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联合国粮食及农业组织
Food and Agriculture Organization of the United Nations
Organisation des Nations Unies pour l'alimentation et l'agriculture
Продовольственная и сельскохозяйственная организация Объединенных Наций
Organización de las Naciones Unidas para la Alimentación y la Agricultura
منظمة الأغذية والزراعة للأمم المتحدة

COMMISSION ON PHYTOSANITARY MEASURES

Eleventh Session

Rome, 4-8 April 2016

Special Topics Session: Sea Containers

Paper on the Role of sea containers in unintentional movement of invasive contaminating pests (so-called "hitchhikers"), and opportunities for mitigation measures

Agenda item 14

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English only

Role of sea containers in unintentional movement of invasive contaminating pests (so-called "hitchhikers"), and opportunities for mitigation measures

(This is an advance paper prepared for the CPM;
a modified version will be prepared for publication in 2016)

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Abstract
The volume of international trade is at unprecedented levels, and much of this is moved with intermodal containers ("sea containers"). An unwanted by-product is the transport of contaminants, including "contaminating pests" (also known as "hitchhiker pests" or simply "hitchhikers"), on the external or internal surfaces of sea containers, which may become invasive species. Contaminating pests found on sea containers, such as gypsy moth (*Lymantria dispar*), giant African snail (*Achatina fulica*), Argentine ant (*Linepithema humile*), and brown marmorated stink bug (*Halyomorpha halys*), threaten agriculture, forests and urban environments, and they cause substantial economic and environmental damage in many countries. Soil contamination of sea containers may contain seeds of invasive plants, nematodes and plant pathogens. We summarize records from sea container inspections carried out by quarantine officers as well as previous analyses of this pathway and evaluate the potential benefits of mitigation measures that would reduce infestations of sea containers with contaminating pests and soil contamination. There is a plethora of records of interception of contaminating pests with sea containers. Inspection records from the United States, Australia, China and New Zealand indicate that thousands of organisms from a wide range of taxa are being moved unintentionally with sea containers. Most data sources do not allow estimation of arrival rates of contaminating pests. However, inspection records of 116,701 consignments of empty sea containers arriving in New Zealand between 2010 and 2015 indicated a 9.7% exterior contamination rate and 5.0% interior contamination. A sea container hygiene system has been implemented in New Zealand for sea containers coming from several Pacific Island countries since 2006. The system involves sea container inspection, cleaning, verification, training, and prevention of contamination, and it resulted in considerably reduced infestation rates and overall cost savings. We assessed the potential benefits and costs of a proposed (draft) International Standard for Phytosanitary Measures 'Minimizing Pest Movement by Sea Containers'; this is likely to provide economic net benefits as a result of avoided 'damages', direct and indirect, caused by invasive species that are moved as contaminating pests and other contaminants associated with sea containers.

Introduction
International and inter-continental trade has increased substantially since the middle of the last century. For example, imports to the United States increased more than 200 times between 1950 and the early 2000s (United States Census Bureau 2008). An unwanted by-product of globalisation, especially increased international trade, is the unprecedented invasion by pests and pathogens that are accidentally transported from their natural range to other locations (Mack et al. 2000). Thousands of exotic species have become established in new environments. For example, there are more than 1300 exotic insect species in Europe

(Roques et al. 2009), 3500 in North America (Yamanaka et al. 2015), and about 1600 in New Zealand (Gordon 2010). Although not all exotic species are damaging, some are serious biological invaders that cause enormous environmental and economic impacts (e.g., Pimentel 2011; Lockwood et al. 2013; Simberloff et al. 2013). Many of the most serious agricultural pests [***footnote**: for the purpose of this paper 'pests' included both animals and microbial pathogens*] that cause crop losses and necessitate the use of pesticides are invasive alien species (Mack et al. 2000; Colautti et al. 2006; Goldson et al. 2015). Other invasive species are primarily environmental pests that can adversely affect the provisioning of ecosystem services (Boyd et al. 2013). The increase in biological invasions that has been observed in the last century has been clearly linked to the growth in international trade (Levine and D'Antonio 2003; Work et al. 2005; Roques et al. 2009).

The unintentional transport of potential pest species can occur via a range of pathways and commodities, for example, with fresh produce, forest products, or live plants. Typically, organisms found with such commodities are species that have some kind of host association with them. By contrast, so-called "contaminating pests", also known as "hitchhiker pests", "hitchhikers" or "stowaways", are merely sheltering or transported accidentally via inanimate pathways including with machinery, shipping containers, vehicles and ships (Toy and Newfield 2010). Well-known "hitchhikers" include plant seeds, snails (e.g., giant African snail, *Achatina fulica*), ants (e.g., Argentine ant, *Linepithema humile*), and other insects such as the brown marmorated stink bug (*Halyomorpha halys*) and gypsy moths (*Lymantria* species). Despite their association with inanimate objects (in terms of their pathway of invasion of other continents) many hitchhikers are important plant or environmental pests and cause considerable damage and economic impacts (e.g., Venette and Larson 2004). Therefore, it is advisable to consider options for regulating pathways that are important in the movement of hitchhikers, and phytosanitary measures designed to mitigate pathways responsible for the transport of hitchhikers are expected to be beneficial.

Sea containers have been identified as a major pathway for the international and intercontinental transport of hitchhiker organisms. Along with the worldwide increase in international trade, there has been a major change in the method of transportation from bulk cargo to increasing containerisation. Standardised shipping containers (so-called general purpose containers) gained in importance since the 1950s and today more than 60% (by value) of all goods shipped via sea are transported in intermodal containers (World Shipping Council 2015) (hereafter referred to as "sea containers"). For the present study, we focus on sea containers because of their important role in the movement of hitchhikers.

The objectives of this study were:

1. To describe trends in sea container movements worldwide;
2. To review the literature on hitchhiker pest movement associated with sea container transport across borders, including the description of case studies that illustrate hitchhiker pest movements by sea containers and their impacts;
3. To compile and analyse information, including interception records, on pests and other organisms detected during surveys of sea container from different countries;
4. To carry out a conceptual analysis of costs and benefits of mitigation measures to address hitchhiker infestations of sea containers.

1. Trends in sea container movements

The number of containers has grown steadily, and it has more than doubled since 2000 and increased nearly six-fold since 1990 (Fig. 1). The most common type of container is the maritime container which comes in lengths of either 6 m ("20 foot" containers) or 12 m ("40 foot containers") and is about 2.4 m wide and either 2.6 m or 2.9 m high. As of 2014, about two thirds (65.7%) were 40 foot containers and one third 20 foot containers. At the end of 2014 there were 23.15 million maritime containers in use, or 34.45 million twenty-foot equivalent units (TEUs) of ocean-borne containers (Drewry Maritime Research 2015). In addition, there were 2.12 million TEUs of land-based containers. For the purpose of this report we focus primarily on ocean-borne containers ("sea containers"). Ninety percent of sea containers were standard containers and the remainder consisted of refrigerated containers (5.6%), special containers (3%), and tank containers for liquids (1.5%) (Drewry Maritime Research 2015). An 'average' sea container is used for approximately 4 to 5 trips per year (more for containers that are used for short-sea trades). However, most trips involve multiple border crossings as containers often pass via transhipment hubs. Therefore, containers pass through approximately 13 ports on average per year per container (or 19.7 per TEU), resulting in a worldwide total port throughput per year of about 300 million containers or about 679 million TEUs (data for 2014, from Drewry Maritime Research 2015).

2. Review of hitchhiker pest movement associated with sea container transport across borders, including the description of case studies

2a. Review of previous studies on hitchhiker movement with sea containers

Sea containers are a well-recognised pathway for a wide range of species that present a biosecurity risk to productive sectors and natural ecosystems (Bulman 1992, 1998; Haack 2001, 2006; Work et al. 2005; Zahid et al. 2008; Toy and Newfield 2010). A detailed survey of 11,265 sea containers that arrived in New Zealand confirmed that shipping containers were a significant biosecurity threat, with 4.5% on average containing some form of contaminant (MAF 2003). A survey of containers arriving in New Zealand found very high rates of contamination of empty containers (MAF 2006). For example, hitchhiker organisms, soil or other contaminating organic matter were found on 48% of empty containers arriving from Wallis and Futuna (N = 751) and on 20% of empty containers from American Samoa (N = 552) (MAF 2006).
Those studies reported numbers of insect interceptions associated with the commodity or packaging that the container was carrying. It is more difficult to find hard data on numbers of hitchhiking pests in sea containers. An official New Zealand government audit (Anonymous 2002) concluded that sea containers were the likely pathway for recent incursions of hitchhiker pests such as the southern saltmarsh mosquito (*Ochlerotatus camptorhynchus*) and the painted apple moth (*Teia anartoides*). Newfield (2008) considered sea containers likely to be an important pathway for hitchhiker moths of significance to forestry, such as Asian gypsy moth, fall webworm and painted apple moth.

