for both freight and passenger transportation in most countries (ITF, 2017; Meurisse *et al*., 2019). Field observations of *Lymantria dispar dispar* L. egg-masses on the surface of commercial land carriers are commonplace, and adults of emerald ash borer (*Agrilus planipennis* Fairmaire) are known to advance their secondary spread in this manner (Buck and Marshall, 2009; Short *et al*., 2020).

Spotted lanternfly (*Lycorma delicatula* (White)) egg-masses, nymphs, and adults can be transported on non-living pathways such as outdoor equipment and all-terrain vehicles, trailers, lawn tractors, and trucks (Pennsylvania Department of Agriculture, 2019). The potential for moving contaminating organisms by land transport varies considerably and depends on pest life stage, season, and frequency of transport among other factors.

While overland transport on trucks and trailers is primarily a domestic concern, new and used vehicles as traded commodities represent an important international pathway for harboring and transporting contaminating organisms (ISPM 41). Military vehicles are also an important pathway for introductions as they are moved between countries, often under unique regulatory conditions (Cofrancesco *et al*., 2007). Vehicles as traded commodities are viewed as higher risk due to factors including storage which provides additional time for contaminating organisms to become associated with the vehicles. New Zealand and Australia have implemented safeguarding programs for vehicle importation that focus on BMSB and other contaminating organisms (Australian Department of Agriculture, 2019; MAF, 2021). While incidence of a particular contaminating organism on imported vehicles may be low, overall introduction can be high due to sheer number of vehicles imported (MAF, 2008; Toy and Newfield, 2010).

4.1.4 Air Transport - airplanes

Airplanes have long been recognized as a high-risk pathway for contaminating organisms. Over a 10-year period from 1997–2007, more than 1,900 live pest interceptions, including insects, weeds, mollusks, and mites were recorded from aircraft holds in the United States (Meissner *et al.*, 2009). High profile pests of aircraft hold, like the Japanese beetle (*Popillia japonica* Newman), have prompted the predeparture use of exclusion devices on airplanes so that cargo can be successfully moved and accepted by western states (USDA, 2020b). Non-indigenous plant pests were transported across the globe on or in airplane cargo during World War 2, including brown tree snakes, *Boiga irregularis* (Bechstein) which were accidently introduced into Guam (Richmond *et al.,* 2015). Management of the brown tree snake in Guam is focused on limiting further dispersal by aircraft (Engeman *et al.*, 2018).

4.2 Forestry commodities

A wide range of forestry commodities are moved in international trade. These may include: unprocessed round wood, sawn wood, plywood, oriented strand board, Christmas trees, or by-products from the manufacture of these, such as sawdust or wood chips. Forestry commodities moving in trade may also include the packaging used to contain or support a commodity, e.g., pallets, crates, or dunnage. Contaminating organisms may be found in association with any of these forestry commodities.

4.2.1 Round wood

Round wood refers to logs, poles, posts, timber, or pilings and is defined as "*wood not sawn longitudinally, carrying its natural rounded surface, with or without bark*" (ISPM 5). Round wood may be attractive to contaminating organisms. For example, the western conifer seed bug

Leptoglossus occidentalis (Heidemann) may be found perching on wood in the fall when looking for places to overwinter. The beech leaf-mining weevil, *Orchestes fagi* (L.) overwinters as an adult in crevices and under bark scales on round wood and on the trunks of both conifers and hardwoods (Morrison *et al*., 2017). Bark beetles may be attracted to debarked round wood due to volatiles emitted by the wood (see section 5.1 Semiochemical attractants) but do not infest the wood. These contaminating organisms are often referred to as perching insects.

4.2.2 Sawn wood (lumber)

Defined as "*wood sawn longitudinally, with or without its natural rounded surface with or without bark*" (ISPM 5). Sawn wood may include squared pieces of wood without bark or partially squared wood with one or more curved edges that may or may not include bark. In the commercial production and sale of sawn hardwood commodities, curved edges are commonly left for subsequent trimming (NAPPO, 2018).

With increased level of processing, wood becomes less attractive to organisms that are drawn to bark remnants and volatile compounds emitted by recently cut wood. Heat-treated wood is less attractive as attractant compounds are often volatilized during treatment (Haack and Petrice, 2009). Some contaminating organisms may be attracted to stacks of sawn wood for refuge. Other insects, such as the BMSB, are attracted to light patterns created by the spaces between boards (see section 5.2.2 Shapes for more examples). In New Zealand, the burnt pine longicorn beetle, *Arhopalus ferus* (Mulsant), is a regular contaminating organism on sawn wood being shipped to Australia and has been more effectively managed with an improved understanding of its biology and climatic data (Pawson, 2009).

4.2.3 Wood chips

Wood chips are wood fragments, with or without bark, produced mechanically from various harvested tree parts and processing residues or post-consumer wood material (EPPO, 2015). Some contaminating organisms are attracted to the volatile compounds released by freshly cut wood (see section 5.1 Semiochemical attractants), and in rare instances may infest freshly processed wood chips. More frequently, insects attracted to freshly chipped wood will be present as contaminating organisms. Many species of pathogenic decay fungi, canker fungi and nematodes may be present in wood chips with or without bark (RSPM 41), but most of these would have originated from infestation of the wood prior to chipping and would not be considered contaminating organisms

4.2.4 Wood packaging material (WPM)

Wood packaging material including pallets, skids, pallet collars (collapsible sidewalls for a pallet base), containers, crating/crates, boxes, cases, bins, reels, drums, load boards, and dunnage is constructed from solid or processed wood. When compliant with ISPM 15 treatments, wood packaging significantly reduces the risk of pests immediately after treatment (ISPM 15). However, as with any other conveyance, contaminating organisms may become associated with any type of wood packaging materials at any point after treatment through the service life of the wood packaging materials. The presence of contaminating organisms on ISPM 15 certified material does not necessarily indicate a failure of the ISPM 15. When a contaminating organism is detected on ISPM 15 certified wood packaging material, it could be a result of contamination of materials post-treatment. This should be taken into consideration when an importing NPPO is reporting a 'notification of non-compliance' to the exporting NPPO (ISPM 13). The most likely cause for the detected contamination should be included in any notification given to the exporting NPPO.

