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How biosecure are we? Case studies with unwanted forestry pathogens and pests.

A further look at New Zealand's import health standards.

I. A. Hood

Pine pitch canker (*SA Forestry*, 20 July, 2015).

Report information sheet

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Authors	I. A. Hood Scion
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Executive summary

The problem

In 2016 Scion reviewed national import health standards from the perspective of the forest industry on behalf of the Forest Owners' Association (FOA). Import health standards are documents that set out the requirements for importing commodities into New Zealand in order to prevent incursions by unwanted pests and disease agents. They are periodically updated by the Ministry for Primary Industries (MPI). All standards were reviewed in order to include pathways that, although not directly related to forestry, might allow unwanted forest organisms to enter the country circuitously. Standards identified as worthy of further consideration comprised those applying to imports of live plants, seed, and wood products such as poles, sleepers, wood chips, sawn wood and wood used as packaging material.

Client initiatives

The FOA wished to pursue this further and requested Scion to undertake a supplementary review by examining the effectiveness of existing import health standards in preventing the entry of a selection of specific pests and pathogens known to cause injury and damage to New Zealand plantation species beyond these shores.

This project

The pathogens selected were *Fusarium circinatum* (cause of pine pitch canker), *Dothistroma septosporum* and *D*. *pini* (dothistroma needle blight), and *Phytophthora pinifolia* (daño foliar del pino). The insect pests chosen were *Rhyacionia buoliana* (European pine shoot moth), *Marchalina hellenica* (giant pine scale) and *Paropsisterna bimaculata* (Tasmanian eucalyptus leaf beetle). Each organism was examined in two stages. Firstly, a summary is provided describing the pest or pathogen and the disease or damage it causes under the subheadings distribution, hosts, biology, signs and symptoms, impact and identification. Then the most likely incursion pathways are considered leading to an inspection of the relevant import health standards and the identification of any gaps or limitations that might allow the organism to invade and establish in New Zealand forest plantations.

Key results and their implications for the client

The import health standard specifications were found to be generally adequate, but there were some openings that might allow an undesirable organism to pass through without interception. Specifically: (1) a laboratory study has shown that the heat treatment prescribed in the wood packaging standard is only partially effective against *F*. *circinatum*, unlike the stronger treatment found in more recent standards for other wood products; (2) wood products of *Pinus* species from countries known to harbour *Fusarium circinatum* require certain treatments that do not appear to apply specifically to those of Douglas fir, also a moderately susceptible host of this pathogen.

Two additional factors emerged during this review. Quality assurance of import health standards is greater when based on quantitative data gathered during field surveys and from interception records. Secondly, an import health standard may be well formulated but challenging to implement, even when procedures are stringently maintained. The sampling protocols prescribed in some standards by practical necessity leave open a path on remaining un-sampled material, but at least the odds of a possible incursion are reduced.

Further work

It is recommended that MPI be requested to review of the import health standard *Wood Packaging Material from all Countries*, particularly in relation to strengthening the heat treatment prescription. MPI might also consider specifying Douglas fir along with *Pinus* species in the standards *Sawn Wood from all Countries* and *Poles, Piles, Rounds and Sleepers from all Countries*, regarding treatments for imports from countries with *Fusarium circinatum*. Subject to funding, there may be merit in conducting offshore testing of the potential for certain herbaceous plants, currently allowed into New Zealand, to act as carriers of pathogens such as *F*. *circinatum* and *P*. *pinifolia*, where these plant species are liable to encounter them in their present distribution ranges.

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Introduction

In order to keep plantation forests free from new pests and pathogens, the Forest Owners' Association (FOA) seeks assurance that the import health standards under the administration of the Ministry for Primary Industries (MPI) are effective in preventing these organisms from entering New Zealand. A previous review of all existing standards[1] found that, although generally adequate, a number warranted some further attention, in particular those dealing with imports of nursery stock, seed, and various wood products such as poles, sleepers, wood chips, sawn wood and wood packaging (Hood 2016).

Following on from this work, FOA has requested Scion to examine the current standards more closely by testing them against a number of specific organisms likely to be especially harmful to the forest industry. This assignment was prescribed in general terms with freedom given to select the particular test organisms at will. It was therefore decided to screen three pathogens and three insect pests, none currently established in New Zealand[2] but all noted for causing significant damage to their hosts overseas. Of those chosen, all but one are injurious to the main New Zealand plantation species, *Pinus radiata*, while for variety and breadth the sixth selection is a potentially serious pest of eucalypts. It was of course not possible to consider all organisms, and some important groups were excluded such as wood boring longhorn beetles (Cerambycidae: Bain 1977; Sopow et al. 2015) and bark beetles (Scolytinae; Brockerhoff et al. 2006). However, these are indirectly covered by the standards applicable to the organisms that were assessed, which encompass a reasonable range of significant incursion pathways.

Travellers and international mail are pathways not subject to import health standards and are therefore not considered at great depth in this report, even though they may pose a real risk for the introduction of some organisms. It is noteworthy, though, that the lack of a relationship between increased passenger travel and numbers of incursions led Sikes et al. (2018) to conjecture that, for pathogens at least, this is not a major pathway, possibly because of professional biosecurity processing at the point of entry (cf. App. 1).

Procedure

The three pathogens (or pathogen set) chosen for evaluation were *Fusarium circinatum* (agent of pine pitch canker), *Dothistroma septosporum* and *D*. *pini* (dothistroma needle blight), and *Phytophthora pinifolia* (daño foliar del pino). The three insect pests selected were *Rhyacionia buoliana* (European pine shoot moth), *Marchalina hellenica* (giant pine scale) and *Paropsisterna bimaculata* (Tasmanian eucalyptus leaf beetle). Each was considered in turn by first providing a brief description of the pathogen or pest and the disease or damage it causes, and then examining the applicable import health standards. The material in the first part, which includes the names of the disease or disorder and its agent(s), is presented under subheadings that cover the present global distribution, known hosts, a brief biology, characteristic signs and symptoms, potential impact, and information on what is known about how it can be quickly and reliably recognised should it be intercepted. Then follows a consideration of likely incursion pathways and the import health standards designed to deal with them, with a concluding judgement on how effectively this is practicably achieved. In particular, possible gaps in the standard protocols are noted where these could lead to a breach at the border.

To avoid unnecessary repetition, consideration of the major pathways and their respective standards is given in greater detail under the first case study (pine pitch canker), and these are generally dealt with less exhaustively for the subsequent pests and pathogens.

[1] Synopses of these import health standards are included in Hood (2016).
[2] One of the pathogens was actually represented by two species that both cause the same disease, dothistroma needle blight. Of these, *Dothistroma septosporum* is of course present in this country, but this review considers the likelihood of further introductions of different genetic stock.

PATHOGENS

Pine pitch canker:

Photo: Julio Javier Diez Casero
http://www.efiatlantic.efi.int/portal/news?bid=1945 https://ufei.calpoly.edu/pitch_canker/management.lasso?guidelines

Pathogen: *Fusarium circinatum*.
Synonyms: *F. subglutinans* f. sp. *pini*, *F. lateritium* f. sp. *pini*,
Gibberella circinata (sexual stage, only seen in culture).

Fusarium circinatum is a regulated organism (it is both unwanted and notifiable). Also listed on the Landcare Research New Zealand Organisms Register as an exotic border intercept. CABI link.

Distribution: United States (south eastern and California), Mexico, Haiti, South America (Chile, Colombia, Uruguay, Brazil; Gordon et al. 2018), Europe (Portugal, Spain, Italy-eradicated, France-eradicated), Japan, South Korea, South Africa.

Hosts: *Pinus* spp. (including *P. radiata*, highly susceptible), Douglas fir (*Pseudostuga menziesii*, low to moderately susceptible). Symptomless in grasses and herbs.

Biology: Conidia (macro- and/or micro-) are produced and released from tiny pink fungal "cushions" (sporodochia) that appear on diseased tissue. Spread of conidia is by air, water (rain and mist) or insect vectors (mainly bark beetles). Infection occurs on susceptible pines at all growth stages. Above ground, entry is through wounds caused by weather, human agency or insects, and infection is enhanced by warm, moist, humid conditions. Roots and the root collar of seedlings become infected by conidia released from infected seeds, soil or litter. In nurseries diseased seedlings may show a clustered distribution due to the localised dispersal of inoculum.
F. circinatum may also infect female "flowers" (strobili), cones and seeds. Infection can therefore lie dormant in seeds, giving rise to a non-distinctive damping off at germination. The disease appears to be monocyclic (one cycle per year) but with variable timing according to season, location and insect cycle.

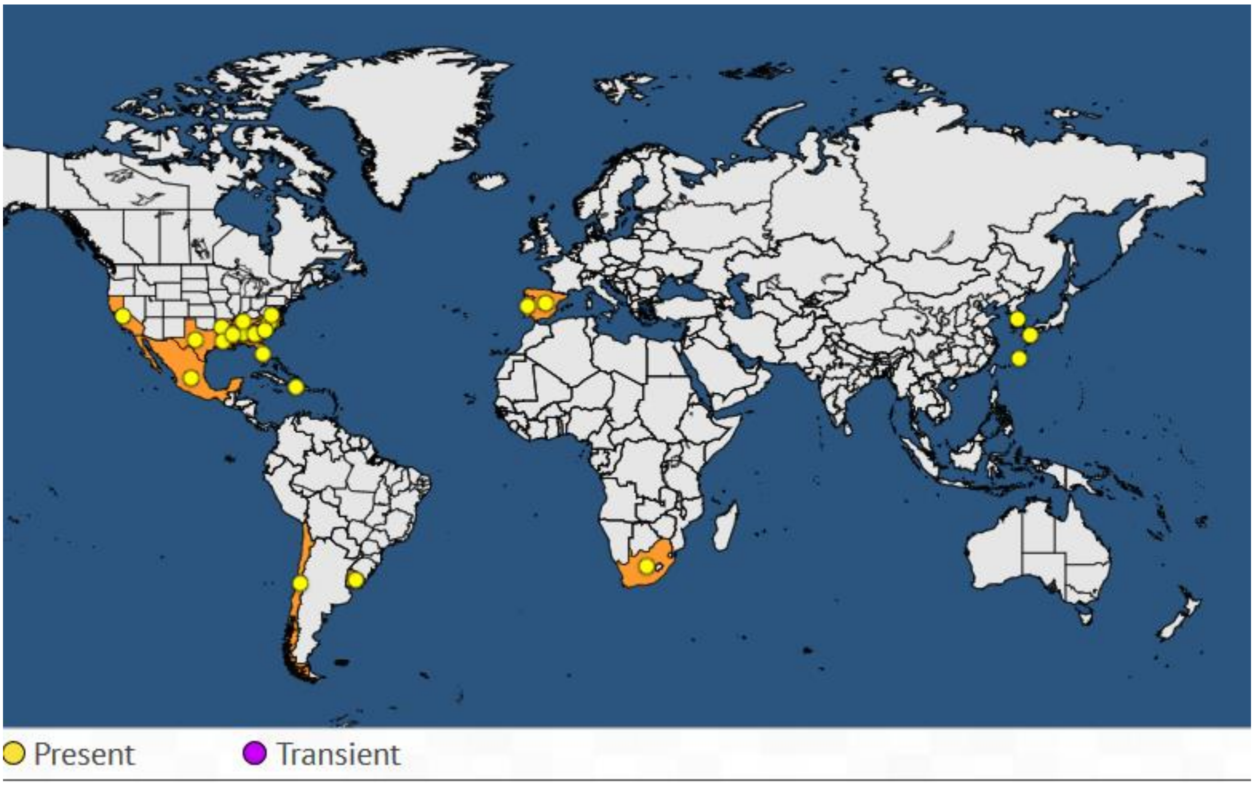

Fig. 1. Distribution of *Fusarium circinatum*. EPPO Global Database.