Inanimate contaminants, such as soil, that may contain high risk organisms including nematodes, plant and animal pathogens and plant seeds, are frequently carried on containers (Toy and Newfield 2010). Under these circumstances, such organisms are considered to be hitchhikers (Toy and Newfield 2010). A number of studies have been carried out on the risk of soil carried on the outside of sea containers. Gadgil et al. (2000) found that that of 3,681 shipping containers that were examined, 31% carried soil contamination on their external surfaces. A number of fungi and other microorganisms from genera known to be pathogenic or plant parasitic (e.g., *Fusarium*, *Verticillium*, *Aphelenchus*) were isolated from the soil. Godfrey and Marshall (2002) isolated *Pseudomonas* species (bacteria that may play a role as plant, animal, and human pathogens) from 19 different countries and concluded that soil on shipping containers may act as a source of new introductions of those species.

Sea containers are rated as a high risk pathway for the introduction of red imported fire ant, *Solenopsis invicta* (MAF 2002) and other ant species (Nendick et al. 2006; Ward et al. 2006). *Solenopsis invicta* may be present either in soil attached to containers or as free hitchhikers. Nendick et al. (2006) stated that around 65% of invasive ants detected at the New Zealand border arrive from the Pacific Islands, on or in empty sea containers and on commodities such as root crops. Ants have been carried to the United States on sea containers (Suarez et al. 2005), and ship cargo is considered the most likely source for the spread of ants through the world (Inoue and Goka 2009).

Sea containers may also carry many free-living hitchhikers that are not associated with soil, including vertebrate and non-vertebrate pests. Rats were introduced to New Zealand as hitchhikers (Moors 1990). Frogs, lizards and snakes are the most likely reptiles and amphibians to successfully hitchhike in containers (Kraus 2009). Skinks (e.g., *Lampropholis* spp.) are regularly intercepted in sea containers from Australia, and approximately 65% are estimated to remain undetected during border inspections (Chapple et al. 2013). Containers carrying military equipment were proposed as a possible pathway for the introduction of the brown tree snake to Guam where it has devastated the local bird fauna (Engeman and Vice 2001).

Of the organisms of most concern to agriculture and natural ecosystems, insect pests are the most common form of free living hitchhiker. A pest risk analysis carried out in New Zealand (Newfield 2008) concluded that while the incidence of hitchhiking moths on or in sea containers was very low, the number of containers received, at over 600,000 per year, increase risk significantly. It suggested that border activities were reducing the risk of Asian gypsy moth establishment, but not to a negligible level, and were not sufficiently effective against painted apple moth or fall webworm. The likelihood of establishment of moths hitchhiking with sea containers was considered to be higher than of those that are moved with ships, but lower than for moths arriving as hitchhikers with used vehicles (Newfield 2008).

A survey of 3,001 empty shipping containers imported to Australia found 39% contained arthropods (Stanaway et al. 2001). Of the 7,861 insects recorded, 1339 (17%) were live. Most of the live insects were pests of stored products, but serious pests of forestry and agriculture were also found (dead or live). The relatively small sample size of 3,001 containers and the expected low frequency of contamination prevented a quantitative risk assessment of individual taxa, but some general conclusions could be made. The study demonstrated that sea containers were an important pathway for the dispersal and establishment in new areas of insects of significance to forestry, agriculture and human health. It was recommended that data from systematic inspections are shared between countries to quantify risk to the satisfaction of international requirements (Stanaway et al. 2001).

Toy and Newfield (2010) review cases of establishment of invasive hitchhiking animals on all pathways, including sea containers. This is one of the most comprehensive reviews of hitchhiking pests, although it did not cover nematodes or microorganisms such as fungi, chromists and bacteria. The review lists examples of the wide variety of invasive hitchhiker pests that may be carried on sea containers. These include snails, wasps, mosquitos, mantids, moths and ants, many of which may be difficult to detect (e.g., egg masses on the underside of a sea container, or mobile organisms that have the ability to hide). Sea containers are a high-volume pathway and these volumes are predicted to increase further. Toy and Newfield (2010) concluded that current actions aimed at reducing risks of hitchhiker organisms are inadequate and they proposed four measures that could help manage invasive hitchhikers: increased international cooperation, reduced reliance on visual inspection, greater use of safe and effective treatments, and increased sanitation at ports where containers were loaded.

2b. Case study: Plant seeds transported with sea containers

Pest interception records from inspections of sea containers entering the United States show that interceptions of plant seeds are very common. Almost 50% of the approximately 1300 plant interceptions were seeds of *Saccharum*, mainly *Saccharum spontaneum*. *Saccharum* species are naturalised in several countries, regulated in the United States, and there is considerable potential for further invasions. Asteraceae are the second-most commonly intercepted seeds, with *Tridax procumbens*, another regulated plant, being the most represented species. A majority of these interceptions were detected on the refrigeration unit of refrigerated sea containers or on the floor of dry containers, but are sometimes found adhering to the external parts of either type of container. The grille of the refrigeration unit is particularly amenable to trapping plant seeds as the air intake facilitates this. Plant seeds being transported in these ways can all be considered hitchhikers, although seeds found on the container floor may be residual seeds from previous cargo. Seeds found externally typically adhere to the container after being blown by wind or after the container was placed on top of a field or an area where seeds are already present on the ground. In addition, many containers are contaminated with soil which often contains seeds.

2c. Case study: Snails and their association with sea containers

Many snail species are serious pests of agriculture and the environment, including a number of invasive species (Barker 2002). Perhaps the best known invader and most serious terrestrial mollusc pest is the giant African snail (*Achatina fulica*) (Raut and Barker 2002). It is listed as one of the 100 worst invasive species (Lowe et al. 2000) and considered to be one of the most significant invasive alien species in China (Li et al. 2014). In the United States, it is one of the priority target species of the CAPS surveillance programme (Magarey et al. 2011).
An economic impact assessment estimated annual losses due to the giant African snail in Florida at $11 million USD (in 1969 dollars) if its eradication had not been successful (USDA 1982 cited in Venette and Larson 2004). Several other invasive snail species are important pests in various crops in southern Australia (Barker 2002).

Hitchhiking with sea containers is a known pathway for snails (Whattam et al. 2014). Indeed, snails are often found on the outside, especially the underside, of sea containers. Snails have the opportunity to crawl onto containers while these are placed on the ground, especially in areas without a hard surface (e.g., bare soil) and where vegetation is present. Empty sea containers in particular are sometimes stored for extended periods at such locations. At some ports, containers are placed on compacted sea shells which may lead to elevated populations of terrestrial snails that are attracted by the abundance of calcium. Snails access the underside of sea containers or other niches suitable for shelter, sometimes for extended periods to aestivate or hibernate. Investigations by the United States Department of Agriculture (USDA) revealed that hitchhiking snails can travel with sea containers for extended periods and remain viable. For example, an interception of a live *Xeropicta derbentina* in New Orleans, Louisiana, in October 2014 was traced back to Piraeus, Greece, as the true origin, after an eight-month journey via the ports of Singapore, Xiamen (China), Hong Kong, Callao (Peru), Balboa (Panama), La Spezia (Italy), Bologna (Italy), and La Spezia (David G. Robinson, USDA, pers. comm.).