Research has indicated that drying wood (whether through kiln drying or through equilibration to ambient moisture conditions over time) may change the types of pests attracted to it (Naves *et al.*, 2019). This may be relevant for contaminating organisms that are attracted to host chemical volatiles in untreated wood with higher moisture content.

The design structure of wood packaging materials lends itself to refuge opportunities for some contaminating organisms. The likelihood of contamination may depend on the design of the wood packaging and its subsequent attractive qualities (see section 5.2 Visual Cues for further explanation).

5. WHY DO CONTAMINATING ORGANISMS BECOME ASSOCIATED WITH FORESTRY COMMODITIES?

Contaminating organisms are found in association with virtually all internationally traded forestry commodities. How and why they become associated with forestry commodities varies with both the nature of the contaminating organism and the substrate. Some contaminating organisms are passively deposited by the air or by water droplets (this applies to most fungi and ballooning arthropod life stages) or are vectored by intermediary organisms (some insects, fungi and nematodes), and others arrive actively under their own locomotion (by flying, crawling, slithering (snakes), or by adhesive locomotion (slugs)). In some cases, contaminating organisms are attracted to a substrate by sensory stimulation through chemical, thermal, auditory, or visual cues, and in other situations they arrive by chance (Bell, 1990; Saint-Germain *et al.,* 2007). Certain biological traits increase the likelihood of contamination, primarily affinity to human activity (e.g., light, and sound production) and human-related objects (e.g., surfaces for *Lymantria* spp. oviposition) (Leibhold, 1995). Other traits of successful contaminating organisms include: ability to complete the life cycle in highly disturbed habitats; a life stage that seeks sheltered areas; a life stage with dormancy that enables survival during transit; and association with common commodity contaminants such as soil (Toy and Newfield, 2010).

Contaminating organisms may choose a wood substrate based on its suitability to increase survival. This can include features that increase predator avoidance and provide short and long-term protection from the elements, depending on the species seasonal movements. The characteristics of the substrate and surrounding habitat may also be chosen for the abundance of nest-building materials and possible nest locations. Contaminating organisms that rely on passive dispersal may be more likely to reach certain substrates based on the movement of wind and water through the natural landscape.

Contamination of internationally traded forestry commodities can occur at any point after application of phytosanitary measures, including: prior to departure from the exporting country; in transit (after departing the exporting country) through cross-contamination from other cargo or improperly cleaned conveyances; or as a result of post-arrival contamination in the importing country. The risk of contamination will vary depending on the organism prevalence and when or where the forestry product is processed or transported along the supply chain. The following subsections describe various physical stimuli and biological factors which help clarify why contaminating organisms are associated with forestry products.

5.1 Semiochemical attractants

Insects can be attracted by volatile organic compounds that are naturally produced by the wood of living trees and wood products such as sawn wood, wood chips, etc. (Moeck, 1970; Wallin and Raffa, 2002; Saint-Germain *et al.*, 2007) or by other insects (Borden, 1989; Allison *et al.*, 2004). Wood-produced chemicals, generally alcohols or terpenes, are used by insects to detect suitable hosts (Kirkendall *et al.*, 2008; Miller and Rabaglia, 2009; Oliver and Mannion, 2001; Roling and Kirby, 1975). Ethanol, a product of anaerobic metabolism, is released by weakened, stressed trees, sawn wood, and wood products (Gara *et al.*, 1993; Kimmerer and Kozlowski, 1982; Steckel *et al*., 2010; Pohleven *et al*., 2019) and is attractive to many species of bark and ambrosia beetles (Graham, 1968; Hayes *et al.*, 2007; Miller and Rabaglia, 2009; Montgomery and Wargo, 1983). Some of these chemicals continue to be emitted long after the wood is cut and dried, although emissions are considerably reduced through heat treatment at high temperatures (Kačík *et al.*, 2012; Pohleven *et al.*, 2019).

When colonizing a new breeding substrate, insects often release aggregation and sex pheromones. Many insects are attracted to combinations of host volatiles and pheromones produced by other insects, suggesting that a suite of attractants is used by these contaminating organisms to find host material. Although this is likely more pertinent to the attack of trees, insects that are associated with any wood commodity could release semiochemicals, thereby attracting other insects to the wood.

5.2 Visual cues

Insects employ a variety of sensors and inputs to orient themselves toward food, oviposition sites and mates. In some cases, visual and olfactory cues are used together to find an appropriate object or condition. Terrestrial gastropods may use visual stimuli for locomotion toward food or away from predators (Chernorizov and Sokolov, 2010; Bobkova *et al.*, 2004).

5.2.1 Light (phototaxis)

Many insects are attracted to light. A well-known example of contaminating pest movement due to light attraction (positive phototaxis), is found in AGM. AGM adult females are attracted to lights during cargo loading in regulated countries. AGM will locate suitable surfaces on maritime vessels and lay their egg masses (Schaefer and Wallner, 1992; Wallner *et al.*,1995). A number of lymantriid moths are specifically attracted to light in the 480-520 (blue-green region) and 340-380 nm range (Crook *et al.*, 2014). Wallner *et al.* (1995) found that use of UV and blue light blocking filters made lights less attractive to female lymantriid moths in the Russian Far East (Mastro *et al.* 2021).

Insects whose larvae or nymphs develop in freshwater possess positive polarotaxis, i.e., are attracted to a source of horizontally polarized light which can include attraction to vertical glass surfaces and other artificial surfaces (e.g., asphalt roads, black plastic sheets, dark colored cars, dark glass surfaces, solar panels) that reflect highly and horizontally polarized light (Kriska *et al.*, 2008). Similar studies on tabanid flies found that repellency and protection of livestock is improved with spotted, striped, or white coats, effectively depolarizing light (Horváth *et al.*, 2017; Blaho *et al.*, 2013).