Symptoms: Resin soaked lesions appear at infection loci. On saplings and mature trees young, non-lignified shoots droop and needles wilt, turn brown and are cast (or persist, if glued by resin), with shoot death following girdling. Repeated cycles of infection lead progressively to an intensification of symptoms in crowns, from red-brown branch flagging through conspicuous dieback to malformation, forking and stunting, with increased susceptibility to wind damage. Resinous, perennial cankers develop on trunks. Infected cones may be stunted or distorted. Seedlings may die, once infection reaches the root collar, or remain asymptomatic. Care is needed not to confuse symptoms with those caused by *Sphaeropsis sapinea* (synonym, *Diplodia pinea*).

Impact: The disease causes mortality, growth reduction, stem malformation and seed losses in *Pinus* plantations and seed orchards. Sporadic outbreaks, some of epidemic proportions, have occurred in plantations (e.g. of *P*. *elliottii*, *P*. *taeda*), seed orchards and nurseries in the south-eastern United States. Extensive mortality also occurred in planted *P*. *radiata* and in densely stocked *P*. *muricata* in California associated with drought during the period 1987-1991. *P*. *radiata* Christmas tree stands are vulnerable. The disease is present in Mexico but damage is found only in managed plantations. Elsewhere in the world the disease is a problem mainly in nurseries due to mortality and to hidden, latent infection with potential for spreading the disease to plantations. Should it establish in New Zealand, pine pitch canker is predicted to impact on the northern coastal parts of the North Island but to increase this range under a climate warming scenario, although a present lack of insect vectors may slow the rate of spread (Ganley et al. 2011; Watt et al. 2011; Brockerhoff et al. 2016).

Identification: Species of *Fusarium* are commonly encountered and could be easily confused with *F*. *circinatum*. With seeds and seedlings, it is necessary to isolate and/or use molecular means for confident diagnosis. With experience, cultures can be identified morphologically with moderate confidence (using characters such as size, shape and septation of macroconidia, characteristic hyphae etc.), but definitive diagnosis requires positive sexual compatibility with a *F*. *circinatum* reference isolate of opposite mating type and/or by molecular sequencing (Ganley and Bulman 2016).

Potential pathways: Based on regional genetic diversity patterns, *F*. *circinatum* is presumed to have spread to its present range from Mexico or Central America since about 1945. It may be carried undetected in symptomless seeds (Wikler and Gordon 2000), seedlings and also in grasses and herbs. In Chile, symptomless infected seedlings have been planted out unawares into plantations (Wingfield et al. 2008). *Fusarium circinatum* was isolated from the following asymptomatic herbaceous plants which acted as potential inoculum reservoirs in a *Pinus radiata* plantation in Spain (Hernandez-Escribano et al. 2018): *Agrostis capillaris* (Poaceae), *Pseudarrhenatherum longifolium* (Poaceae), *Centaurea debeauxii* (Asteraceae), *Teucricium scorodonia* (Lamiaceae), *Sonchus oleraceus* (Asteraceae), *Rubus ulmifolius* (Rosaceae) and *Hypochaeris radicata* (Asteraceae). In these plants the pathogen was confirmed present in leaves, stems and (for *H*. *radicata*, only) seeds, but not roots. Epidemics in the United States are known to have originated from contaminated nursery stock. *Fusarium circinatum* does not survive as well in soil as *Fusarium* species with chlamydospores, but still remains viable for six months in wet and up to one year in dry soil (Wingfield et al. 2008; EPPO 2009). In the United States, guidelines indicate that where the disease is present, logs should not be taken to new areas without "proper treatment", since it can survive for one year or more in infected wood (e.g. wood chips and branches, Wingfield et al. 2008). It is not known how long it can survive in needle litter or on insects (Wingfield et al. 2008). Management recommendations also indicate that prunings, slash and dead plants should be destroyed and not moved from diseased stands to new areas. However, elsewhere it is suggested that roundwood, especially if debarked, poses low risk internationally. There are fungicides available (e.g. dazomet) but they are not considered cost/effective for use in management. Various seed treatments using fungicides and other procedures have been explored (Gordon and Dick 2003; Wingfield et al. 2008; EFSA 2010).

Potential introduction to New Zealand is likely to be, to a greater or lesser extent, through infested seed or soil, on insects or on live or dead plant material, including timber and wood products (Dick 1998; Ganley 2007). Hidden infection in seed is of particular concern. Sampling and identification procedures for detection of *F*. *circinatum* in plant tissues and seeds have been described in detail (Eppo 2009; EFSA 2010). Particular care is needed for recognition in seed when levels of infection may be low. The importance of vigilance in preventing a New Zealand incursion was highlighted when the pathogen was intercepted in imported Douglas fir scion material, which was destroyed, in 2003 (Ramsfield et al. 2008; Scion 2008). The source was traced back to a breeding orchard in California where *F*. *circinatum* had not previously been detected (Vogler et al. 2004). *F*. *circinatum* may possibly be carried with pollen (Dick 1998). Other possibilities include footwear and camping equipment, externally on containers from locations near forests, vehicles and used logging machinery.

Using an EPPO pest risk assessment procedure, Gadgil et al. (2003) ranked the potential incursion pathways in descending order of importance as follows:

High risk	
Seed of *Pinus* spp. And *Pseudotsuga menziesii* for sowing	68
Insects (bark beetles, cone and twig borers)	67
Soil	64
Used logging machinery	62
Live plant material (including pollen of *Pinus* spp. and *Ps*. *menziesii*)	62
Cargo containers	61
Medium risk	
Camping equipment	53
Wood, lumber, packaging, dunnage	51
Low risk	
Pine cones for decorative purposes	43
Mailed items	41
Seed of *Pinus* spp. for human consumption	36

With respect to each pathway, Gadgil et al. (2003) also examined aspects such as the ability for a successful incursion to establish and capacity for survival in transit (cf. Brockerhoff and Liebhold 2017). These are generally not considered in this review, which focuses on the effectiveness of the import standards themselves in preventing incursions.

An assessment of the risk of *F. circinatum* entering Europe by different pathways rated seed, wood material, plants and plant parts as "very likely" and travellers, soil, vehicles and forestry machinery as "likely" (EFSA 2010).

Incursion management plans have been prepared: Gadgil et al. (2003), Ganley and Bulman (2007).

Import health standards:

The current import requirements relevant to pine pitch canker are summarised by Biosecurity New Zealand (2018).

Live plant material:

Concern about the spreading of diseases by increased trading in live plants was recognised in the IUFRO[3] Montesclaros Declaration (2011). The importing of living plants, including cuttings (scions) and tissue cultures, is covered by the import health standard, *Nursery Stock* (June, 2018; some amendments since Hood 2016). The import status of particular plant species in relation to this standard can be found on the online MPI *Plants Biosecurity Index* (Dickson 2009). Unlisted species may not be imported. *Pinus radiata* and *Pseudotsuga menziesii* are both listed as "requiring assessment" and so also cannot be imported as live plants. This may be why *F. circinatum* has not been included among a number of other pest and disease agents specifically named in the standard. *Pseudotsuga macrocarpa*, native to California, and Asian *Pseudotsuga sinensis*, may be imported under "special conditions", which include a requirement for post entry level 3B quarantine for a period of not less than six months. It does not appear to be known if these species are susceptible to *F. circinatum*, but it seems possible, at least for *P. macrocarpa*[4]. Of the herbaceous plants reported as asymptomatic "carriers" in Spain (see above), only *Rubus ulmifolius* may be imported, with particular requirements as detailed in the standard. However, a number of other *Rubus* species may enter New Zealand under a variety of "special conditions" (including post entry quarantine for not less than six months), and some species of *Centaurea* other than *C. debeauxii* may also be imported, under "basic conditions" requirements. Specifications for "basic conditions" include absence of visible symptoms pre-export, provision for treatment, destruction or re-shipment if soil or any other extraneous material is present, and a post-entry quarantine period at a prescribed level of not less than three months to check for *regulated pests*. Pre-export and post-entry requirements, including quarantine, for *P. macrocarpa* and *Rubus* spp. tissue cultures, and for *Rubus* scion material, are also specified in the standard. Imports of pollen for any plant species are dealt with on a case by case basis.

The regulations for live plant material therefore give good cover against a pine pitch canker incursion, but there are some gaps, even if small. The full number of plants capable of asymptomatically harbouring *F. circinatum*, and the likelihood of their being imported, are not known. The interval before which plants endophytically infected by *F. circinatum* express visible symptoms, if at all, appears uncertain (Wingfield et al. 2008). It has been noted that *F. circinatum* cannot be reliably detected by visual inspection without testing (EFSA 2010). This has implications for the period and effectiveness of post-entry quarantine procedures. The successful interception and treatment of infected Douglas fir cuttings, referred to above, shows that this pathway should not be underestimated. According to Biosecurity New Zealand (2018) there were in fact three such interceptions of *F. circinatum* on Douglas fir scion stock in that same year from places in California (Sierra-Nevada region) and Oregon, leading to the destruction of infested material and suspension of permits for the importation of Douglas fir cuttings from the United States. It is gratifying, however, to know that existing biosecurity infrastructure was effective in intercepting this material, potentially preventing an incursion of the disease.