2d. Case study: Brown marmorated stink bug, a high-risk hitchhiker pest

The brown marmorated stink bug (BMSB), *Halyomorpha halys*, has a very wide host range and is a serious pest of agriculture and horticulture (Rice et al. 2014). It is native to northeast Asia but has invaded the United States where it was first detected in 2001 (Hoebeke and Carter 2003), although the first establishment probably occurred in the 1990s. In Europe it was first detected in Switzerland in 2007 (Wermelinger et al. 2008) but there may have been an earlier detection in Liechtenstein in 2004 (Milonas and Partsinevelos 2014). By 2014, BMSB was reported to be present also in Germany, France, Italy, Greece (Milonas and Partsinevelos 2014), and Hungary (Papp et al. 2014), and several other adjacent countries. In its native region and invaded areas, damage from BMSB feeding has been reported from many vegetables (e.g., beans, tomatoes, peppers, and sweet corn) and fruits (e.g., apples, peaches, nectarines, pears, and grapes), often causing considerable economic impacts (e.g., Hoebeke and Carter 2003, Rice et al. 2014).

For example, in the United States in 2010, damage from BMSB's feeding on apple alone caused losses of about $37 million USD (Rice et al. 2014). In addition, in its native range BMSB is known to act as a vector of plant pathogens that can severely affect *Paulownia* trees, and possibly other trees. BMSB is also a major household nuisance pest (Rice et al. 2014).

Despite its association with numerous crops, its invasions are unlikely to be related to imports of fresh produce. Instead, it is believed to have invaded as a hitchhiker, transported with inanimate objects. This is because adults of BMSB aggregate in autumn to overwinter in dry crevices such as under bark or various man-made structures such as under the external cladding of homes, in vehicles or sea containers (Hoebeke and Carter 2003, Rice et al. 2014). In fact, its invasion of North America has been assumed to be related to hitchhiking with 'freight containers' from northeast Asia (Hoebeke and Carter 2003). This notion is confirmed by border interception records; for example, out of 493 interceptions of BMSB at New Zealand's border, 90% were associated with imported vehicles, sawn timber, sea containers, ships, and luggage, primarily from the United States, Italy, and some from northeast Asia (Table 1). Sea containers were implicated in at least 16% of interceptions. The majority (91.7%) of all these interceptions occurred between October and March, confirming that diapausing BMSB sheltering in inanimate objects, including sea containers, are most probably responsible for its invasions.

2e. Case study: Hitchhiking moths and butterflies (Lepidoptera) on sea containers

Non-native Lepidoptera are serious pests of agriculture and forestry worldwide. Non-native Lepidoptera include 79 species established in the European Union, 291 in North America, 208 in New Zealand, 207 in Hawaii and 45 species in Japan (Liebhold et al. 2016). Historically, live plants are probably the dominant pathway by which Lepidoptera enter but a significant number of species also arrive via the hitchhiking pathway (Kiritani and Yamamura 2003; Smith et al. 2007; Newfield 2008; Toy and Newfield 2010; Liebhold et al. 2012). Several Lepidoptera species have behaviours that cause them to be associated with inanimate objects and consequently be transported passively. For example, many species pupate or oviposit in cryptic locations that are not necessarily host plants. Types of inanimate objects with which they may become associated include sea containers; pupae or eggs may be affixed to the surface of a container, particularly in crevices that offer some level of protection but which also may be difficult to observe during inspections.

Historic records by USDA port inspectors (2011-2015) report interception of species in the following Lepidoptera families associated with sea containers: Arctiidae, Coleophoridae, Geometridae, Hesperiidae, Lycaenidae, Noctuidae, Notodontidae, Oecophoridae, Pyralidae, Sesiidae, Sphingidae, and Tineidae (records obtained in December 2015 from the USDA AQAS PestID Database – formerly known as the PIN Database (see McCullough et al. 2006). The Australian Department of Agriculture, Fisheries and Forestry reports the following Lepidoptera species to be found associated with sea containers: scrofa hawk moth (*Hippotion scrofa*), grapevine hawk moth (*Hippotion celerio*), Convolvulus hawk moth (*Agrius convolvuli*), white-spotted tussock moth (*Orgyia leucostigma*), castor caterpillar (*Ariadne merione*), cabbage white butterfly (*Pieris rapae*), common brown butterfly (*Heteronympha merope*), and gypsy moth (*Lymantria dispar*) (http://www.ridgewayintl.com/AQISContainerHygiene.pdf).

The gypsy moth, *Lymantria dispar*, is just one of many Lepidoptera associated with sea containers and it provides a good example of the risk associated with this pathway. The European strain of this species has been established in North America for nearly 150 years and the impacts of this species have been estimated at over $200 million (USD) annually (Aukema et al. 2011). While *L. dispar* populations established in North America originate from Europe, there is concern about establishment of Asian strains of the gypsy moth and other tussock moth species in North America. Species of *Lymantria* and other tussock moths are also a significant concern elsewhere in the world, outside their native ranges. All strains of the gypsy moth have a

tendency to pupate and oviposit on inanimate objects and thus are prone to accidental movement via pathways such as transport on used cars, ship superstructures and sea containers.
Interceptions of gypsy moth egg masses on sea containers are a common occurrence in New Zealand. For example, from 1995 to 1997, 22 gypsy moth egg masses were intercepted, arriving from Russia, Hong Kong and Japan (Newfield 2008). It was noted that egg masses on containers are difficult to detect, particularly when laid on the bottom of containers, and thus many more contaminated containers are likely to enter the country than are detected. Gypsy moth egg masses have also frequently been intercepted on the superstructures of ships arriving in N. America from Asia. Populations of gypsy moth from Asia tend to be flight-capable and attracted to light. This behaviour often results in oviposition on objects in lighted areas including ships being loaded at docks as well as sea containers (Fig. 2). Incursions by a species of *Lymantria* and several other moths that were deemed to potentially cause substantial and costly damages occurred in the last two decades in New Zealand (Newfield 2008). Most of these are thought to be caused by hitchhiking with sea containers. The combined cost of programmes to eradicate these moth incursions exceeded $200 million NZD (Brockerhoff et al. 2010).

2f. Case study: Sea containers as a pathway for ant invasions

Ants are a particularly prominent group of invasive species that are easily transported because of their small size and their effective dispersal, owing to their colonial nature (Holway et al. 2002). In North America alone there are 116 established non-native ant species (Formicidae) with the majority originating from the Neotropic region (Yamanaka et al. 2015). Although few ants are pests of plants, there are well-documented indirect effects of invasive ants. Perhaps the best known type of indirect damage is related to ant's tending of homopteran insects (such as aphids and scale insects) and their protection from natural enemies of homopterans. This has been shown to increase survival and reproduction of aphids and scale insects and, consequently, increased plant damage and crop losses resulting from ant invasions (Holway et al. 2002). If the red imported fire ant (RIFA) became established in New Zealand, the expected damages (full annual costs) are estimated $318 million NZD per annum, mostly affecting households, infrastructure and cattle farming, with smaller losses in crop production (MAF 2001).

Many invasive ant species utilize ephemeral nest sites and engage in nest relocation in response to changes in the physical environment (Holway et al. 2002). This behaviour facilitates their transport via association with man-made objects that may be transported. Arriving populations lacking queens are usually unable to successfully found new colonies but in some species, workers can rear eggs and early instar larvae into sexuals in the absence of queens (Aron 2001). In many species, populations with no workers commonly fail to establish because queens may lack sufficient metabolic reserves to found colonies on their own (Hee et al. 2000).

A significant pathway for historical ant invasions has been imports of produce but hitchhiking with sea containers is another significant invasion pathway (Ashcroft et al. 2008; Ward et al. 2006). The life history traits mentioned above contribute to the accidental international transport of founding invasive ant populations via various "hitchhiking" pathways.

Ward et al. (2006) reported a total of 4355 interceptions of ants during ordinary inspections at New Zealand ports from 1955 to 2003. As part of a more comprehensive inspection programme targeting ants, approximately 32% of ant interceptions were associated with sea containers (Table 2), although this could be an under-estimate or an over-estimate of the true share of arrivals attributable to sea container arrivals. A total of 8,821 interceptions of ants occurred at United States ports from 1912 to 2012 (unpublished USDA records). A more detailed analysis of interceptions in the United States from 2011 to 2015 indicates that at least some ant interceptions are associated with sea containers, including species of the genera *Camponotus*, *Monomorium*, *Paratrechina*, *Pheidole*, and *Solenopsis*. Most of these interceptions were associated with the interior of the container, although such detailed information is rarely recorded in the United States interception data.