5.2.2 Shapes

Many bark beetles use a combination of cues to locate a host. For example, *Dendroctonus* species use shape to locate trees, and are attracted to objects that are upright, cylindrical and similar to the silhouette and color of a host tree (Campbell and Borden, 2006). This information led to the design of funnel traps which mimic the silhouette of an upright tree (Lindgren, 1983). Some insects, like *Triatoma infestans* (Klug), exhibit a strong negative reaction to light and are attracted to black patches or shapes, potentially for shelter with and without olfactory cues (Reisenman *et al.*, 2000). Bees and wasps can be attracted to dark cavities or shapes for nesting. Attraction to different patterns associated with shadows and cracks could also be associated with cardboard, metal, plastic, or other materials.

5.3 Sound

Acoustic communication is widespread among vertebrate animals, but insects are the lone invertebrate group where sound production and hearing are well developed (Hoy, 1998; Pollack, 2017). Sound is generally divided into “airborne sound” and “sensing of vibration in the substrate,” the former being less prevalent in insects due to short wavelength constraints. Sound production when emitted is used to attract, repel or threaten. Sound is also used for detecting and locating predators, hosts and mates (Pollack, 2017). Sound is used, with varying degrees of success, as the basis for pest management programs focused on disruption of mating and repellency (Gammon, 2015; Mankin, 2012).

A variety of beetles use acoustic sounds or “chirping” produced by the friction of body surfaces to communicate. They use these calls to signal aggression or mating readiness (Barr, 1969; Rudinsky and Michael, 1973). Sound production can also be used for predator avoidance (Spangler, 1988) or host detection in the case of parasitic insects such as tachinid flies (Lehmann and Heller, 1998). Arthropods and vertebrates generally produce sound for communication in the range of 1-10kHz; abiotic noise is typically below this level (Luther and Gentry, 2013). However, anthropogenic noise can be heard at a wide range of frequencies. Depending on the species, it can lead to interference of communication, altered behaviors, confusion, or attraction to auditory cues of human origin (Bunkley *et al.*, 2017). Some organisms, particularly those with fast reproduction and short life cycles, such as *Oecanthus* tree crickets, adapt to noise pollution quickly with little interference to communication (Costello and Symes, 2014). The emergence of data on the effect of anthropogenic sound on insect communities has important implications for the management of shipped commodities. Bunkley *et al.* (2017) conducted studies on industrial natural gas fields with elevated noise levels due to compressors and other increased background noise and confirmed distributional change in insect communities as a result. Commercial activities around ports and other industrial locations, involving shipping and storage could have similar effects on contaminating organisms.

5.4 Temperature

Thermal signals may be detected by insects in search of food sources and habitat. The western conifer seed bug, *Leptoglossus occidentalis*, has specialized organs that detect infrared radiation emitted by their main food source, conifer cones (Takács *et al.*, 2009). Multiple insect orders are attracted from great distances to infrared radiation emitted by fires. As the fires subside these insects attack the damaged trees that would otherwise be uninhabitable. The jewel beetle, *Melanophila acuminata* (DeGeer), has been reported to fly up to 80 km to reach burning materials (Evans, 1964; Schmitz and Bleckmann, 1998).

Thermoreceptors on insects vary greatly by species. Some insects can detect minor temperature changes, such as conifer cones that are 15°C warmer than conifer needles. Others can sense large spikes in temperature, such as fires ranging from 500 to over 1000°C (Takács *et al.*, 2009; Schmitz and Bleckmann, 1998). This attraction to heat may pose a risk during wood processing and storage. For example, wood with residual heat following kiln treatment or wood exposed to sunlight may result in attractiveness to a range of contaminating organisms.

5.5 Moisture

Olfactory receptors are used by many organisms to locate sources of water vital for metabolic function. Odorant receptors in vertebrates are comprised of two major classes of receptor genes. The first class is believed to detect water soluble odorants and are primarily found in fish, amphibians, and some mammals. The second class, found in tetrapods, likely detect airborne odorants (Freitag *et al.*, 1998). Insects such as the blowfly, *Phormia regina* (Meigen), detect water with chemoreceptors in their antennae and tarsi. The presence of hygroreceptors in insects also gives some species the ability to detect moisture and humidity (Tichy and Kallina, 2013; Wigglesworth, 1972).

While organisms use various methods to locate water directly, others may use indirect methods such as detecting volatile organic compounds (VOCs) that can be emitted from other biotic components of the ecosystem that are associated with water. Fungi and microbes cause the release of VOCs when they decompose wood, which can attract symbiotic insects that make use of the altered substrate and food source. Predatory or parasitic insects may also be attracted to these conditions (Mali *et al.*, 2019; Kandasamy *et al.*, 2016). Small, slow-moving invertebrates such as snails and slugs similarly use VOCs, released by plants, diatoms and algae, to locate a moist habitat that contains sustenance (Brönmark and Hansson, 2012; Hanley *et al.*, 2018).

5.6 Refuge

Following arrival on a surface, which could include a forestry commodity or its conveyance, many organisms assess the conditions and suitability for refuge (moisture content, light/dark, temperature). For example, the Tulip-tree beauty moth, *Epimecis hortaria* (Fabricius), finds shelter on tree bark that matches its markings making it very difficult to locate. Many organisms make use of camouflage within their environment to avoid predators which presents inspection challenges. Other species make use of holes and crevices or hide under bark. These shelters also provide protection from the elements such as extreme temperatures, precipitation, and wind. Beech tree cankers, caused by beech bark disease, provide more refugia for overwintering adult beech weevil, *Orchestes fagi* (L.) than uninfected trees with smooth bark (Morrison *et al*., 2017).