[3] International Union of Forest Research Organisations.
[4] *Pseudotsuga macrocarpa*, from California, unlike (apparently) Asian species of this genus, is susceptible to *Nothophaeocryptopus gaeumannii*, cause of Swiss needle cast of Douglas fir.

Seed:

Fusarium circinatum is able to survive dormant and undetected (unable to be isolated) in viable *P. radiata* seed until germination, and can live saprophytically in cones for up to a year (Gadgil et al. 2003). The pathogen can also be found on the seed surface in healthy cones. Douglas fir seed may likewise potentially harbour the pathogen. *Fusarium circinatum* may have entered both Chile and South Africa in contaminated seed stock (Ganley 2007). Seed imports of species of *Pinus* (including *P. radiata* but excluding *P. contorta*, which is prohibited) and *Pseudotsuga* are covered by the import health standard *Seeds for Sowing* (July, 2018; amendments since Hood 2016 not material). Seed of these genera may therefore be imported but under special conditions. A phytosanitary certificate is required confirming pre-export inspection and approved fungicide treatment, and post-entry level 3B quarantine is prescribed for a period determined by MPI. Seed from regions with pine pitch canker must have an import permit.

The conditions required for importing seed are rigorous, but rely on a finite sampling of the consignment, so if an infestation is low there is a small chance that the pathogen may slip through undetected (Dick 1998; EPPO 2009). However, it is difficult to see how this can be addressed further, except by prohibition. It has also been suggested that seed from countries adjacent to infested regions may pose some risk (Ganley 2007). *Fusarium circinatum* was found in seed of *Hypochaeris radicata* (see above), so could conceivably also enter undetected in seed of other unknown herbaceous species. Seed of four *Hypochaeris* species (including *H. radicata*) may be imported under "basic conditions", without specific reference to *F. circinatum*. There may also be incursion risk from seed of other species e.g. possibly *Zea mays* and some grass species (Ganley and Bulman 2016). Basic conditions require that the seed be clean and free from soil and extraneous material, that they must be certified free of visually detectable regulated pests or be inspected on arrival, and that they must spend a period in post entry quarantine for monitoring and/or specified treatment. *Fusarium circinatum* is a regulated organism (it is both unwanted and notifiable), but as noted there is still a chance that it could potentially remain undetected during inspection and quarantine.

Timber and wood products:

These commodities are covered by the import health standards *Sawn Wood from all Countries*, *Poles, Piles, Rounds and Sleepers from all Countries* and *Wood Packaging Material from all Countries*. The first two standards have been updated to October, 2018 (in a new format, without change in content), while the third dates to 2009. The first two standards require that the imported items must be free of regulated pests (including *F. circinatum*), packed in a container that prevents contamination by such pests, be without bark and be relatively free of extraneous material such as soil and leaves (which will include pine needles). Specifically, if from a region where *F. circinatum* is present, imports of *Pinus* under the first two standards must within 21 days prior to export be treated by fumigation with methyl bromide or sulphuryl fluoride as specified or be heat treated as prescribed (e.g. to 70 °C for 4 hours, or for shorter periods at higher temperatures) or be chemically treated with a specified reagent at a prescribed rate (compounds of boron or copper, or for insects, arsenic or permethrin). If the consignment on arrival is found to be untreated, or considered to be untreated because of irregularities, further provisions are outlined for prescribed treatment or for reshipping or destruction. There are no such requirements for treatment of Douglas fir. The Wood Packaging standard encompasses wood materials such as dunnage, crates, fillets, spacers, pallets, drums and reels. Requirements are similar to those for sawn wood, piles, rounds and sleepers, except that although *F. circinatum*, *Pinus* and Douglas fir are not specifically mentioned, treatment is required for all consignments according to a range of prescribed options. However, the heat treatment requirement is less stringent (56 °C for 30 minutes[5]).

Imported bark is dealt with under the import health standard *Bark from all Countries* and other wood products under the standards *Woodware from all Countries*, *Wooden Panels from all Countries* and *Sawdust, Wood Chips, Wood Shavings and Wood Wool from all Countries*. These standards have all been updated in a new format to October, 2018, without change in content. The requirements for the Bark standard and the Sawdust, Wood Chips etc. standard are similar to those for sawn wood, piles, rounds and sleepers (e.g. where the heat treatment is applied pre-

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[5] This is the same as the temperature requirement specified in ISPM 15 (International Standard for Phytosanitary Measures 15, Regulation of Wood Packaging Material in International Trade, 2009; International Plant Protection Convention).

export or post-entry, the specification is to heat to not less than 70 °C for 4 hours, or for shorter periods at higher temperatures). The Woodware standard covers products regarded as low risk and requires inspection under quarantine, but treatment as for the other standards is specified only if there is an unprocessed element present as with e,g, wooden burls with bark. The Wooden Panels standard is similar, also applying to processed, not raw wood products, requiring inspection, but treatment only if deemed necessary (e.g. potentially for products such as imported used panels). Approved treatments are listed on the MPI website (Section 1.5 Forest produce).

Other pine materials include *Pinus* and Douglas fir cones, which come under the import health standard *Dried and Preserved Plant Material, and Fresh Plant Material for Testing, Analysis or Research* (January, 2016), and must be heat treated (70 °C for 4 hours), autoclaved or irradiated as outlined in standard *Approved Biosecurity Treatment for Risk Goods*.

The standards for sawn wood, poles, rounds and sleepers are rigorous and specifically directed towards *F. circinatum*. Nevertheless, they apply only to imports of *Pinus* and not Douglas fir, though consignments of this species may be of lower risk (Gadgil et al. 2003). There is also a possibility that material from regions judged to be free of *F. circinatum* may still pose some risk (Ganley 2007). Based on laboratory heating studies, Ramsfield et al. (2010) predicted a 28% survival of *F. circinatum* following treatment at 56 °C core temperature for 30 minutes. However, their prediction of 99.99% mortality of the fungus at 69 °C for 30 minutes is within the prescription in the standards, which are therefore adequate. On the other hand, the heat treatment specified in the Wood Packaging standard, if this option is used rather than fumigation or chemical treatment, is not sufficient to eliminate completely any *F. circinatum*, which is not specifically referred to by name. Treatments for the other wood commodities appear adequate, although none specifically refer to *F. circinatum*. Wood packaging may pose the greater risk also because it is possible that it is more likely to be imported than e.g. sawn timber. Brockerhoff et al. (2006) note that the replacement of raw by processed wood packaging would reduce the level of risk.

Equipment, *vehicles and machinery*:

These pathways are covered by a revised import health standard, *Vehicles, Machinery and Equipment* (August, 2018; upgraded since Hood 2016). The standard *Used Equipment Associated with Animals or Water* (June, 2017) is judged to have little relevance. However, the Vehicles, Machinery and Equipment standard and Gadgil et al. (2003) note that pests and unwanted organisms have frequently been intercepted in second-hand vehicles and logging machinery on arrival in New Zealand (including dust that yielded isolates of species of *Fusarium* related to *F. circinatum*). This standard requires that these items be internally and externally free of contaminants and regulated pests to specified thresholds. There is zero tolerance for e.g. live arthropods (dead arthropods, including insects, are not seen as contaminants), fresh plant material, visible fungi (except that mildew that can be wiped off is not regarded as a contaminant), fruit (including cones and seeds), and pine needles. Up to five pieces of loose dead or dry plant material (e.g. bark, leaves, saw dust, twigs) is accepted as is up to 20 g loose soil. Items are inspected externally on arrival. There are specific requirements for particular items such as used vehicles, machinery and equipment, which require cleaning externally and internally. Treatments (Section 1.12), as specified (e.g. to certain goods such as wire cables, used tyres), include heating (for heat tolerant items), fumigation or spraying with an insecticide. Imports from countries such as Japan require prescribed treatment during an eight month period of the year (September to April) as a precaution against an introduction of the brown marmorated stink bug (*Halyomorpha halys*) or Asian gypsy moth (*Lymantria dispar*).

This standard is rigorous, but maintaining it in every small detail is a challenge.

Shipping containers

These pathways are addressed by the standards *Sea Containers from all Countries* and *Air Containers from all Countries* (both October, 2018).

Shipping containers were surveyed by Gadgil et al. (2000, 2002) and reviewed by Brockerhoff et al. (2016). Of 991 air containers sampled, 13% were found to have potentially quarantinable contaminants (Gadgil et al. (2002). Of 3681 sea containers, 23% were contaminated externally (Gadgil et al. 2000). The import health standards prescribe that all containers imported into New Zealand must be clean and free from pests and biosecurity contaminants (e.g. soil, plant material, insects, egg masses). Inspections to verify this must be conducted by MPI accredited personnel using MPI inspection guidelines. Regulations apply regarding opening of containers, the inspection location, procedures for handling contamination and specified treatment, if needed. Thresholds for contaminants in air containers are as prescribed for equipment, vehicles and machinery.

These pathways are well addressed by these standards. However, Brockerhoff et al. (2016) note the benefits and importance of maintaining a high level of inspection, cleaning, training and prevention of contamination of containers. See also remarks under Discussion.

Soil

Soil as a contaminant is dealt with under the respective import health standard applicable. If specially imported (e.g. for research or another purpose), it is covered by the standard *Soil, Rock, Gravel, Sand, Clay, and Water* (October, 2018; some amendments since Hood 2016). The standard *Fertilisers and Growing Media of Plant Origin* (October, 2018) applies to processed or manufactured commodities which are judged to pose little risk. As prescribed in the soil, rock etc. standard, material must be securely packaged, subject to possible inspection by an approved inspector and must not be used to propagate plants. A permit is required before any organisms may be isolated from the imported material. A permit is also required for imports of soil greater than 10kg in weight. Soil less than this quantity, if not intended for research purposes must be heat treated (100 °C for 25 min. at 40% relative humidity, or 85 °C for 15 hr. at 40% relative humidity) or be irradiated. If more than 10kg, an import permit is required specifying specific requirements. If there is a large quantity of soil with a significant amount of organic matter it may be desirable to test the effectiveness of fumigation by isolating for *Fusarium* spp. (Gadgil et al. 2003). Imported rock, gravel, sand and clay must be free from organic matter.