3. Detection of hitchhiker organisms during surveys and inspections of sea containers, including analysis of interception records

United States interception data

The United States accounts for about 6.8% of global movements of sea containers (Anonymous 2016). Phytosanitary risks to agriculture and the environment have long been a concern in the United States (e.g., The Plant Quarantine Act, August 20, 1912 was passed more than 100 years ago). As a result there is a long legacy and ongoing inspection of imports to detect infestations by pests and pathogens. The United States Department of Agriculture (USDA) maintains several databases of pest interceptions at ports of entry.

We obtained interception data on hitchhiker organisms associated with sea containers from the USDA AQAS PestID database for the five-year period of fiscal years 2011-2015 (1 October 2010 to 30 September 2015). Only records for hitchhiking pests found 'at large' on or in containers were included, based on information in the 'comments' field of the database (there is no specific field for this in the database). Where possible, interception records were stratified by the location where interceptions were recorded (exterior, inside, or on the refrigeration unit), but often this was not recorded. It is important to note that these data cannot be used for a strict quantitative analysis because multiple pest interceptions can be associated with a single container, because containers from different origins and with different commodities are not inspected with the same level of intensity, and because the database does not contain information on the number of containers that were inspected without anything being found. Therefore, these particular PestID interception records cannot be used to calculate infestation rates. However, despite this, the data are useful to obtain information on the wide range and the identity of hitchhiker organisms that were intercepted with sea containers, and, with caution, can give an indication which organisms are found more or less frequently.

Plant material, primarily seeds, was the most commonly intercepted contaminant of sea containers with more than 71% of all interceptions (Table 3). Most interceptions were associated with the refrigeration unit or unknown locations while smaller proportions were found elsewhere on the outside or inside of containers. There was a wide variety of plant taxa from 23 orders (Table 3, also see above). Insects were the next most common intercepted organism (with about 19% of interceptions), especially Coleoptera, Lepidoptera, Diptera, Hemiptera and Hymenoptera (Table 3). Most insect orders appeared to be found more on the inside than the outside of containers except for Lepidoptera. This is consistent with the propensity of some Lepidoptera to oviposit on the outside of containers (see above). Molluscs represented about 5% of interceptions, primarily on the outside of containers (Table 3; also see above). Smaller numbers of arachnids, nematodes and fungi were recorded. Overall, these interception records demonstrate that a very wide variety of organisms can be moved as hitchhikers with sea containers, including numerous groups that contain pest species.

New Zealand interception data

New Zealand's share of the worldwide sea container movements is only about 0.5% (Anonymous 2016), but there is a wealth of information on biosecurity risks and pathway risk management. New Zealand's Ministry for Primary Industries maintains a comprehensive interception database that documents the results of inspections of sea containers and other risk goods. We obtained data from inspections of 116,701 consignments of empty containers that arrived in New Zealand from July 2010 to October 2015, a period of just over five years. These data and percentages are reported on a per-consignment basis whereby each consignment consists of about 21 sea containers, on average. By analysing information on empty containers we could ensure that the interception records related to hitchhiker species and not to organisms and contaminants associated with cargo transported with sea containers.

Almost 15% (17,095) of these 116,701 container consignments were found to have some kind of contamination (Table 4). Contamination of the exterior of empty containers was recorded in 11,311 cases (9.7%), whereas contamination of the interior was recorded in 5,854 cases (5.0%). Soil was the most common contaminant, especially on the outside of empty containers, followed by plant products, insects, seeds, spiders, and snails. This demonstrates that empty containers often carry hitchhiker organisms and other contaminants, including a number of regulated organisms such as giant African snail.

Australian interception data

Australia accounts for approximately 1.1% of global container movements (Anonymous 2016). Like New Zealand, Australia places much importance on minimising biosecurity risks associated with international trade and profiles and targets some ports of origin (and/or transiting ports) because of the historical, identified risk of hitchhikers and soil contamination. The Australian Department of Agriculture and Water Resources (DAWR) inspects arriving containers whereby those from high-risk origins (CAL countries, see http://www.agriculture.gov.au/import/before/pests/cal) are especially targeted, based on frequent contamination of sea containers from those origins with soil or actionable organisms such as giant African snail, other actionable snails, actionable ants, and black spiny toads. We obtained data from DAWR summarising inspections of sea containers and interceptions from January 2010 until June 2015 (a period of 5.5 years). These included data for arrivals of 11,699,488 full containers and 816,854 empty containers. A total of 270,919 of these containers from CAL countries underwent six-sided external inspections, of which 44,701 (or 16.5%) showed high-level contamination (i.e., high levels of contamination of soil, plant or animal material that cannot be removed easily on site, or the presence of live pests, or contamination that cannot be accessed for cleaning or where mechanical means are required for its removal). A total of 2,823,272 'non-CAL' containers underwent wharf gate inspections whereby 12,645 (0.45%) revealed 'high-level contamination', primarily on the outside of containers. These results show that the external surfaces of containers, especially from some origins, present a considerable risk of transport of hitchhiker organisms and soil that may contain such organisms.

Chinese interception data

China accounts for about 26.7% of global container movements (Anonymous 2016). We analysed 98,564 interception records that originated from inspections of empty containers that arrived in China between 2010 and 2015 from many countries. The data were provided by the China Inspection and Quarantine Services. We focused on empty containers because this ensured that intercepted organisms were likely to be hitchhikers. These interceptions were classified by various levels of taxonomic specificity. For the purpose of this assessment we compiled a summary of interceptions by higher level taxon (e.g., insects, nematodes, etc.). In addition, intercepted species were categorised as 'quarantine pests' and 'other pests'.

Insects were by far the most commonly intercepted group with 80,814 interceptions (82% of all interceptions in this dataset). However, only 256 of these were considered quarantine pests including fruit flies (*Bactrocera* species), sawyer longhorn beetles (*Monochamus* species), coffee berry borer (*Hypothenemus hampei*), giant African snail (*Achatina fulica*) and red imported fire ant (Solenopsis invicta). Weed seeds accounted for 10,874 interceptions or 11%. Of these, 136 were considered quarantine pests, such as ragweed (*Ambrosia* *artemisiifolia* and *Ambrosia trifida*) and Australian dodder (*Cuscuta australis*). In addition there were 142 interceptions of nematodes, 88 fungi, 8 mites and 3 bacteria and 2 viruses (bean pod mottle virus). Again, these findings demonstrate that many important pests can be moved as hitchhikers with sea containers.

4. Economic benefits and costs of a phytosanitary policy for sea containers

4.1 General considerations and the draft 'ISPM: Minimizing Pest Movement by Sea Containers'

The environmental and economic impacts of invasive species have received considerable attention in recent years (e.g., Mack et al. 2000; Colautti et al. 2006; Aukema et al. 2011; Pimentel 2011; Lockwood et al. 2013). Damage from invasive pests amounts to billions of dollars each year. In addition, pest control measures require substantial expenditure [***footnote**: For example, worldwide pesticide exports in 2013 totalled $75.7 billion USD according to the FAO Statistics Division, see* *http://faostat3.fao.org/download/R/RT/E*], and much of these are necessitated by invasive species. Expenditures for control measures would not occur if they were not required. However, in the case of phytosanitary measures aimed at preventing or minimising invasions, it is more uncertain what the extent of damages is that are prevented in the future, and what amount of expenditure is justified to achieve these benefits in the future.

Assessments of impacts and potential impacts most commonly focus on individual invasive species. However, phytosanitary measures aimed at reducing the likelihood of establishment of invasive pests are often targeting entire pathways with multiple species that are being transported inadvertently, rather than individual species. Therefore, when the benefits and costs of phytosanitary measures are evaluated, it is important to consider all species that are relevant for a given pathway (Lodge et al. 2006; Leung et al. 2014).

A benefit-cost analysis of a phytosanitary policy was undertaken by Leung et al. (2014), using ISPM 15 (International Standards for Phytosanitary Measures No. 15, Regulation of Wood Packaging Material in International Trade) as a case study. They conducted a 'pathway-level economic risk analysis' that integrated (i) the economic impacts resulting from damages caused by invasive wood borer and bark beetle species, (ii) policy effects on invader establishment and the expected reduction in damages, and (iii) costs of the policy including policy effects on changes in trade (Leung et al. 2014). Essentially, their work is a benefit-cost analysis for a pathway-wide phytosanitary measure, and it serves as a useful example for measures aimed at reducing accidental movements of hitchhiker pests and contaminating materials transported with sea containers (hereafter simply referred to as '**phytosanitary measures for sea containers**' or '**PMSC**').