5.7 Rest

In some cases, organisms rest on objects when searching for or when locating food, mates, or shelter. Migratory behavior can result in sudden arrival of organisms that are moving towards or away from overwintering sites. This can occur over multiple generations in which case each generation stops and lays eggs before dying. The offspring continue migrating and repeat the process in a new location. Migration can take place over long distances or locally depending on the species. Some species such as the red palm weevil, *Rhynchophorus ferrugineus* (Olivier), fly short distances before resting while others use the wind to propel themselves great distances, as is the case with the cabbage webworm, *Hellula undalis* (Fabricius) (Ávalos *et al.*, 2014; Shirai and Yano, 1994).

5.8 Nesting

Wood that is stored undisturbed for a length of time may provide suitable nesting sites for a range of contaminating organisms such as solitary wasps, bees, spiders, moths, and ants, among others. Leaf-cutting bees (family Megachilidae) use crevices and pre-existing cavities in wood for nesting sites (Michener, 2000). The giant wasp *Vespa mandarinia* Smith also builds nests in pre-existing cavities in wood, but these are more often found in subterranean, concealed cavities (Matsuura and Sakagami, 1973).

Conveyances such as sea containers can also provide suitable nesting sites for a range of vertebrates and invertebrates (see section 4.1.1). The interior of sea containers, including under the floors, provide refuge and nesting sites for stored product pests, wasps, and a variety of other contaminating organisms (Stanaway *et al.*, 2001).

5.9 Wind, water dispersal

Some contaminating organisms or contaminant materials, such as fungi, nematodes, seeds, or soil, do not actively sense, assess, or choose substrates. They are deposited passively on substrates by means of wind, water, or vectoring organisms.

Fungal spores, for example, can disperse considerable distances, and many are spread via wind. Spores can be dispersed by insect vectors, animals, or rain. Rust spores have been shown to travel as contaminating organisms on commodities or packaging as is evidenced by *Austropuccinia psidii* (G. Winter) Beenken on new sawn, kiln-dried timber (Grgurinovic *et al.*, 2006), but their survival and risk of spread are extremely low (Lana *et al.*, 2012). Spore longevity varies among fungal species and should be considered in assessing the risk of fungal spores as contaminants (Sussman, 1982). Fungal spores are very common in the air and could be detected as contaminant organisms on forestry products, especially with highly sensitive molecular detection methods. Their presence, however, does not necessarily imply a risk, and careful evaluation of the potential for spread to new hosts should be considered.

Some nematode species can survive for long periods of time, in some cases decades (Wharton, 1986), in a desiccated state (anhydrobiosis), and then be wind-dispersed with fine soil particles (Fielding, 1951; Carroll and Viglierchio, 1981; Guar, 1988; Treonis and Wall, 2005; Nkem *et al.*, 2006). When they land on moist surfaces (including stacks of sawn wood), these nematodes can rehydrate and feed on fungi or bacteria. Foliar nematodes (e.g., *Aphelenchoides*) can be dispersed to nearby surfaces (other vegetation or wood) by water droplets (Kohl *et al.*, 2010).

Other passively dispersed organisms such as bacteria and pollen could be considered contaminating organisms. Plant pathogenic bacteria, for example *Erwinia amylovora* (Burr.) Winsl. *et al.* and *Ralstonia solanacearum* (Smith) Yabuuchi, Kosako, Yano, Hotta & Nishiuchi have been reported as contaminants on fruit crates and wood (Ceroni *et al.*, 2004; di Bisceglie *et al.*, 2005).

6. HOW THE BIOLOGY OF CONTAMINATING ORGANISMS AFFECTS PHYTOSANITARY RISK

An understanding of the biology of the contaminating organisms, including which life stages could be transported and survive the voyage, are combined with additional factors (*e.g.*, existing climatic conditions enroute, post-shipment availability and contact with potential hosts) to determine their overall pest risk. These biological considerations are important factors considered in the pest risk assessment stage of a pest risk analysis (PRA) (ISPM 2, ISPM 11 and ISPM 21).

6.1 Life stage

Each life stage of contaminating organisms presents a different inherent risk depending on factors such as commodity type, transport pathway, and post-entry conditions. For example, life stages that can withstand unfavorable conditions may pose a greater risk than life stages with specific needs. Khapra beetle larvae exhibit extreme hardiness and withstand long periods of diapause under various conditions in cracks and crevices of containers and conveyances (Ahmedani *et al.*, 2007; NAPPO, 2019). Some egg-masses may be difficult to detect which facilitates their dispersal when attached to the exterior of a human-made object (see AGM example, section 5.2.1).

6.2 Physiological requirements

The physiological requirements of a contaminating organism should be considered when conducting a pest risk analysis. For example, an obligatory rest period (e.g., obligatory diapause) or the necessity of an alternate host to complete its lifecycle may impact overall pest risk. Diapause is a state of dormancy often entered by organisms to survive extreme environmental conditions. In some cases, diapause is triggered by environmental conditions (facultative) and in others it is obligatory depending on life stage (Kostál, 2006). If diapause requirements are not met for a particular life stage on the pathway, then the risk is negated (e.g., temperature requirements in degree days for egg hatch). If such physiological requirements are not met the overall risk is lower.

6.3 Reproductive strategies

Reproductive strategies of contaminating organisms are important when assessing their overall risk. For example, a gravid (mated) female has a higher establishment potential than an unmated female or single male insect, mollusk, or vertebrate organism. Higher female fecundity further increases pest risk. Other reproductive strategies - for example, parthenogenetic (asexual) organisms such as the hemlock woolly adelgid, *Adelges tsugae* (Annand) (Havill *et al.*, 2006) and organisms with haplo-diploid strategies that do not require a sexual mate, may facilitate pest establishment (Kirkendall *et al.*, 2015).