Camping equipment

Boots, shoes, camping gear, clothing and items that may have been exposed to pine forests are, of course, not addressed by an import health standard. Tents have been shown to carry a significant amount of plant debris (Gadgil and Flint 1983), but quarantine inspection and procedures at airports address this pathway (Dick 1998).

Invertebrates:

The role of insects in vectoring *F. circinatum* is thoroughly reviewed by Wingfield et al. (2008). Known or possible carriers include bark and twig beetles in the genera *Ernobius*, *Hylastes*, *Hylurgops*, *Hypothenemus*, *Ips*, *Orthotomicus*, *Pissodes* and *Pityophthorus* (Dick 1998; Romón et al. 2007). Other possible carriers include species of *Brachyderes* (root weevil), *Contarinia* (needle midge), *Rhyacionia* (pine tip moths) and cone and seed feeding insects (species of *Conophthorus*, *Laspreyresia*, *Leptoglossus*, *Megastionus* and *Tetrya*; Wingfield et al. 2008). Spores of *F. circinatum* have also been found on insects not known to feed on pines, including species of flies and wasps. Infested insects may potentially be carried by any of the pathways already described, notably in raw wood products, equipment and cars, and an incursion of *F. circinatum* by this means should therefore be prevented by the protocols listed in the respective import health standards. Nevertheless, a number of bark beetles in the genera listed above are periodically intercepted by quarantine officers at New Zealand ports so the risk remains real (Dick 1998). Gadgil et al. (2003) provided the following data for interceptions at New Zealand ports between 1950 and 1995 of bark and twig beetles known to be vectors of *F. circinatum*:

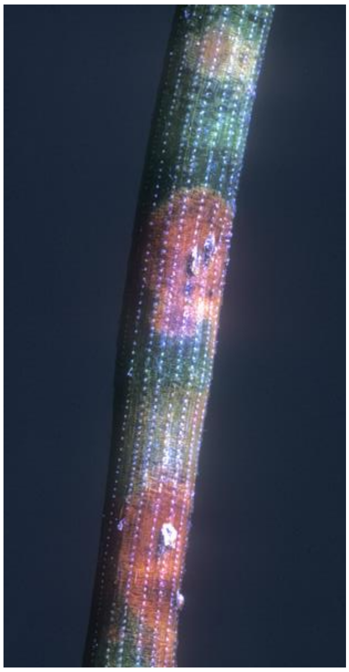
Insect genus	Nº. interceptions	% ex North America
Dendroctonus	8	88
Ernobius	868	5
Ips	151	28
Pissodes	52	21
Pityophthorus	21	48

Interceptions in Australia on imported coniferous timber have included species of *Dendroctonus*, *Phloeosinus*, *Pseudohylesinus* and *Xyleborus* (Gadgil et al. 2003).

Conclusion:

The diversity of pathways that could carry the pine pitch canker pathogen into New Zealand is daunting, but most openings are potentially blocked by protocols in the respective import health standards. Apart from the vigilance and sheer labour necessary to administer the standards to their ultimate practicable extent, including what is judged to be an acceptable level of sampling for some items, there appear to be certain openings that should be addressed. Imported wood products of Douglas fir may need to be treated in the same way as that of *P*. *radiata*. And, thought should be given to the heat treatment of wood packaging which does not appear to be sufficient.

Dothistroma needle blight:

Natural Resources Wales UK Forestry Commission.

Pathogens: *Dothistroma septosporum*.
Synonyms: *Mycosphaerella pini*, *Scirrhia pini*.

Dothistroma pini.

Note: there are two[6] species, *D*. *septosporum* and *D*. *pini*. Although previously known here as *D*. *pini*, only *D*. *septosporum* is present in New Zealand. Furthermore, New Zealand has only one clone of this fungus with just one of the two mating types required for sexual reproduction, implying that there has been only a single incursion of *D*. *septosporum* in the nearly 50 years since it was first detected (Hirst 1997; Hirst et al. 1999; Groenwald et al. 2007; Barnes et al. 2014).

Both species are listed as regulated organisms (but not formally as unwanted or notifiable; but see Bulman et al. 2013). *Dothistroma septosporum* is listed on the New Zealand Organisms Register as present, exotic. CABI link.

Distribution: Earliest records of *Dothistroma* are from Europe, these being 1880 in Denmark for *D*. *septosporum*[7] and 1907 in France for *D*. *pini* (Drenkhan 2016). *Dothistroma septosporum* is now widespread in Europe, North, Central and South America, Africa, parts of Asia and Oceania, including of course, New Zealand (Figs. 2 and 4[8]). *Dothistroma pini* is also widely distributed, but is known only in parts of Europe and North America (Figs. 3 and 4). *Dothistroma septorum* appears to be native on indigenous pines in parts of Europe, North America (e.g. British Columbia) and Asia (e.g. Bhutan), and *D*. *pini* likewise in North America (central northern United States) and possibly parts of Europe, but the centres of diversity remain to be properly defined (Drenjkhan 2016). *Dothistroma septosporum* is invasive on exotic *Pinus* spp. planted in the southern hemisphere.

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[6] *Dothistroma flichianum*, described in 1897 from foliage of *Pinus nigra* and *P*. *mugo* in France, is considered to be either *D*. *septosporum* or *D*. *pini* (Barnes et al. 2016).
[7] Probably this species; applies to a record of *Dothistroma* sp. with the sexual stage present (keeping in mind, however, that, although the sexual stage has not been reported for *D*. *pini*, it cannot yet be ruled out that where both species occur together, some records of *D*. *septosporum* with sexual fruitbodies might actually have been of *D*. *pini*, i.e. that this species may also be capable of sexual reproduction; Barnes et al. 2016; Drenkhan et al. 2016).
[8] Fig. 4 is included as an independent comparison with Fig. 2 and Fig. 3.

There may have been multiple introductions into some African countries where there has been a longer history of pine plantation forestry (Drenkhan et al. 2016).

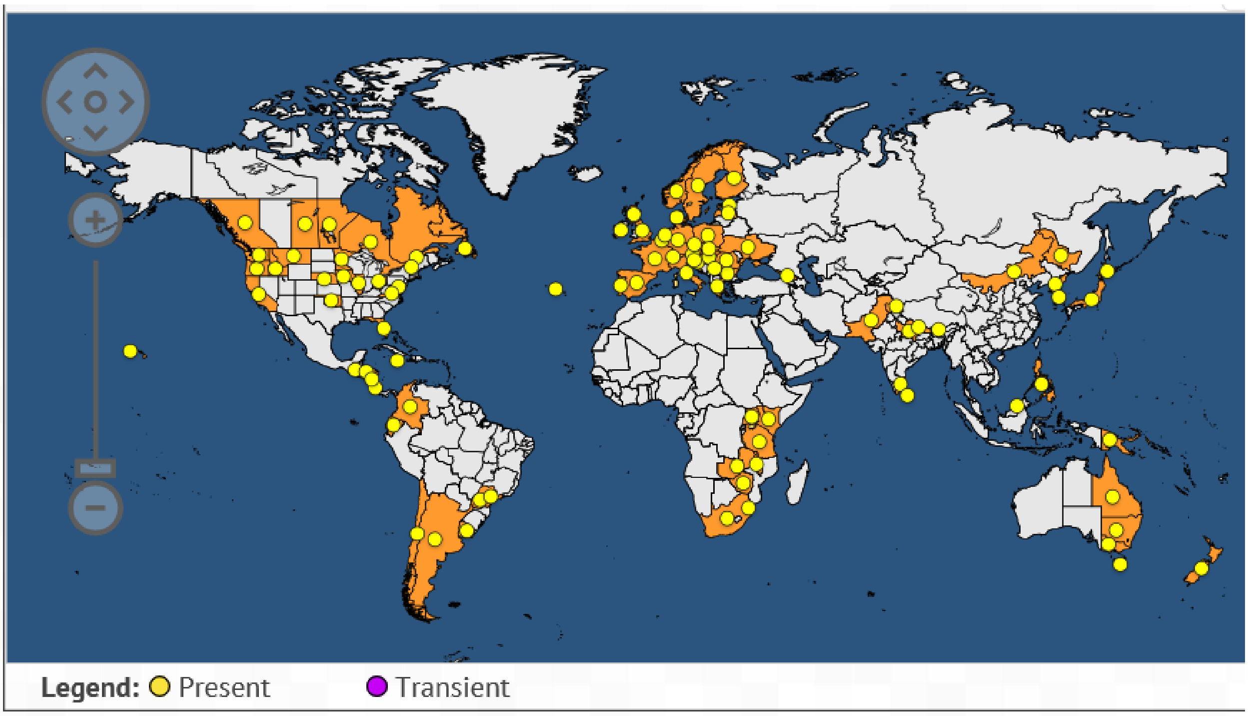

Fig. 2. Distribution of *Dothistroma septosporum*. EPPO Global Database.