Here we consider a PMSC standard that is being considered by the IPPC, the 'Draft ISPM: Minimizing Pest Movement by Sea Containers (2008-001)' (https://www.ippc.int/en/publications/draft-ispm-minimizing-pest-movement-sea-containers/). It is proposed that this ISPM specifies (quoted text in italics):

- **Steps to ensure containers are *considered free from contamination and organisms*** [i.e., hitchhikers]*, including invasive alien species, i.e. all life stages of insects, snails, slugs, fungi, seeds or other plant parts* [as well as] *[…] such things as soil, organic residues from previous cargoes, dunnage,* including:
    - o *Visual examination of sea containers for contamination.*
    - o *Methods to eliminate contamination* [e.g., *sweeping*, *water washing*, *heat treatment*, etc.].
- **Certification of shipping companies *based on their ability to undertake specific procedures that may result in clean sea containers****:*

  - *Visual examinations, cleaning or other methods for removing contamination if necessary, or treatment on assumption that contamination is present,* etc.
- ***Verification of Cleanliness***
  - *When a container has been visually examined and found to be clean it should be verified as clean.*
  - *Information including whether the sea container was visually examined and found to be being clean and the date of last visual examination should be made available upon import.*
- ***Preventing the Contamination of Clean Containers***
  - *Shipping companies should ensure that appropriate measures are taken to prevent the contamination of clean containers. This may involve taking measures when a sea container is moved to / from a depot or terminal to another site to be unpacked, packed or stored or is transiting through another country and may include storing the sea container.*
- ***Guidelines for Importing Countries***
  - *Inspection for compliance (*carried out by *NPPOs of importing countries […]* unless the *NPPO has confidence in the documentary verification supplied by the shipping company, [which] should reduce the on-arrival compliance inspections.*
  - *Where non-compliance occurs, the importing country may take phytosanitary action […]*
  - *Notification of significant non-compliance should follow the requirements of ISPM 13:2001.*
- ***Cooperation among importing and exporting countries' NPPOs and shipping companies*** which *may include*
  - *Improvement of the cleanliness measures when non-compliances have been found,*
  - *Research on methods to prevent contamination,*
  - *Information exchange including inspection results.*

To undertake a benefit-cost analysis of an ISPM specifying such measures would require detailed information on benefits and costs of these measures. These benefits and costs would include items such as the following, and these will be discussed in the following paragraphs.

The benefits are any kind of avoided cost due to the PMSC, including:

- Avoided damages and other economic impacts from pests that would have arrived as hitchhikers on or in sea containers and subsequently established.
- Reduced costs (and time) of inspection (assuming that certified containers are inspected less and, therefore, processed more quickly).
- Fewer delays due to detected contamination that would require mitigation.
- Economic benefits from the labour created by the additional cleaning and inspection activities.
- Economic value of protected non-market ecosystem services.

The costs that would be incurred include:

- Potentially enhanced inspection by NPPOs.
- Cleaning sea containers (referring to the methods being considered in this context).
- Implementing a certification scheme.
- Measures to prevent contamination or re-contamination.
- Container down time (while containers are being cleaned, etc.).

4.2 Potential benefits from phytosanitary measures minimizing pest movement by sea containers

Avoided 'damages' from invaders

Invasive pests can cause direct damages (such as crop losses) as well as a variety of indirect costs such as pesticide application and other control measures, eradication and other incursion response costs, loss of market access, loss of economic activity (e.g., GDP and employment), and loss of market and non-market ecosystem services (e.g., Pimentel et al. 2005; Colautti et al. 2006; Turner et al. 2007; Holmes et al. 2009; Boyd et al. 2013). Pimentel et al. (2005) carried out a comprehensive assessment of the environmental and economic costs of invasive species in the United States. They estimated that these costs amount to approximately $120 billion USD per year (Pimentel et al. 2005). These annual costs include, for example, $27 billion USD for losses and control costs due to invasive crop weeds, $21.5 billion USD due to pathogens of crop plants, and $14.4 billion USD due to arthropod pests of crop plants. A similar analysis carried out for Canada estimated that impacts of a limited number of high-profile invasive species ranges from about $13.3 to $34.5 billion CDN per year (Colautti et al. 2006).

A recent thorough assessment of economic impacts of the emerald ash borer (*Agrilus planipennis*) in the United States (Aukema et al. 2011) estimated annual costs at $38 million USD federal government expenditures, $850 million USD local government expenditures, $350 million USD household expenditures, $380 million USD residential property value loss, and $60 million USD forest landowner timber loss. In New Zealand, the impact of a single invasive crop pest, the clover root weevil (*Sitona lepidus*) was estimated at $1.4 to $8.1 billion NZD (net present value over 35 years) (Goldson et al. 2015). Incursion response costs to prevent the establishment of a number of high-profile invasive insects in New Zealand in the last 20 years amounted to more than $342 million NZD (Goldson et al. 2015). Additional impacts from individual invasive species are provided above in the case study sections.

Holmes et al. (2009) cautioned that scaling up and extrapolating from small-scale impact assessments may lead to over-estimates of true economic impacts. However, they also indicated that the common failure to consider the economic value of non-market ecosystem services leads to under-estimates of true impacts (Holmes et al. 2009). In fact, they suggest that losses of such non-market values may in fact exceed other types of losses. Indirect costs can also include the economic activity lost as a result of direct damages, such as lost manufacturing potential which can be translated into loss of employment and subsequent consumption by employees (Patriquin et al. 2007; Chang et al. 2012).

An important point regarding such assessments of economic impacts of invaders is the uncertainty about what pathway was responsible for the arrival and establishment of an individual species. This is a problem particularly with regard to hitchhiker pests, because most such species may arrive by a variety of pathways, and it is difficult to quantify the extent to which hitchhiking with sea containers is responsible. For example, only about 16% of interceptions of the brown marmorated stink bug were attributed to hitchhiking with sea containers, with the remainder being associated with vehicles, sawn timber, and other pathways (Table 1). Notwithstanding this, the true share of the sea container pathway could be higher or lower, given that inspections and interceptions are not likely to reflect the true proportions of pathway volumes (for example, fresh produce is being inspected more thoroughly than sea containers or bulk cargo). For some pests, the role of hitchhiking with sea containers is likely to be higher (than 16%) whereas for other pests that are strictly associated with particular crops or commodities, hitchhiking may not play an important role.

In addition, phytosanitary measures are never 100% effective, and only a proportion of pest arrivals can be averted. For example, in the case of ISPM 15, it was estimated that the arrival rate of pests associated with wood packaging materials was approximately halved as a result of ISPM 15, leading to an expected reduction of establishments by about 50% (Brockerhoff et al. 2014; Leung et al. 2014). It is not known how effective the proposed standard for sea containers would be on a worldwide scale. And it would be difficult to obtain an estimate of its effectiveness, given exact measures in the new standard are yet to be agreed, the considerable variation in contamination rates among ports and countries, types of containers (e.g., standard full or empty, refrigerated, etc.), commodities transported, and uncertainty about the relative role of sea containers vs. other pathways by which hitchhikers can be moved. This is a research question that deservers further scrutiny because of its importance in a potential cost-benefit analysis. However, a suitable case study is available.