6.4 Establishment potential

Establishment potential can be estimated using information about a given contaminating organism such as its life cycle, availability of suitable hosts, suitable environment, reproductive strategies, natural dispersal mechanisms, and other factors affecting its survival (Tobin and Liebhold, 2011). These can be considered in a pest risk analysis conducted. Training material on pest risk analysis, including establishment potential, is provided by the IPPC, and is based on ISPM 2, ISPM 11 and ISPM 21 (FAO, 2020b).

7. PHYTOSANITARY MEASURES TO REDUCE THE RISK OF CONTAMINATING ORGANISMS

Specific phytosanitary measures were mentioned in previous sections. Listed below are examples of existing programs and associated best practices implemented to reduce the risk of specific contaminating organisms. The phytosanitary measures identified below are not intended to be a comprehensive list of approaches to manage the risk of contaminating organisms. Furthermore, the accidental omission of a measure from this list is not a reflection of that measure's effectiveness in reducing the risk of contaminating organisms.

7.1 Phytosanitary measures applied prior to shipping

Phytosanitary measures applied prior to shipping reduce the risk of specific contaminating pests. Their applicability and effectiveness may be limited by the nature of the commodity, timing of contamination, types of treatments, and post-treatment management practices (e.g., safeguards, physical barriers.

Treatments for forestry commodities can be separated into two major categories, chemical or non-chemical. Fumigants dominate the chemical treatments, with methyl bromide most commonly applied inside containers and under tarpaulin. In accordance with the Montreal Protocol, many countries are moving away from methyl bromide due to environmental concerns (Velders *et al.*, 2007) and other fumigants are used, and new fumigants being tested (see section 7.1.2). In addition, aerosols, dips, dusts, and sprays are treatment options for forestry products under certain circumstances. Among non-chemical treatments, heat in various forms is most commonly used. Cold and irradiation are also non-chemical treatments, but their use is mostly restricted to perishable commodities. Phytosanitary measures for conveyances could include fumigation, pesticide application, inspection, and sanitation/cleaning.

Phytosanitary measures specifically applied to eliminate wood pests may not have long-lasting effects which would be effective against contaminating organisms, unless they are chemical treatments (e.g., preservatives, anti-sap stain, fungicides, and insecticides) that remain in the material or on the surface at sufficient concentrations to provide residual protection. However, some organisms may contaminate commodities in spite of residual chemical levels. In contrast, moisture reduction in wood achieved through heat treatment (e.g., kiln drying), may have a lasting effect, making the wood less attractive to some contaminating organisms.

Because of the temporary effectiveness of some of these phytosanitary measures, there is no guarantee that treated commodities will be free from contaminating organisms. The likelihood of contamination will increase with time elapsed after treatment. Storage conditions should also be taken into consideration when assessing the likelihood of contamination.

7.1.1 Heat treatment

Heat treatment (including conventional dry heat treatment, forced hot air, steam, vapor heat and hot water immersion) are effective against a wide variety of contaminating organisms (NAPPO, 2014). Treatment schedules will vary depending on the contaminating organism, the nature of the commodity, and other factors. Dielectric heat, which includes microwave and radio frequency, is recognized as a treatment alternative for solid wood packaging material (ISPM 15). Products sensitive to heat, such as Christmas trees, will not be able to withstand heat treatment (NAPPO, 2014).

7.1.2 Fumigation

Fumigation is widely available and is generally easy to apply to consignments of commodities and containers, but efficacy may be a concern depending on the type of forest product and proper application among other factors. Furthermore, fumigation may not be applicable because of chemical absorption, toxicity or environmental and health concerns. Processes have been developed to alleviate some environmental concerns; for instance, methyl bromide fumigant is recaptured after treatment of forestry commodities. Sulfuryl fluoride and phosphine are also listed as alternative fumigants for certain commodity categories. Proper application of fumigation requires a licensed professional who is certified.

7.1.3 Physical removal of contaminating organisms

In some cases, contaminating organisms can be removed from commodities prior to shipping. For example, as recommended in RSPM 37:

> “may be mechanically shaken using a motor or tractor driven shaking unit. This method is considered to be effective in reducing the incidence of some pests on trees. Each unbound tree should be shaken with sufficient intensity and duration to dislodge insects and other contaminants, and until most of the dead needle fall is eliminated” (RSPM 37).

This procedure has been shown to be effective in the removal of yellow jackets (*Vespula* spp.) (Hollingsworth *et al.*, 2009) and has been implemented in import regulations for Christmas trees to Hawaii and other countries. Signs of contaminating organisms may also be identified through inspection and the organisms subsequently removed (e.g., ant or wasp nests).

In sawn wood production, processing steps such as debarking, squaring of round wood, and planing of sawn wood can physically remove contaminating organisms which may be present (RSPM 41).

7.1.4 Inspection prior to shipping

Inspection may occur as a measure applied immediately prior to shipping or at any point in a forest commodity supply chain. A sampling intensity level can be developed from information found in the AQIM Manual (USDA, 2021), or equivalent guidance from other countries, or ISPM 31 which contains detail on inspection (see section 7.7 in current document).

7.1.5 Pesticide application

Topically applied pesticides are used extensively on round wood and processed wood, primarily for domestic protection, at commercial wood processing facilities. Aerosol applications are used for the protection of containers and conveyances. Large-wood treatment companies have specific divisions that address pest deterrence and improved wood preservation through the application of pesticides.

Application of pesticides can provide an added layer of protection against contaminating organisms. Pesticides are typically applied to wood as sprays, or through rolling, dipping or vacuum/pressure impregnation. A variety of pesticide formulations exist (Lebow, 2010). Pesticides are generally applied to wood during processing and prior to shipment. Pesticide application to conveyances or containers are generally done prior to shipment (MAF, 2009). Most onboard pesticide applications are related to maritime vessel management and target rodents, cockroaches, and stored product pests (United States Navy, 2008).