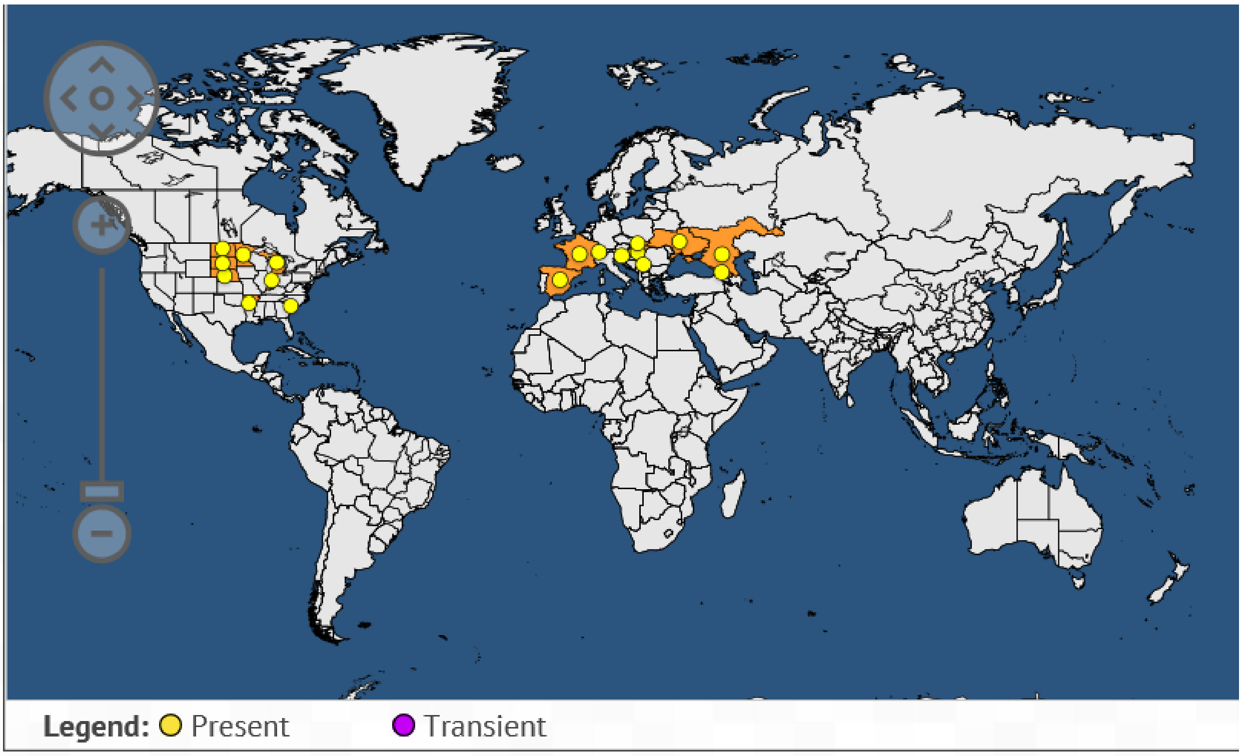

Fig. 3. Distribution of *Dothistroma pini*. EPPO Global Database.

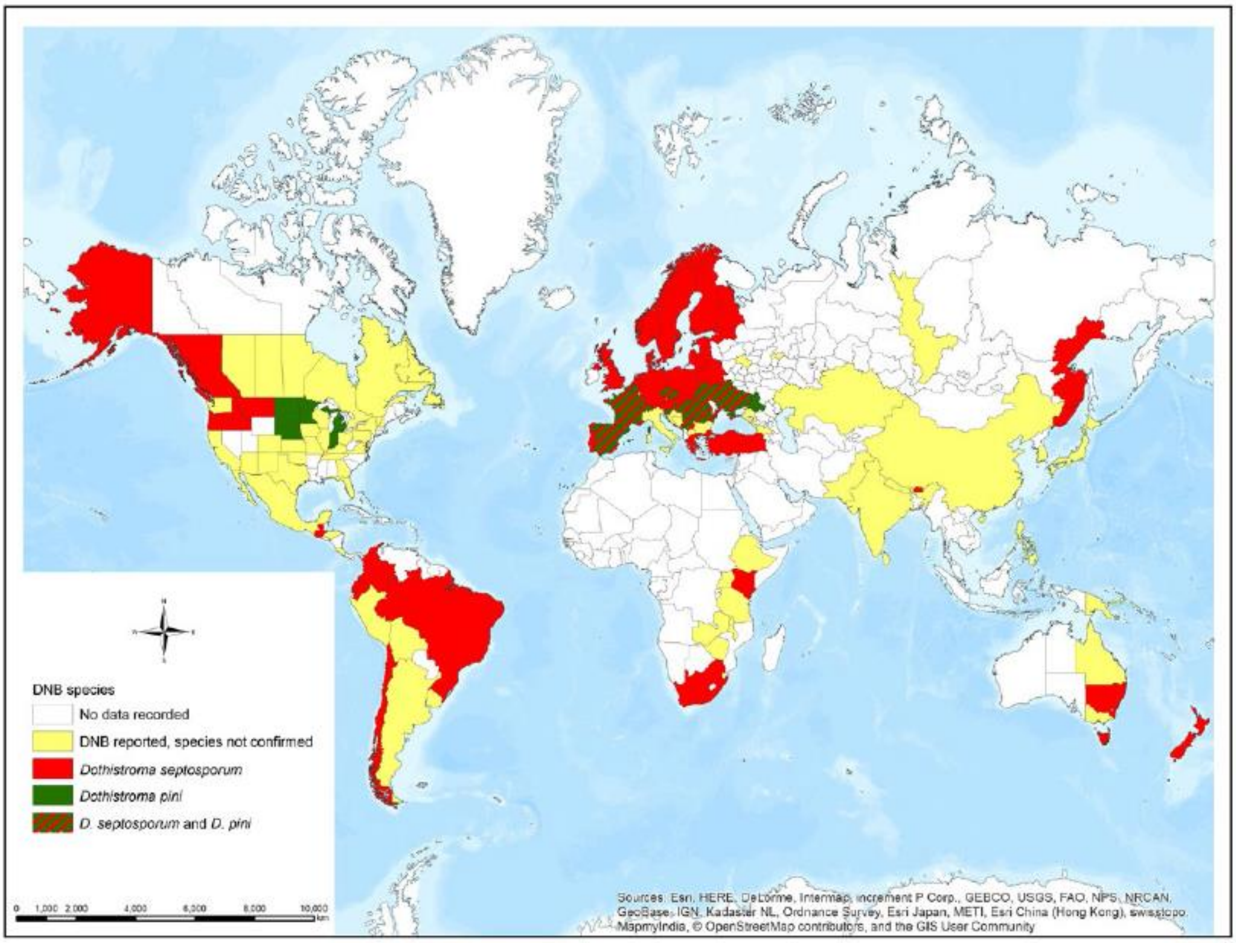

Fig. 4. Distribution of *Dothistroma* species, from Drenkhan et al. (2016); https://arcgis.mendelu.cz/monitoring/.

Hosts:

Dothistroma septosporum: *Pinus* spp. (95 spp., including *P*. *radiata*), and species of *Abies*, *Cedrus*, *Larix*, *Picea* and *Pseudotsuga*.

Dothistroma pini: *Pinus* spp. (12 spp., including *P*. *radiata*). All hosts of *D*. *pini* are also hosts for *D*. *septosporum* (except *P*. *albicaulis*, which may eventually also prove to be a host of both species).

Pinus radiata ranks as highly susceptible to dothistroma needle blight and to *D*. *septosporum*, but the degree of susceptibility of this host species to *D*. *pini* is not reported (Drenkhan et al. 2016).

Biology: Dothistroma needle blight has been thoroughly studied in New Zealand (and elsewhere) and only brief summaries of the biology and symptom expression of the disease are provided here. For greater detail see Bulman et al. (2004, 2013); Gadgil (1967, 1970, 1874, 1977); Gadgil and Holden (1976); Gilmour (1981); and Gilmour and Noorderhaven (1971). During November or December, once temperatures have warmed sufficiently, asexual spores (conidia) are produced from infected, still attached needles in sufficient numbers to infect new needles, This occurs after dispersal in rain splash during wet weather under adequate lighting conditions. Needles infected at this time eventually produce new fruitbodies and release further conidia around February, if rain occurs, leading to a second cycle of infection. The disease therefore varies in severity between years depending on seasonal weather conditions. It was found that spraying with a copper fungicide at these critical times controls the disease by stopping fruitbody production and spore release and to a lesser extent, preventing spore germination. Spread of *D*. *septosporum* spores is mainly local between stands and with *P*. *radiata* in New Zealand infection does not take place after mid rotation age. Even in countries where sexual reproduction occurs conidia, rather than sexual ascospores, may be the main method of local dispersal (Groenwald et al. 2007; with *D*. *septosporum*, opposite mating types must meet for sexual mating to take place). Globally, the disease is favoured in regions with warm, moist conditions, although it occurs over a wide range of climates (Watt et al. 2011; Drenkhan et al. 2016; Patton and Lewis 2019).

Symptoms: A distinctive lesion in the form of a band several millimetres long, coloured a dull reddish due to the production of a compound called dothistromin, develops at the point of infection on green needles (Patton and Lewis 2018). Tiny blackish fruitbodies producing distinctive conidia erupt through the needle epidermis and cuticle. Needle tissues brown and die distal to the lesion. The faded red band colour can often still be made out after the needle ages and discolours. Infection takes place in the lower foliage nearer to the ground, giving rise to a diffuse, reddish, horizontal zone at the base of each green crown in a stand of young diseased trees.

Impact: Dothistroma needle blight causes growth loss and affects the quality of trees in Christmas tree plantings (Bulman et al. 2013). Mortality is generally uncommon. The disease became established and caused damage to *P*. *radiata* plantations in different African countries in the 1940s and 1950s, in Chile in the 1950s, New Zealand in the 1960s and Australia in the 1970s (Barnes et al. 2014). Severe outbreaks that have occurred more recently in European countries and parts of North America are attributed to larger forest plantation areas (and hence increased inoculum loads), changing climate or possibly the emergence of more virulent pathogen strains resulting from sexual reproduction (Groenewald et al. 2007; Bulman et al. 2013; Barnes et al. 2014). Disease impact is also affected by variation in species and provenance susceptibility.

Identification: The genus is readily identified morphologically, but differentiating the two species is almost impossible without DNA-based techniques (Barnes et al. 2014, 2016; EPPO 2015). Both produce similar symptoms on foliage (Drenkhan et al. 2016). Early recognition, identification and eradication of a new *Dothistroma* incursion in New Zealand is likely to be impeded by the presence of *D*. *septosporum* already in this country. An introduction might be detected early under a programme of routine field sampling and molecular screening, but realistically, a marked, localised increase in disease severity may be what reveals the presence of a new, virulent strain (Groenewald et al. 2007). The discovery of a sexual stage[9] would strongly imply a new strain of *D*. *septosporum*, which would be confirmed by molecular means. However, at the border, the interception and identification of *Dothistroma* species in infected foliage would be determined by molecular analysis. *Lecanosticta acicula* (synonyms: *Mycosphaerella dearnessii*, *Scirrhia acicula*; not present in New Zealand), also infects pine needles and is sometimes confused with *Dothistroma* species, but is morphologically and molecularly distinct and should be clearly distinguished in the laboratory following an interception.