The New Zealand Ministry of Agriculture and Forestry implemented a sea container hygiene system for empty containers originating from several Pacific Island nations where rates of contamination by hitchhikers, soil and other contaminants were found to be particularly high (MAF 2009). A benefit-cost analysis was carried out for this sea container hygiene system (SCHS) (MAF 2009) which included many of the elements of the proposed sea container ISPM (including utilizing hard surfaces for storage of containers to avoid contamination, cleaning interior and exterior surfaces, control of pest species within port operational areas, reducing pest habitat at load ports, segregating compliant containers during storage and on-board vessels, defining contamination performance targets to reduce physical container inspection on arrival, and agreeing on ongoing improvement and auditing). One of the benefits of this programme were estimated as the savings from reduced requirements of container inspection. Prior to implementation of the SCHS it was required that 100% of containers were inspected on arrival and there were higher costs for movement and treatment of containers. This created substantial expenditure for shipping companies; for example, the annual cost in 2008 of empty containers originating from Apia (Western Samoa) would have been approximately $306,000 NZD. After implementation of the SCHS, the inspection rate was reduced to 10% and the rate of contamination requiring treatment was also reduced, providing ongoing annual savings of about $247,300 NZD (MAF 2009). This was based on a total of about 3,000 empty containers arriving from Apia, per year, using the number of containers recorded for 2006. However, by 2015 this number grew to nearly 6000 which means that the benefit from reduced inspection is likely to have increased substantially. Several other expected benefits were considered by MAF (2009) although these were not quantified. In addition, potentially substantial benefits were expected if the Australian Quarantine and Inspection Service (which is now part of the Department of Agriculture and Water Resources) accepted the SCHS and reduced inspection requirements for containers originating from countries participating in the SCHS. In the meantime this has resulted in Australia joining the SCHS, which is providing various additional benefits including from shared administration costs (e.g., monitoring and audits). Furthermore, there should be economic benefits from the labour created by the additional cleaning and inspection in the Pacific islands where the SCHS was implemented, and probably some benefits for exports from SCHS countries. Crucially, the SCHS appears to have resulted in fewer pest arrivals and, as a result, reduced incursion response and pest management costs can be expected (MAF 2009). At the present time, it is too early to quantify this effect as there will be a time lag between a reduction in pest arrivals and a noticeable response in the rate of establishments (see Leung et al. 2014 for an illustration of this). However, with damages from a potential establishment and spread of the red imported fire ant in New Zealand being estimated at $318 million NZD per year (full annual costs) (MAF 2001), these benefits are likely to far exceed those from reduced inspection costs.

It is not possible to directly extrapolate from the Pacific Island sea container hygiene system to an ISPM that would ideally be implemented worldwide. Benefits from reduced inspection and treatment are likely to be smaller for imports to most countries as inspection requirements are generally less stringent than in Australia and New Zealand. Nevertheless, some benefits of this nature are likely to occur worldwide. However, the main benefits are expected to be caused by the averted future pest damages and expenditure for incursion responses. To illustrate the potential magnitude of these benefits the following scenario can be considered as an example. Assuming that the proposed sea container standard would be about 50% effective, and that about 50% of hitchhiker pest establishments are attributable to sea containers, then the standard would reduce arrivals by about 25%. Arrival rate (i.e., propagule pressure) is one of the key determinants of successful invasions (Lockwood et al. 2005), and it can be expected that a reduction in arrivals would lead to a concomitant reduction in the probability of establishment of potential invaders (e.g., Brockerhoff et al. 2014). Therefore, even a moderate reduction in pest arrivals as a result of a sea container standard would be expected to reduce future damages from invasive pests. Because these damages are very substantial, as illustrated above, this would be highly beneficial.

4.3 Potential costs of phytosanitary measures minimizing pest movement by sea containers and estimates of net benefits

The sea container hygiene system (SCHS) that was implemented by the New Zealand Ministry of Agriculture and Forestry for empty containers originating from several Pacific Island nations (MAF 2009) serves as a useful example of the costs that may be incurred under a sea container ISPM. The benefit-cost analysis carried out for the SCHS considered ongoing 'maintenance costs' of the programme as well as one-off 'set-up costs' that occurred in conjunction with the initial implementation. These set-up costs included travel for scoping trips, expenditure for chemicals and applicators, yard improvements, training and auditing. In the case of Apia (New Zealand receives approximately 3,000 empty containers per year from Apia), these set-up costs came to about $58,700 NZD, while the annual maintenance costs were about $8,000 NZD (MAF 2009). Given the cost reduction of about $247,300 NZD from reduced inspections, etc. (see above), the net benefits were estimated to be about $180,600 NZD in the first year and about $239,300 NZD in following years (MAF 2009). Similar net benefits (approximately proportional to the volume of trade) were calculated for the other Pacific Island countries participating with the SCHS. Given that the benefits of averted costs of future pest damage, control measures, incursion response expenditure, lost value of ecosystem services and other indirect economic impacts (e.g. employment) exerted by hitchhiker pests are in addition to savings from reduced inspection, the total net benefits of the SCHS will be considerably greater, although difficult to evaluate.

Again, it is not possible to extrapolate from the New Zealand SCHS example to obtain an estimate of the net benefits of an ISPM for sea containers because there are too many variables that differ among the affected countries. The benefits in terms of lower expenditure for reduced inspection requirements associated with a cleaning and certification scheme would not occur in countries that currently do not inspect a large proportion of arriving sea containers. It is also conceivable that in many countries the additional compliance costs for a sea container ISPM would outweigh those benefits (although much of the cost would not result in a deadweight loss, as it increases employment and may increase economic activity). Furthermore, it is not certain at this time what exactly the agreed measures are likely to be and what their costs would be in different countries. However, inspection and cleaning could be planned to coincide with other examination that already occurs for other purposes. For example, empty sea containers are typically inspected when they enter depots to remove waste, examine the functionality of doors, and to ensure they comply with safety regulations under the International Convention for Safe Containers (IMO 2014). Therefore, additional exterior examination and mitigation measures for hitchhiker pests and contaminants would not necessarily add considerable expenditure and hold-ups. Nevertheless, the main global economic benefit of a sea container ISPM is likely to occur as a result of avoided 'damages', direct and indirect, caused by invasive species that are moved as hitchhikers with sea containers. The largest avoided cost items are probably reduced expenditure for incursion response and eradication of recent invaders, avoided pest damages and avoided market access impacts (e.g., trade bans, etc.), as well as avoided loss of ecosystem services (e.g., Pimentel et al. 2005; Turner et al. 2007; Holmes et al. 2009; Brockerhoff et al. 2010; Aukema et al. 2011). However, as indicated above, to quantify these avoided 'damages', better estimates of predicted future damages and the share that is attributable to hitchhiker pests moving with sea containers are needed, and these are currently not available. A flowchart outlining the elements of a benefit-cost analysis is provided in Fig. 3.

A further complication in the analysis of these benefits and costs is that these are largely caused and borne by different parties (Holmes et al. 2009). Invasions are a by-product (externality) of international trade. International trade benefits exporters in the exporting country as well as importers and consumers in the importing country. By contrast, the damages incurred from invasive pests are borne by producers (e.g., growers, farmers, forest owners), property owners, or the general public in the invaded country. Incursion response costs are usually borne by government agencies and, ultimately, by the tax payer, although some governments seek contributions from affected producer parties. However, in most countries, exporters and importers are not contributing to the costs caused by invasions resulting from international trade, nor do they face substantial costs for inspection of imports. Therefore, the implementation of phytosanitary measures does not provide direct economic benefits to exporters and importers, and hence there are only limited incentives for exporters and importers to minimise pest movement. The introduction of a phytosanitary standard that requires, for example, inspection, cleaning and certification of sea containers would go some way towards internalising the costs of managing risks of invasive species.

Conclusions

Sea containers play an increasingly dominant role in the transport of internationally traded goods. There is substantial evidence that sea containers represent an important pathway for the unintentional movement of species on the external or internal surfaces of sea containers, some of which are known to be invasive pests. New Zealand's sea container hygiene system, which involves inspection and cleaning of containers, verification, training, and prevention of contamination, provides net benefits. Based on our assessment, the proposed (draft) International Standard for Phytosanitary Measures 'Minimizing Pest Movement by Sea Containers' is likely to provide economic net benefits as a result of avoided 'damages' caused by invasive species that are moved as hitchhikers with sea containers.

Acknowledgements

We are grateful for information, data and helpful advice from John Hedley, Peter Thomson, Jeremy Chirnside, Catherine Duthie, Dave Nendick, Bridget Roberts and Sina Waghorn (New Zealand Ministry for Primary Industries), Robert Griffin and David Hanken (United States Department of Agriculture), Steve Tonkin and Rama Karri (Australian Department of Agriculture and Water Resources), Guanghao Gu (China Inspection and Quarantine Service), and Mike Downes (Maersk). This study was partly funded by the New Zealand Ministry for Primary Industries (contract 4005008) and MBIE core funding to Scion (contract C04X1104) via the Better Border Biosecurity Collaboration (www.b3nz.org).