Pesticide toxicity can be a concern for human and environmental health, prompting worker safety best practices for handling to avoid residues. Also, trading partners need to agree on allowed products and their concentrations. Pesticide schedules can be customized to meet the required duration of protection in accordance with label specifications.

7.2 How shipping season affects the phytosanitary risk of contaminating organisms

Contaminating organisms associated with forestry commodities may show seasonal development and be dormant or present as immature life stages at certain times of the year. Also, some contaminating organisms are only associated with commodities or conveyances at certain times of the year. During these times, the cold or dry season for example, it may be possible to export forestry commodities with low risk of transporting contaminating life stages capable of establishing in a new environment. However, when forestry commodities are shipped from cold to warm climates, pests may become activate if their dormancy requirements have been met (e.g., diapause in some insects). For example, AGM egg-masses laid on sea containers, maritime vessels or other substrates may complete development enroute and be ready to hatch and disperse upon arrival (models for development of AGM illustrate this example (Gray, 2016)). Vessels visiting AGM infested areas are regulated during periods of the year when female flight occurs (RSPM 33). An example from the USA is the export of heat-treated lumber outside of the flight season (October–April) of sawyer beetles, *Monochamus* spp. This approach ensures that neither pinewood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer) Nickle nor its vector, *Monochamus* spp. have the probability of being transported with the wood (Bragard *et al.*, 2018). Careful consideration of pest life cycles, shipping windows and transit across temperature zones should be made when assessing pest risk and determining required phytosanitary measures.

7.3 Pest free areas or areas of low pest prevalence and pest free places of production

Pest free areas (PFAs) are a valuable risk management strategy because once they are identified, certified, and fully implemented and continually verified and documented by the exporting NPPO they do not require further additional phytosanitary measures when certain requirements are met. (ISPM 4; FAO, 2019). Pest free areas are defined as "*an area in which a specific pest is absent as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained*" (ISPM 5). An area of low pest prevalence is defined as "*an area, whether all of a country, part of a country, or all or parts of several countries, as identified by the competent* *authorities, in which a specific pest is present at low levels and which is subject to effective surveillance or control measures*" (ISPM 5).

Pest free areas can be difficult to establish, certify and maintain, and certification of pest freedom is specific to each pest. PFAs do not preclude the transport of contaminating organisms that have not been detected or identified. PFAs require a thorough and effective certification process to ensure that the pest population is absent in the area. This certification process also needs to be clearly developed, communicated, and agreed upon by the importing and exporting NPPOs (ISPM 4). The concepts were designed for infesting regulated pests and may be appropriate, and thus considered, for contaminating pests.

7.4 How storage conditions affect phytosanitary risk

When schedules do not permit shipment of a commodity immediately following processing, protection from contamination during storage may be considered. Commodities may be stored in a variety of places and conditions using best management practices, depending on the risks associated with contaminating organisms that may be present. Producers, processors, and shippers should be aware of contaminating organism concerns in the importing country and should consider risk management options accordingly. Storage options may vary depending on the type of commodity, environmental conditions (temperature, relative humidity), time of year, and associated contaminating organism risks.

Proper storage includes implementation of best practices that are effective in reducing the likelihood of contamination. The effectiveness of these practices is dependent on organism type, the nature of the commodity as well as prevailing environmental conditions. Importing and exporting countries should share information and best practices on the most effective storage conditions and their implementation. Ideally, shippers, freight forwarders, and shipping equipment manufacturers should be involved in developing effective storage practices that do not create barriers to trade.

Best storage and handling practices should be used to minimize the risk of forestry commodities becoming contaminated taking into consideration the types of contaminating organisms in a given circumstance. They can include but are not limited to:

Storage:

- Store indoors if at all possible.
- When storage is outdoors, cover with shade or pest protective net.
- Store as far away from live trees and shrubs as possible.
- Avoid storage under bright lights, particularly at night.
- Avoid contact with soil, ideally on a dry riser and/or a solid surface.
- Avoid storage in weedy or grassy open yard areas.
- Avoid contact with water and other liquids.

Handling:

- Inspect forestry commodities for contamination prior to movement along the supply chain.

- Clean forestry commodities to remove any contaminants (e.g., compressed air, water or vacuum).
- Rotate inventory where possible (first in, first out approach).
- Maintain clean loading and packing equipment

Additional Protective Phytosanitary Measures:

- Store round wood under water or spraying water as a protection.
- Use anti-aggregation pheromones to deter secondary insect contamination (Hughes *et al*., 2017; Borden *et al.*, 2001).

Other:

- Maintain clean floors, containment, wrapping, and yards (e.g., sanitation may include bark removal in wood processing and storage areas).
- Decrease storage periods.

7.5 Using systems approaches to reduce the risk of contaminating organisms

Integrating several of the phytosanitary measures discussed in this document into a systems approach may provide an alternative risk management option and be more effective at reducing and managing the occurrence of contaminating organisms on forestry commodities moving in trade. A systems approach is defined as "*a pest risk management option that integrates different measures, at least two of which act independently, with cumulative effect*" (ISPM 5). Systems approaches for forest products as outlined in RSPM 41 include risk reduction options applied at different critical points along the production pathway. Risk reduction measures may be applied during production, storage, shipping and post shipping. Systems approaches may be designed to target contaminating organisms in the same way they are used for regulated pests – using biological information and applying sound scientific approaches for risk reduction.

An example of a systems approach used to manage a contaminating pest is the Canadian Sawn Wood Certification Program to detect BMSB. This combines inspection, segregation of organism-free wood, specified storage conditions, oversight, traceability and use of a manual specifying the components of the entire system (CFIA, 2019). New Zealand has implemented a systems approach to reduce the risk of contaminating organisms moving with sea containers in the Pacific Island region which combines cleaning, storage on hard surfaces, pest control, reducing pest habitat in port areas, auditing, and certification (MAF, 2009; Ashcroft *et al.*, 2008).