Potential pathways: Dothistroma needle blight is considered to have been spread globally on *Pinus* planting stock (Barnes et al. 2014), which may not always show symptoms when first infected (Drenkhan et al. 2016). Drenkhan et al. (2016) provide a number of examples where introductions appear to have occurred by this means. Although native in Europe, the population structure of *D*. *septosporum* in that region is also suggestive of a degree of spread by human activity (Barnes et al. 2014; Piotrowska et al. 2017). It has been suggested that *D*. *septosporum* in New Zealand may have been carried back by visitors to a forestry conference in Kenya, but this was not supported by DNA analysis (isolates from both countries did not share genotypes; Barnes et al. 2014). It is therefore not known how the disease reached this country. The pathogen may have spread to Australia from New Zealand via spores in mist clouds, although there appear to have been additional introductions into Australia from elsewhere as well (Barnes et al. 2014). In fact, natural spread over longer distances leading to new incursions seems generally unlikely (Bulman et al. 2013).

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[9] This would probably only occur if an introduction comprised (or included) a strain of *D*. *septosporum* with mating type different from that (MAT2) already present. The seemingly different form and prominence of the sexual fruitbody in, for instance, infected foliage of shore pine (*Pinus contorta* subsp. *contorta*) in British Columbia, may distinguish it from the asexual fruitbody using a hand lens in the field (*pers*. *obs*.), followed by laboratory confirmation. It is noteworthy, however, that for some reason the sexual fruitbody of *D*. *septosporum* has not been observed in either the United Kingdom or South Africa, despite the presence of both mating types in each country (Groenwald et al. 2007).

Gadgil (1970) found that *D*. *septosporum* in infected needles suspended above, but not in contact with moist needle litter containing competitive saprpophytic fungi survived and produced conidia for 4 months or more. This suggests that infected detached foliage could survive a journey on or in wood produce, vehicles, machinery, containers, camping equipment or as an unclean seedlot contaminant in a viable and infectious state.

There does not currently appear to be an incursion plan for a potential introduction of *D*. *septosporum* or *D*. *pini* into New Zealand.

Import health standards:

Although already present in New Zealand, a further introduction of either species, with potentially severe consequences, is possible. The pathway by which the present single clone of *D*. *septosporum* reached this country is not known. The introduction of a strain with the opposite mating type gene would open the way for sexual recombination and increased genetic variability, with the risk of new, more virulent strains. *Dothistroma septosporum* is not specifically featured in import health standards, probably because it is already present in this country. However, both *Dothistroma* species are classed as regulated pests with respect to relevant standards.

The import health standards relevant to *Dothistroma* species are *Nursery Stock*, *Seeds for Sowing*, the several wood products standards, *Vehicles, Machinery and Equipment*, *Used Equipment Associated with Animals or Water*, *Sea Containers from all Countries*, *Air Containers from all Countries* and *Soil, Rock, Gravel, Sand, Clay, and Water*. Apart from the first, all standards relate to possible extraneous needle contamination of consignments which must be free, or relatively free of leaves and foliage. Imports of live *Pinus* and Douglas fir plants are not permitted under the Nursery Stock standard. The only other likely pathway is through incoming travellers and their effects, including camping equipment, which are all checked at air and sea ports. In addition, it has been shown that successful infection of fresh foliage requires a very large number of conidia (Bulman et al. 2004), which virtually eliminates the possibility of a new strain of *Dothistroma* becoming established, in the unlikely event of a breach at the border. Nevertheless, vigilance is necessary, as shown by the level of contamination found in studies of incoming tents and shipping containers (Gadgil et al. 2000, 2002; Gadgil and Flint 1983).

Conclusion:

The risk of an introduction of a new strain of *D*. *septosporum* or *D*. *pini* appears to be sufficiently addressed by existing import health standards.

Daño foliar del pino (foliage damage of pine):

Ahumada et al. (2013a).

Durán et al. (2008)

Durán et al. (2008)

Pathogen: *Phytophthora pinifolia*

A regulated organism (not present on either the unwanted or notifiable organisms lists; recorded as absent from New Zealand on the New Zealand Organisms Register). CABI Link.

Distribution: Chile.

Hosts: *Pinus radiata*. The first confirmed occurrence of a *Pinus* needle and shoot disease by an aerial *Phytophthora* species (Hansen 2012[10]**).** *Pinus pinaster* and *Pseudotsuga menziesii* planted near diseased radiata pine did not become infected (Durán et al. 2010). Lesion lengths in shoots of 13 *Pinus* species inoculated with *P*. *pinifolia* plugs ranged from greatest with *P*. *radiata* and *P*. *durangensis* to least with *P*. *taeda* and *P*. *pinaster*, indicating that *P*. *radiata* is particularly susceptible (Ahumada et al. 2013b).

[10] It has since been demonstrated by molecular examination of earlier foliage collections that *P*. *kernoviae* was present in needles of *P*. *radiata* in New Zealand at least as far back as 1986, but this was not known at that time (McDougal 2013).

Fig. 5. Distribution of *Phytophthora pinifolia*. EPPO Global Database

Biology: The biology and symptoms of *P. pinifolia* are similar, though not identical, to those of *P. pluvialis*[11], and *P. kernoviae*[12], in New Zealand (Dick et al. 2014; Hood et al. 2017; Williams and Hansen 2018). As with *P. pluvialis*, sporangia protrude through needle stomata and mostly persist without being shed (Durán et al., 2008, assumed the sporangia, themselves, were the infective propagules but this requires verification, since attached sporangia are often empty of zoospores; Ahumada et al. 2013b). Sporangia are said to be produced on dead as well as green needles, among branches of trees or on the forest floor (Ahumada et al. 2013a). Infection occurs throughout the year, but particularly during winter and spring, which is the main period of rainfall in the affected region (Ahumada et al. 2013a). Symptoms of the disease are observed over the same period, between autumn and late spring (Ahumada et al. 2013a; Sanfuentes 2018; as with red needle cast). Like red needle cast, stands are affected at all ages from 1-year-old to maturity (Durán et al. 2010; Ahumada et al. 2013a). Young diseased trees are mostly found adjacent to older diseased stands (Durán et al. 2008; again, as occurs with red needle cast, implying a limited dispersal distance in mist and rain splash). Unlike red needle cast, infection extends on from the needle bases into shoot tissue, especially on epicormic branches (Hansen 2012). The necrotic lesions produced eventually girdle the shoot, leading to tip wilting and death in young seedlings (in contrast to red needle cast behaviour). In older trees the disease first appears at the base of the green crown and develops upwards, affected foliage becoming brown, greyish, and persisting until casting occurs during windy periods in November and December. Older trees recover each year, but some may die if defoliation is repeated and excessive or if they are attacked by *Sphaeropsis sapinea* (*Diplodia pinea*; Durán et al. 2008). *Phytophthora pinifolia* survives at low levels in litter during summer (it is not yet known how *P. pluvialis* survives between seasons).

Symptoms: A paler zone at the point of infection on the green needle, with tiny black resinous marks or bands (Durán et al. 2008; Sanfuentes 2018; similar to symptoms of *P. pluvialis* and *P. kernoviae* on *P. radiata* in New Zealand). Diseased needles tend to project at right angles to the branch, due to the collapse of infected needle bases. Infection is initially more pronounced on the

[11] Agent of red needle cast.
[12] *Possibly* the agent of physiological needle blight.

lower side of the branch where moisture persists for longer (Hansen 2012). Cankerous, resinous lesions develop in the stem and shoot wilting and tip death occurs on trees up to four years old (Durán et al. 2008).

Impact: The disease first appeared in coastal areas of Arauco province, Chile, in 2004, over an area of 3,300 ha (Durán et al. 2008; Ahumada et al. 2013a). This area increased to 54,000 ha in 2006 but subsequently reduced to 2,000 ha in subsequent years (Sanfuentes 2018). Stands on shaded, cooler, wetter southern slopes were more affected (Durán et al. 2008). Disease reduction is attributed to years with drier weather conditions, felling of diseased stands and management procedures such as the replacement of pines with eucalypts on higher risk sites, selection of disease tolerant planting stock and chemical control (Ahumada et al. 2013a; Brockerhoff and Bulman 2014). At the landscape level, severity is related to sites having more days with high relative humidity and rainfall (Ahumada et al. 2013a; Sanfuentes 2018). The variation in severity between years appears similar to red needle cast behaviour in New Zealand. Mortality occurs in severely diseased seedling stock as a result of terminal shoot death (Durán et al. 2010).

Identification: In culture, *P*. *pinifolia* forms distinctive coralloid hyphae and spherical swellings occur. Non-papillate, subglobose to ovoid, mostly non-dehiscent sporangia are produced on single sporangiophores in soil water, releasing zoospores. Unlike homothallic *P*. *pluvialis* and *P*. *kernoviae*, which readily form oogonia and oospores, these organelles are not seen in cultures of *P*. *pinifolia*, even after attempted mating with tester A1 or A2 isolates of certain heterothallic species (Hansen 2012)[13]. Isolates of *P*. *pinifolia* will therefore be morphologically distinguishable from those of *P*. *pluvialis* and *P*. *kernoviae*[14]. Molecular techniques to identify *P*. *pinifolia* have been developed (Durán et al. 2009; Ahumada et al. 2013a).

A searchable, web-based database for identifying *Phytophthora* species from sequences is available on: http://phytophthora-id.org/index.html.

As with *Dothistroma* species, early detection of an incursion past the border could be hampered by the existence of two similar pathogens, *P*. *pluvialis* and *P*. *kernoviae*, already present in New Zealand radiata pine plantations. However, the recognition of *P*. *pinifolia* in young plants should be aided by the occurrence of lesions, cankering and resinosis in the stem (as well as by the more typical needle symptoms), leading to shoot tip wilting and drooping, features not found with *P*. *pluvialis*. A preponderance of affected needles on the undersides of branches may also be indicative, if this is not just a phenomenon related to particular local environmental conditions where it is currently found. Also, sampling and molecular analysis are currently undertaken for red needle cast on a recurring basis in both research studies and with material received in the diagnostic laboratory, which would reveal the presence of *P*. *pinifolia* should it ever reach a New Zealand pine forest.