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Table 1. Interceptions of the brown marmorated stink bug (*Halyomorpha halys*) with imports to New Zealand (based on interception records from January 2005 to January 2016).

'Pathway'	USA	Italy	Japan	China	South Korea	Hong Kong	Malaysia	PNG	Unknown	Grand Total	Percent of total
Vehicles (new or used)	174		8		1				7	**190**	38.5%
Sawn timber	98									**98**	19.9%
Sea Container (or container vessel)	51	25	2	1			1			**80**	**16.2%**
Vessel (ship)	13					1		1	26	**41**	8.3%
Personal effects / Luggage	31		1	2	1					**35**	7.1%
Cargo	4	3	11	1						**19**	3.9%
Building material	8	3								**11**	2.2%
Household effects	2	1							1	**4**	0.8%
Fresh produce		3								**3**	0.6%
International mail	3									**3**	0.6%
Unknown	1								2	**3**	0.6%
Wood packaging	1	2								**3**	0.6%
Air container (airfreight)									1	**1**	0.2%
Aircraft			1							**1**	0.2%
Handicrafts	1									**1**	0.2%
Grand Total	**387**	**37**	**23**	**4**	**2**	**1**	**1**	**1**	**37**	**493**	100.0%

Table 2. Interceptions of ants during a targeted inspection program in New Zealand in 2004-2005 (from Ward et al. 2006).

Pathway	**Commodity**	**Number of interceptions**
Air Cargo	Produce	44 (23%)
Air Cargo	Personal items	5 (3%)
Air passenger	Produce	29 (15%)
Air passenger	Personal items	24 (13%)
Maritime Cargo	Containers	60 (32%)
Maritime Cargo	Used vehicles	26 (14%)

Table 3. Interceptions of hitchhiker organisms associated with sea containers based on inspection at United States ports from 2011 to 2015 (fiscal years). Note: Differences in frequency of interception between sea container exterior, interior and refrigeration unit are not necessarily indicative of differences in infestation rates because inspection rates vary.

Taxon	**Exterior**	**Interior (empty or full)**	**Refrigeration unit**	**Unknown location (in or on container)**	**Grand Total**	**Percent of all interceptions**
Insects	39	104	1	113	350	**19.1%**
Blattodea					3	
Coleoptera	2	43	1	53	136	
Collembola		1			1	
Diptera	5	15		14	43	
Hemiptera	4	7		6	30	
Hymenoptera	1	8		14	29	
Isopoda		1			1	
Isoptera					1	
Lepidoptera	17	13		12	54	
Orthoptera		4		6	12	
Psocoptera	1				7	
Trichoptera					1	
(Unspecified)	9	12		8	32	
Arachnids	2	2		9	16	**0.9%**
Acari		2		6	10	
Araneae	2			2	5	
Opiliones				1	1	
Molluscs	70	4		20	100	**5.5%**
Basommatophora	1				1	
Cycloneritimorpha					1	
Heterurethra	4	1		4	10	
Littorinimorpha	1				1	
Stylommatophora	60	3		15	81	
Vetigastropoda					1	
(Unspecified)	4			1	5	
Nematodes	2			1	3	**0.2%**
Fungi	3	3		4	15	**0.8%**
Coelomycetes	1				1	
(Unspecified)	2	3		4	14	
Plants	113	102	515	466	1304	**71.3%**
Apiales		2			2	
Arecales	1	1		1	3	
Asterales	16	5	50	67	207	
Capparales	1			1	2	
Caryophyllales	1				1	

Cyperales	80	47	463	357	971	
Fabales	3	26		11	44	
Fagales		3			4	
Gentianales		2		1	3	
Hamamelidales	2	1			3	
Illiciales		1			1	
Lamiales		1		1	3	
Linales	1	1		3	5	
Malvales	4	2		2	9	
Myrtales	1				1	
Pinales		1		1	2	
Polygonales				1	1	
Sapindales		1			1	
Scrophulariales		1		1	2	
Solanales		1		1	2	
Typhales	1	1	2	6	12	
Urticales		1			1	
Violales		1		1	3	
(Unspecified)	2	3		11	21	
Unspecified taxon	7	5	2	14	40	**2.2%**
Grand Total	**236**	**220**	**518**	**627**	**1828**	

Table 4. Interceptions of hitchhiker pests and contaminants during inspections of 116,701 consignments of empty containers that arrived in New Zealand from July 2010 to October 2015.

Contaminant	External contamination		Internal contamination		External and/or internal contamination	
Soil	6446	(5.52%)	643	(0.55%)	6982	(5.98%)
Plant products	2761	(2.37%)	1541	(1.32%)	4257	(3.65%)
Insects (not ants)	373	(0.32%)	860	(0.74%)	1247	(1.07%)
Seeds	325	(0.28%)	610	(0.52%)	946	(0.81%)
Spider(s)	394	(0.34%)	352	(0.30%)	763	(0.65%)
Ants	32	(0.03%)	500	(0.43%)	537	(0.46%)
Other Packaging (not wood)	14	(0.01%)	475	(0.41%)	503	(0.43%)
Forest debris	185	(0.16%)	141	(0.12%)	341	(0.29%)
Snails (not GAS)	255	(0.22%)	25	(0.02%)	281	(0.24%)
Animal products	102	(0.09%)	177	(0.15%)	280	(0.24%)
Reptiles	115	(0.10%)	60	(0.05%)	177	(0.15%)
Non-ISPM 15 WPM	1	(0.00%)	68	(0.06%)	72	(0.06%)
Mould	1	(0.00%)	52	(0.04%)	55	(0.05%)
Straw	39	(0.03%)	9	(0.01%	55	(0.05%)
Giant African snail (GAS)	11	(0.01%)	4	(0.00%)	16	(0.01%)
Other contaminants	257	(0.22%)	337	(0.29%)	585	(0.50%)
No contamination					99606	(85.35%)
Grand Total	**11311**	**(9.69%)**	**5854**	**(5.02%)**	**116701**	

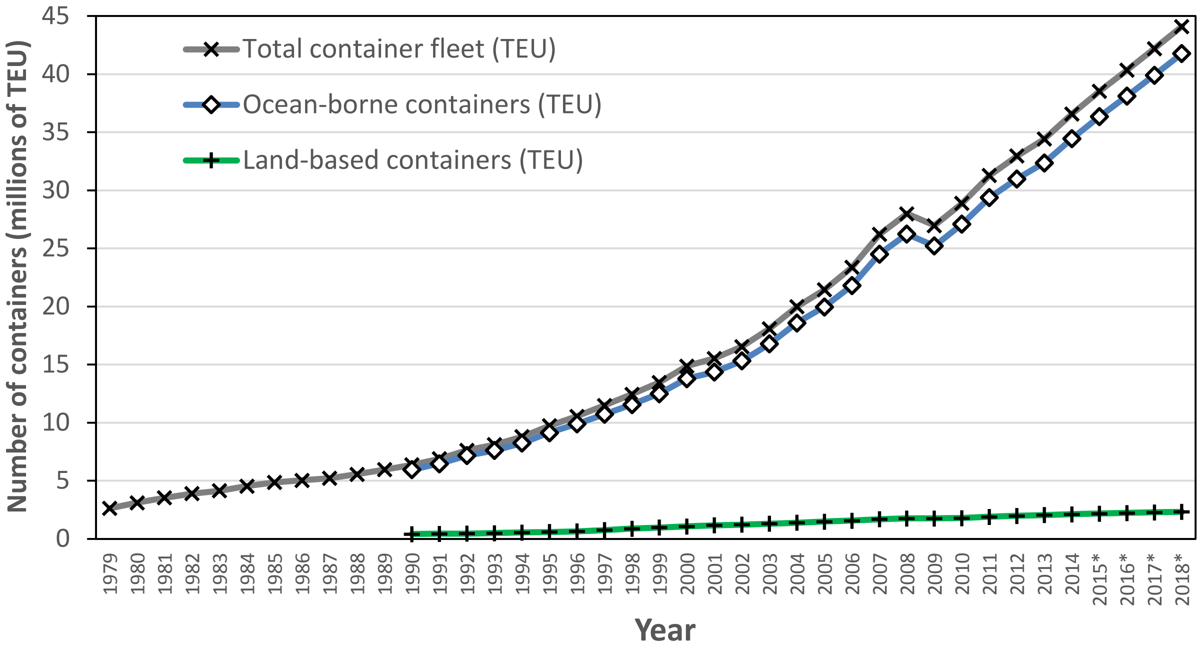

Fig. 1. Development of world maritime container fleet (oceanborne containers) in thousands of twenty-foot equivalent units (TEU). Note, values from 2015 onwards are estimates based on current trends. Source: Drewry Maritime Research (2015).