7.6 Post-shipping phytosanitary risk-reduction options

Contaminating organisms may become associated with a commodity or conveyance at several points along its export-import pathway, from the site of production to the final destination. Post-shipping measures provide an opportunity to address contaminating organisms before they leave the commodity or conveyance and potentially establish in a new environment. Post-shipping risk reduction may include any phytosanitary measures applied after the product has left the exporting country (listed in Section 7), such as inspection, physical removal of organisms, application of pesticides, fumigation, heat treatment, etc. Storage, restricted use, and/or limited distribution at destination are alternative options available to address contaminating organisms associated with a specific product (for example, wood chips to be used for pulp or biofuel). Processing post-shipping, in conjunction with careful storage requirements, may be deemed a practical risk-reduction option.

RSPM 33 Pre-entry inspection for AGM

RSPM 33 provides guidelines for risk management to minimize the entry and establishment of AGM into the NAPPO region. Phytosanitary measures are related to inspection and subsequent certification of vessels prior to reaching a port of entry. This approach can be used with other contaminating organisms or pests. If signs of AGM or other pests are discovered, they are removed and disposed of. NPPOs within NAPPO have manuals that offer special guidance and protocols to follow when suspect AGM samples are collected (USDA, 2016).

This approach poses nominal disruption to trade for compliant vessels while reducing risk of introduction of AGM. It requires constant communication between importing and exporting NPPOs to coordinate inspection and certification processes, as well as training of NPPO officials and vessel crew.

7.7 Inspection

Inspection is used by both exporting and importing countries to certify pest presence/absence, attest to the phytosanitary status of forestry commodities and transport vessels or verify documentary procedures. Inspection is defined as the "*official visual examination of plants, plant products or other regulated articles to determine if pests are present or to determine compliance with phytosanitary regulations*" (ISPM 5). ISPM 23 and ISPM 31 support the use of inspection as a phytosanitary measure. Each country can determine its own inspection approach and the comprehensiveness of its policies. Varying levels of inspection frequency and scrutiny can be a challenge for importing and exporting NPPOs reaching agreement on acceptable protocols. Moreover, inspection requires appropriate infrastructure. The importing country must also determine its approach/response to infested consignments and must develop appropriate courses of action, for non-compliant cargo and/or conveyances found during inspection. These actions may include fines or penalties, rejection, treatment, destruction, or seizure/detention of non-compliant shipment.

There are specific considerations for designing inspection programs. Inspection requires well-trained personnel to be effective. In addition, because inspection is time and resource intensive only a small percentage of imported goods are typically inspected. Depending on the size of the consignment, a percentage-based inspection can result in over or under inspection of a consignment, whereas "risk-based" inspections, where the lot size and confidence limit vary according to confidence and infestation level, more precisely predict the appropriate inspection rate. Inspection challenges are magnified by the cryptic nature of contaminating organisms. Contaminating organisms that are hidden in cracks and crevices or are well camouflaged may be missed during inspection (see example in section 5.6 Refuge).

Inspection success can be improved through the identification of higher risk pathways and/or lower risk shippers. By using a risk-based sampling approach to identify high-risk pathways, inspectors can focus efforts on the most likely sources of contaminating organisms. Voluntary programs, such as Customs Trade Partnership Against Terrorism (CTPAT) in the United States, help to identify shippers who are willing to adhere to strict guidelines to decrease phytosanitary risk, so that inspection resources can be devoted to higher risk pathways (US Customs and Border Protection, 2021).

Inspection of commodities and conveyances may take place at any point along the commodity pathway. Inspection details and record keeping are part of a production manual approved and certified by the NPPO of the exporting country.

In Mexico, the verification of imported forest products and by-products is overseen by the official personnel of the Federal Attorney for Environmental Protection (Procuraduría Federal de Protección al Ambiente-PROFEPA), and then carried out in the facilities of ports, airports, and national borders. The official procedures for the phytosanitary inspection and for the decision-making that are mandatory in this regard are established in the *Manual of Procedures for the Import and Export of Wildlife, Forest Products and By-Products, and Hazardous Materials and Residues, subject to Regulation by the Ministry of Environment and Natural Resources (Manual de Procedimientos para la Importación y Exportación de Vida Silvestre, Productos y Subproductos Forestales, y Materiales y Residuos Peligrosos, Sujetos a Regulación por parte de la Secretaría de Medio Ambiente y Recursos Naturales)* which was published in the Official Gazette of the Federation since 2004.

7.7.1 Inspection considerations

Inspection processes should be based on sound statistical concepts, to ensure that desired protection levels are achieved, and to also ensure that the information coming from inspections is meaningful and accurate. One use of inspection programs is to better identify and rank non-compliant imports, and this applies to wood packaging as well as cargo. Inspection, and targeting based on quantitative results has been used by countries to identify high risk commodities associated with contaminating organisms, and to identify entities frequently associated with problematic detections.

Sampling for detection of contaminating organisms in wood materials may be possible to target items in the pathway with higher probabilities of being infested, but this is challenging because the information about the incoming cargo may or may not usefully reflect the risk profile of the wood material associated with it. Sampling schemes are often designed specifically for each inspection location to reflect unique characteristics of that location and its personnel. Canada uses both a target-based approach for a commodity or pest and a randomized sampling approach for determining sampling lots, and inspection units.

The size of a sample for inspection purposes usually depends on a risk-based sampling objective. The sampling objective is influenced by the risk associated with a specified regulated pest of a specific commodity from a particular origin (*i.e.*, country, grower, exporter). The NAPPO *Risk-*

Based Sampling Manual – Part I, outlines how to design, evaluate, and manage risk-based sampling (NAPPO, 2021a). Europe, Australia, and many other importing countries all have individualized risk-based sampling programs that combine elements of random and targeted sampling. Operational costs and other considerations often dictate that targeted-based inspection sampling be the favored approach.