Potential pathways: The origin of *P*. *pinifolia* is unknown, but isolates in Chile are all of a single clone (of two almost identical genotypes), implying an introduction (Ahumada et al. 2013a; the unlikely alternatives that a native phytophthora has undergone a host shift, or that interspecific hybridisation has produced a new pathogen, are discounted; Durán et al. 2008; Webber et al. 2014). Durán et al. (2010) suggest that in the absence of information on how *P*. *pinifolia* reached Chile, there is risk for other *P*. *radiata* growing areas in the world. Possible pathways include movement of infected plants or infested water and soil (EPPO 2013; Webber 2014), although how long the pathogen can survive in water and in soil remains to be determined. *P*. *pinifolia* does not produce resistant, resting oospores as do *P*. *pluvialis* and *P*. *kernoviae*, and zoospores or sporangia are unlikely to survive in water or soil for long. *P*. *pinifolia* is not known to have a soil borne stage (Durán et al. 2010). Research has shown that green sawn timber is not a likely pathway (Ahumada et al. 2012; cf. Hood et al 2014). It is not known for how long *P*. *pinifolia* can survive in needles that may be carried as a contaminant on wood or in soil but, again, there is no resistant oospore stage that would prolong survival (Webber 2014). It is understood that there have

[13] The three species are not closely related, *P*. *pinifolia* residing in Clade 6 of the ITS-based phylogeny (Hansen 2012) and *P*. *pluvialis* in Clade 3 (Williams and Hansen 2018). *Phytophthora kernoviae* is in Clade 10 (Cooke et al. 2000).

[14] Cultures of *P*. *pinifolia* grow between temperatures of 7 °C and 30 °C (with an optimum growth temperature of 25 °C; Webber 2014). Those of *P*. *pluvialis* grow between temperatures of 8 °C and 25 °C (data of M.A. Dick and R. Tetenburg quoted in Williams et al. 2016).

been studies to monitor infected needles suspended in branches and placed in litter in order to investigate survival during the summer lull period, but results have yet to be published. Are cut branches or cones a possible risk pathway (EPPO 2013)? *Phytophthora pinifolia* is not known to be vectored by insects (Webber 2014).

There is currently no specific incursion plan for a potential introduction of *P*. *pinifolia* into New Zealand. A *P*. *pinifolia* risk analysis has been prepared for use in the United Kingdom although the likelihood of entry into that country is considered low (Webber 2014).

Import health standards:

The import health standards relating to this pathogen are similar to those for the two *Dothistroma* species, being *Nursery Stock*, *Seeds for Sowing*, the several wood products standards, *Vehicles, Machinery and Equipment*, *Used Equipment Associated with Animals or Water*, *Sea Containers from all Countries*, *Air Containers from all Countries* and *Soil, Rock, Gravel, Sand, Clay, and Water*. As for *Dothistroma*, the implementation of these standards and the biosecurity procedures in place at airports appear to cover all possible pathways by which *P*. *pinifolia* could enter New Zealand. This conclusion is similar to that reached by Webber (2014) who considered that, although the probability of establishment of *P*. *pinifolia* in the United Kingdom was high (after a successful incursion), the risk of entry categories were "unlikely" with plants for planting (due to prohibitions on their movement) and "low" to "very low" with movement of soil and timber[15]. However, the same author suggested that *P*. *pinifolia* could pose a high level of risk to parts of the world where *P*. *radiata* is grown commercially as a plantation tree. She also noted that although the host range of *P*. *pinifolia* is assumed to be limited to *Pinus* (or at least conifer) species, if in fact it was found to include a wider range of plant families (as with other invasive phytophthoras such as *P*. *cinnamomi* and *P*. *ramorum*), there could still be some gaps in the import health standard shield.

Conclusion:

The risk of an incursion of *P*. *pinifolia* appears to be low and adequately addressed by present import health standards as fully implemented. However, Brockerhoff and Bulman (2014) considered *P*. *pinifolia* to be a significant threat and risk to New Zealand forestry, and it is of some concern that the pathway by which it entered Chile is unknown. Similarly, the way two genetic clusters of *P*. *pluvialis* invaded New Zealand from its North American home is not known (Brar et al. 2017). There would appear to be some justification for undertaking further host range testing to encompass a selection of other coniferous and non-coniferous plant species as possible (or unlikely) carriers.

[15] *Phytophthora pinifolia* was placed temporarily on the EPPO Alert List when it was first discovered, but subsequently removed (Webber 2014).

INSECT PESTS:

European pine shoot moth:

Universidad Austral de Chile

Pest: *Rhyacionia buoliana*

A notifiable and regulated organism. Not present on the New Zealand Organisms Register. CABI link.

Distribution: Widely distributed in Europe and North America. Also in South America (Argentina, Chile, Uruguay), Africa (Algeria) and Asia (Iran, Israel, Japan, Syria, Turkey). In Chile it can be found throughout the area where *P*. *radiata* plantations occur.

Hosts: Many species of *Pinus*, including *P*. *radiata*. Also *Picea abies*, *Picea pungens* and *Pseudotsuga menziesii*.

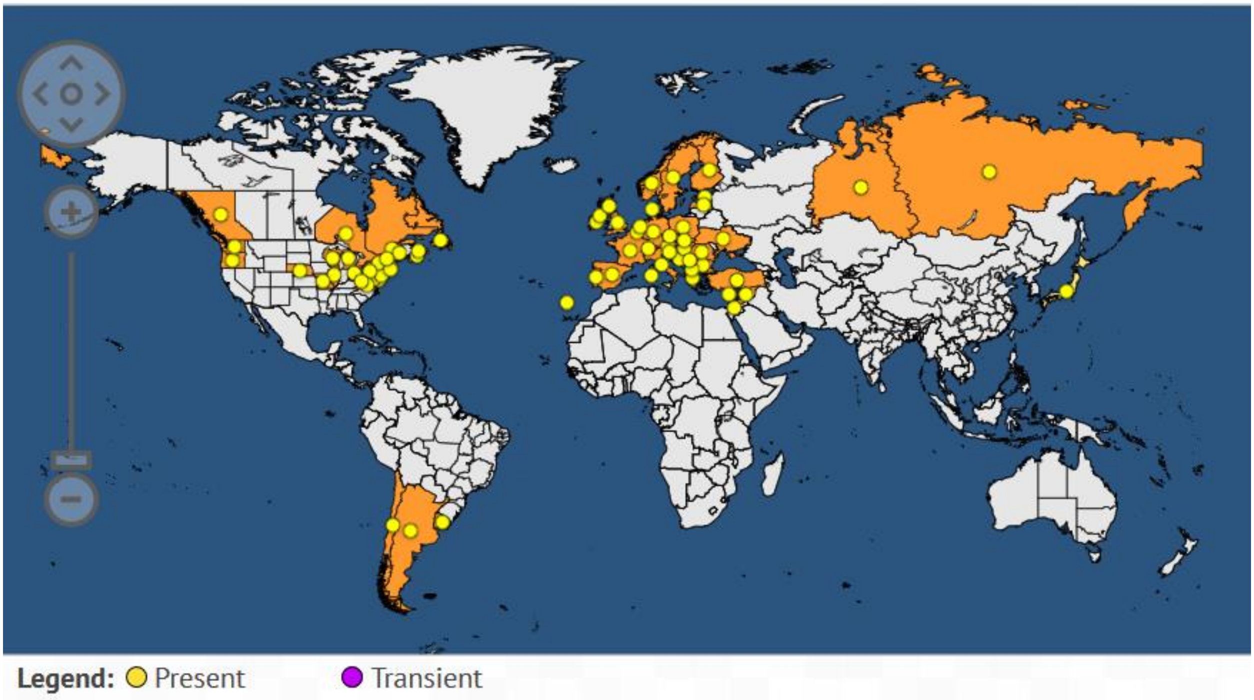

Fig. 6. Distribution of *Rhyacionia buoliana*. EPPO Global Database.

Biology: *Rhyacionia buoliana* completes its lifecycle on *Pinus* spp., producing one brood per year. Eggs hatch, 1-2 weeks after laying, during spring (mid-October in Chile, or later further south where it is cooler). Larvae feed on needle bases and buds during summer prior to overwintering in a chamber of resin and silk. In the following spring larvae feed on new buds and shoots in the upper canopy. Pupation occurs in October or, further south, in mid-December (Chile). Adults emerge in spring and females may fly a considerable distance before egg-laying. In Chile, where there are no major competitors, *R*. *buoliana* feeds on *P*. *radiata* for up to nine months of its life cycle (elsewhere, *R*. *buoliana* has up to 100 species of natural enemies).

Signs and symptoms: Holes and galleries in growing shoots and buds caused by larval feeding, followed by death, distortion or breakage of shoots. Small, white, larval resin masses accompany dead needles. Breaking of shoot tips, eventually causes forking, multi-leadering and subsequently breakage and stem malformation.

Impact: Attack by *R*. *buoliana* results in stem malformation, growth loss and multi-leadering, but not mortality. Damage increases with successive annual infestations. An *R*. *buoliana* outbreak occurred in Europe early in the twentieth century. In the United States, plantations of *Pinus resinosa* were reduced because of *R*. *buoliana* damage, and the pest is now considered to be a significant but sporadic problem in pine stands. *Rhyacionia buoliana* has impacted severely on some stands in Chile, where it is widespread. Plantations of *P*. *radiata* are generally most susceptible before age 15 years, but in Chile at age 1-4 years. *Rhyacionia buoliana* can be controlled chemically and by removal of affected shoots in small stands. There has been concern about the environmental effects of the large amounts of insecticides that have been applied in the past. Much research has gone into biological control testing a range of parasitoids.

Identification: The various life stages are well described. It is considered that the form of symptoms as viewed in the field is unique to *R*. *buoliana*, even though several other insects cause similar damage. *Rhyacionia buoliana* has been confused with *R*. *pinicolana*, which can be distinguished by its adult genitalia.

Potential pathways: *Rhyacionia buoliana* has spread from Europe to other regions, reaching North America (the United States) in 1914 and South America (Uruguay) in 1936. According to CABI the U.S. detection was in seedlings imported from Europe. The pest was first detected in Chile in 1985, but may have arrived earlier. *Rhyacionia buoliana* may potentially be carried as eggs, larvae or pupae on logs, shoots or branches. It is not known to be carried on wood packaging, bark, cones, plant growing medium, foliage, roots, seeds or (despite the above comment) seedlings (CABI). Using international data, Meurisse et al; (2018) found the most common pathways for transporting lepidopterous insects to be (in descending order of importance) containers, vehicles/machinery and mail, followed to a significantly lesser degree by passengers, wood packaging and live plants. Brockerhoff et al. (2016) considered live plants to be an important pathway for lepidoptera, followed by containers.