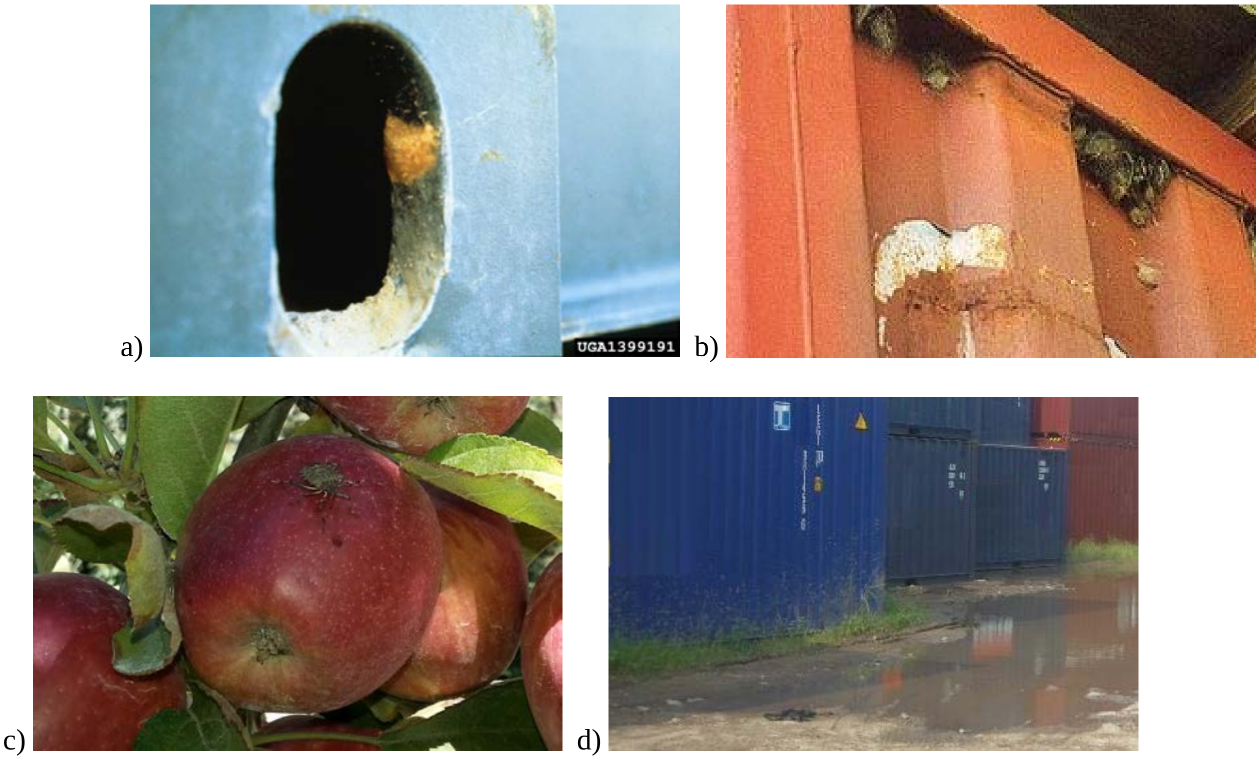

Fig. 2. Examples of contamination and species that are frequently encountered as 'hitchhikers' with sea containers: a) Asian gypsy moth (*Lymantria dispar*) egg mass in a corner fitting of a sea container (photo: Manfred Mielke, USDA Forest Service); b) giant African snails (*Achatina fulica*) on the external surface of a container (photo: New Zealand Ministry for Primary Industries); c) brown marmorated stink bug (*Halyomorpha halys*), here seen piercing and sucking on an apple (photo: Eckehard Brockerhoff, Scion); d) container storage site with bare soil which facilitates contamination of sea containers with soil and potential pests (such as nematodes and soil-borne pathogens (photo: New Zealand Ministry for Primary Industries).

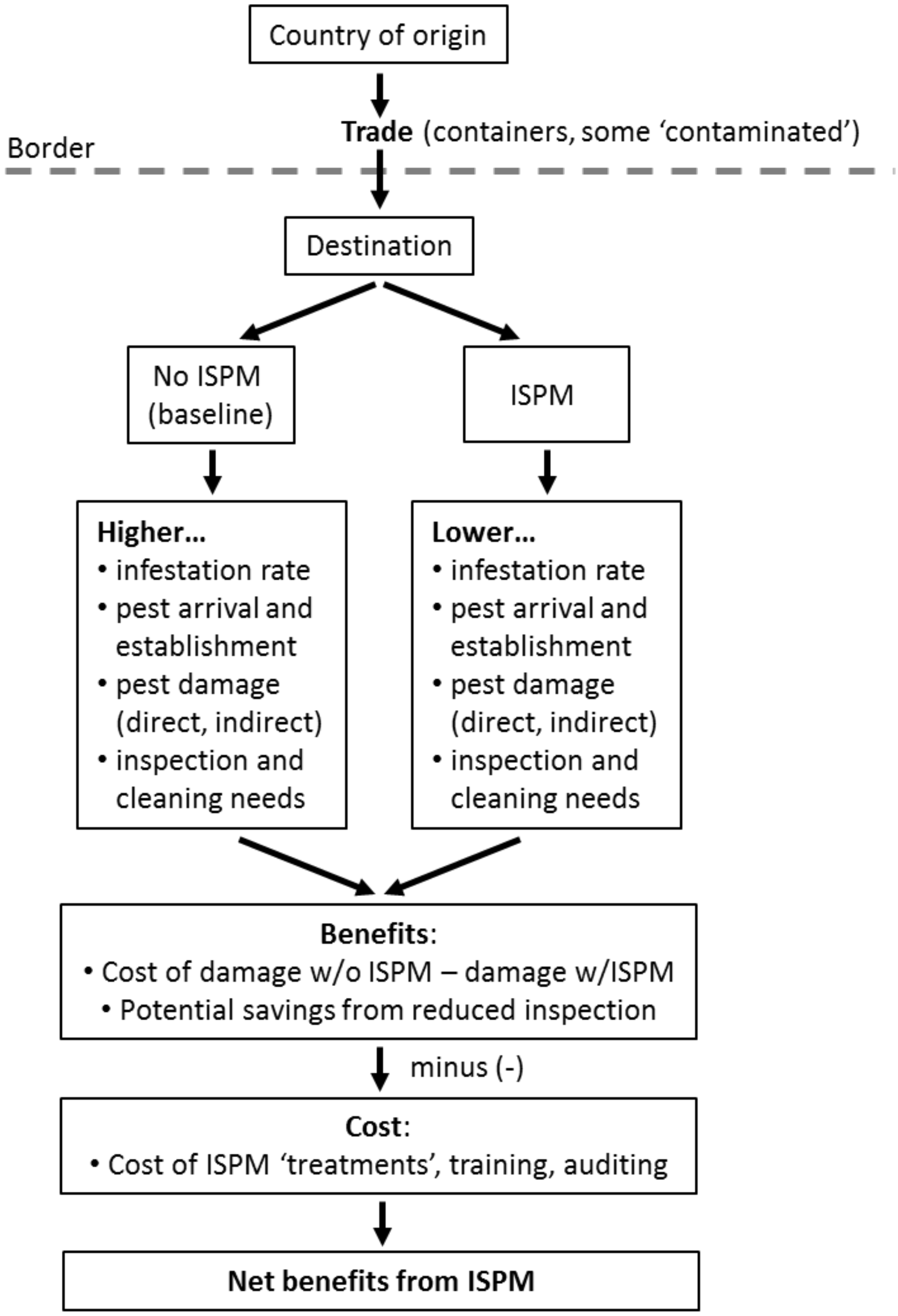

Fig. 3. Flow diagram of a conceptual benefit-cost analysis of a potential ISPM for sea containers.