7.7.2 Developing an inspection manual for contaminating organisms on forestry commodities

Developing an inspection manual for contaminating organisms on forestry commodities may provide an opportunity to engage experts to provide guidance for inspection, targeting specific contaminating organisms in specific circumstances. A manual also ensures consistent application of chosen procedures and can fulfill requirements of the importing country. Manuals may also be developed for the implementation other phytosanitary measures. When a manual is required to address a specific contaminating pest, it may contain, as appropriate, the following:

- Best practices in consignment inspection and risk assessment.
- Record maintenance.
- Phytosanitary management systems to align with requirements of importing countries.

NPPOs may consult experts for inspection guidance manual development. The AQIM Handbook provides a decision-making process from which a manual can be created. The handbook includes decision tables, where contaminating pests are used as a recognized category. Inspection information is then entered into the Agricultural Risk Management (ARM) database. RSPM 33 was developed for guidance from which NAPPO countries developed regulations and procedures to address the risk of AGM on vessels entering North America (USDA 2016). AGM regulations for marine vessels arriving in Canada from regulated areas are outlined in the CFIA policy document D-95-03 (CFIA, 2021).

Mexico has a Manual of Procedures for the Import and Export of Wildlife, Forest Products and By-Products, and Hazardous Materials and Residues, subject to Regulation by the Ministry of Environment and Natural Resources (*Manual de Procedimientos para la Importación y Exportación de Vida Silvestre, Productos y Subproductos Forestales, y Materiales y Residuos Peligrosos, sujetos a Regulación por parte de la Secretaría de Medio Ambiente y Recursos Naturales* (SEMARNAT, 2004)) which is a general procedures guideline to verify/inspect imported forest products and by-products and their documentation, which PROFEPA's official staff applies at points of entry for these types of commodities. The decision-making process for intercepted pests and the specific requirements that must be verified/inspected are established in the Technical Report for Taxonomic Determination and the Mexican Official Norms (NOM, as per its Spanish acronym). One of those examples is the NOM-013-SEMARNAT-2020 which establishes the specifications and phytosanitary requirements for the importation of natural Christmas trees in the genera *Pinus* and *Abies* and the species *Pseudotsuga menziesii*. Information on inspections is included in the database of SEMARNAT General Directorate for Forest and Soil Management.

7.7.3 Training

Training and competency of inspectors and other personnel increase the likelihood that inspected pathways and products are free from contaminating organisms. An accredited body or institution may provide training for inspection consistency and accuracy and address the facility and exporting country's NPPO (accreditation body) requirements. Training material can be useful in the overall understanding of contaminating organisms, but as individual contaminating pests become identified, more specific training materials may need to be developed. Training materials are often developed by and used within NPPOs.

7.7.4 Audit

In some instances, phytosanitary requirements are formally agreed upon bilaterally between trading partners. Audits and oversight of the inspection, certification, and phytosanitary management aspects of these agreements, plus authorized certification, are critical to ensure integrity and maintain transparency. Audits of authorized facilities are important for identifying non-conformances, corrective actions, and the need for follow-up audits. Corrective actions may be monitored by the NPPOs. Audits may be requested by either the NPPO of the importing country or exporting country and may be conducted by either trade partner's NPPO or an authorized third party entity (ISPM 45).

7.8 Traceability

Traceability is defined in RSPM 41 as "*the documentation and verification of the movement of the commodity from the initial control point to the final product*" (RSPM 41). Traceability generally describes concepts of origin, trace-forward, and trace-back. This is accomplished through universal recognition and use of phytosanitary certificates or third-party certificates (under NPPO oversight, ISPM 45) as an instrument that guarantees regulated articles meet specified phytosanitary import requirements.

The vast majority of successful trace-back and trace-forward programs have been restricted to positive pest/host relationship, *i.e*., infested wood material. Contaminating organisms may lack host specificity and thus traceability can be more difficult to achieve when required. For this reason, successful trace-back and trace-forward programs should be designed with flexibility that considers cost, difficulty of identifying a product to origin, transportation and distribution logistics, and other factors. It may be advantageous to broaden focus from commodities to include conveyances and pathways, as focus on the commodity alone may not be useful in some cases. Successful trace-back programs for AGM on ships, snails on military ordinance containers, and brown marmorated stink bug on vehicles are but a few examples. Bilateral agreement between industry and regulatory authorities is essential in developing and maximizing the potential of traceability programs.

8. CONCLUSIONS

A wide range of contaminating organisms, including animals, plants, bacteria, and fungi move with commodities and conveyances in international trade. These organisms can be categorized according to the nature of their association with commodities or conveyances (infesting or contaminating organisms) and whether they are considered pests. Historically, phytosanitary regulations have focused on infesting organisms, specifically pests: those organisms that have undergone PRA. Contaminating organisms, organisms that become associated with commodities or conveyances, but do not infest them, can be more difficult to predict and manage and novel approaches may be needed to prevent their movement. While there are some well-known contaminating organisms that have undergone PRA and are identified as contaminating pests, regulated pest lists developed by countries largely include infesting pests. Many contaminating organisms have the potential to be deemed a contaminating pest, particularly if they find their host upon arrival at the commodity or conveyance destination.

This document identifies a number of factors related to how and why contaminating organisms become associated with a commodity or conveyance including passive dispersal, attraction to physical cues such as light/dark, moisture level, temperature, olfactory cues, etc., and biological considerations of the organism (life stage and life history strategy). An understanding of these factors as they relate to different types of commodities is critical for the development of science-based tools to identify (through surveillance, inspection, PRA, etc.) and manage the risk of contaminating organism movement with forestry commodities through the application of phytosanitary measures applied pre- and post-production. As our understanding of contaminating organisms increases, NPPOs will explore additional ways to manage them and share information in a collaborative and harmonized manner. This will inform the development of effective policies and practical guidance for plant health inspectors to reduce the risk of contaminating organisms moving in trade and avoid the unnecessary regulation of non-pest organisms.

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