Import health standards:

Based on the possible pathways, the import health standards that are relevant to preventing an incursion of the European pine shoot moth are *Sea Containers from all Countries*, *Air Containers from all Countries*, *Vehicles, Machinery and Equipment*, and to a lesser extent, *Wood Packaging Material from all Countries*, and *possibly Nursery Stock*. Nor can one rule out *Sawn Wood from all Countries* and *Poles, Piles, Rounds and Sleepers from all Countries.* As noted previously, live plant imports of susceptible hosts such as *P*. *radiata* and *Pseudotsuga menziesii* are prohibited (*Plants Biosecurity Index*). The hosts *Picea abies* and *P*. *pungens*, as well as other *Picea* species, may be imported as nursery stock, but under regulations that require post entry quarantine level 3B conditions for a minimum period of 6 months, in addition to other general conditions including requirements for an import permit, cleanliness, pre-export and post-entry inspections and pesticide treatment. Shipping containers are required to be clean and free from soil, foliage and twig debris which might harbour eggs of *R*. *buoliana*. Similarly, wood packaging must be free from regulated pests and extraneous material such as leaves and soil, and to have undergone treatment with heat, fumigation or fungicide. Conditions for other wood items are similar. Imported vehicles and machinery must also be clean and free from extraneous matter, and may be required to undergo some form of treatment.

Conclusion:

The full implementation of the relevant standards appears adequate for preventing the entry of *R*. *buoliana* into New Zealand pine plantations. Brockerhoff and Bulman (2014) considered that although *R*. *buoliana* represents a significant threat to pines in this country, the prohibition applying to live pine imports, which they regard as the main pathway, means that it is unlikely that this pest will establish here. However, the varying importance attributed to different incursion pathways indicates how much remains to be learned.

Giant pine scale:

Source

Source

Source

Source

Pest: *Marchalina hellenica*.

Synonyms: *Monophlebus hellenicus*, *Marchalina caucasica*.

Not listed as an unwanted, notifiable or regulated organism. Not present on the New Zealand Organisms Register. CABI Link.

Distribution: Italy, Greece, Turkey and Victoria, Australia. Believed to originate in the eastern Mediterranean region.

Hosts: Species of *Pinus*, including *P. radiata*. Also *Abies cephalonica*. *Picea engelmanni* and *Picea orientalis*.

Biology: There is generally one generation per year. In spring-early summer (November to January, southern hemisphere), adult females produce up to 300 eggs parthenogenetically. According to Agriculture Victoria (2018), the eggs are retained within the female body and hatch after the death of the female. There are two instars, the first present during January to May (southern hemisphere autumn) and the second in May to September (overwintering stage).

Signs and symptoms: Female adults and instars are found in bark crevices covered by white waxy secretions. If in large numbers they effect a snow-like appearance, especially on the lower part of the trunk, but also on branches and exposed roots. Sooty mould may be present feeding on honeydew exuded by the scale. If in large numbers host trees show dieback, decline and ultimately death.

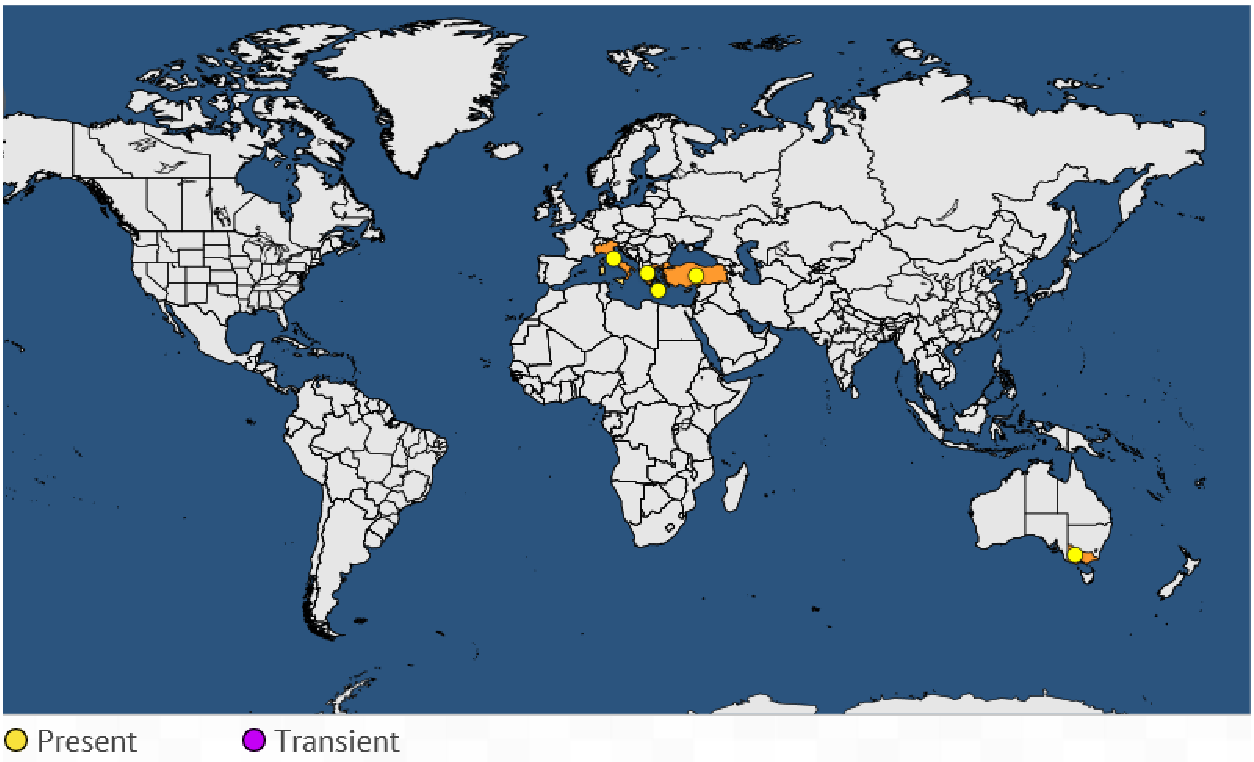

Fig. 7. Distribution of *Marchalina hellenica*. EPPO Global Database.

Impact: In Greece, in the late 1990s, severe decline accompanied by mortality in pine forests coincided with the deliberate, human spread of *M. hellenica* undertaken to encourage the production of honeydew for bees for the honey industry. As a causative relationship, the association between the decline and the giant pine scale was controversial, but a study in Turkey found that an infestation by the scale led to up to 3.4% growth loss. It does appear that large populations are damaging to trees. Giant pine scale was added to the EPPO alert list in 2006, but removed in 2008. *Marchalina hellenica* was found in Melbourne in 2014, and is also reported from Adelaide. It is considered to represent a threat to Victoria's softwood plantation industry (Agriculture Victoria 2018). In Australia it is reported on *P. radiata* and *P. halepensis*.

Identification: Adult females are bright yellow, wingless, up to 7-11 mm long and covered in a waxy secretion (antennae of eleven segments). First instar larvae (ca. 1 mm long) are light yellow and secrete a waxy substance like cotton (antennae of six segments). Second instar larvae (up to 7 mm long) have antennae of nine segments. Adult males (rarely seen) have wings of span ca. 11 mm.

Potential pathways: Although *M. hellenica* has limited natural dispersal (e.g. up to 50 m in one year), artificial human spread in Greece allowed giant pine scale populations to reach high levels. The most likely import pathway is through live plants and cut branches (EPPO 2008). Other possibilities include pine logs, pine foliage fragments and other parts (e.g. needles and cones) in vehicles and machinery, and on travellers' clothing (Agriculture Victoria 2018). Meurisse et al. (2018) give vehicles and machinery, containers and mail, and to some extent live plants and wood packaging, as the greatest risk pathways for Hemiptera (to which *M. hellenica* belongs). It is apparently not known how the pest reached Australia, but a look at the global distribution map clearly indicates it was transported by human agency. The inability of female adults and instars of this pest to fly implies that *M. hellenica* is unlikely to arrive trans-Tasman in New Zealand by natural means, despite its proximity. Its limited ability to disperse also suggests that eradication may be a feasible option if implemented early in the event that the pest is discovered in pine plantations.

Import health standards:

Based on the possible pathways, the most applicable import health standards are *Nursery Stock*, *Poles*, *Piles*, *Rounds and Sleepers from all Countries*, *Wood Packaging Material from all Countries*, *Vehicles, Machinery and Equipment*, *Sea Containers from all Countries* and *Air Containers from all Countries*.

As noted previously, the importing of live plants of *Pinus* is not permitted. Wood products must be bark free. Contamination by pine material in vehicles, machinery, and in and on shipping containers poses the same low level of risk as for the European pine shoot moth under the relevant standards.

Conclusion:

The present import standards are adequate for preventing the incursion and establishment of the giant pine scale as fully implemented. Nevertheless, the presence of *M*. *hellenica* in nearby Australia is cause for maintaining awareness and vigilance.

Tasmanian eucalyptus leaf beetle:


Source: Edgar (2011).


Source: Martinlagerwey.


Source.

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Pest: *Paropsisterna bimaculata*
Synonym: *Chrysophtharta bimaculata*

Listed as a regulated and unwanted pest. Not listed as a notifiable organism. Not present on the New Zealand Organisms Register. CABI Link. Atlas of Living Australia.

Distribution: Tasmania and Victoria in Australia.

Hosts: Species of *Eucalyptus* in the subgenera *Monocalyptus* and *Symphyomyrtus*, including *E*. *delegatensis*, *E*. *globulus*, *E*. *nitens* and *E*. *regnans*.

Biology: There is one generation per year (Edgar 2011). Eggs are laid during two or three peak periods between mid-November and mid-February after adults appear, following overwintering. Eggs hatch within 10 days and larvae pass through four instars during a period of three weeks to a month. Larvae and adults feed on new season's foliage, the larvae gregariously. Pupation occurs about one month after egg laying in soil or leaf litter after fourth instar larvae fall to the ground. Adults emerge two weeks later and undertake some feeding before spending the winter in small groups in bark crevices, cracks, bracken fern litter and on nearby vegetation such as *Gahnia* species and grasses.

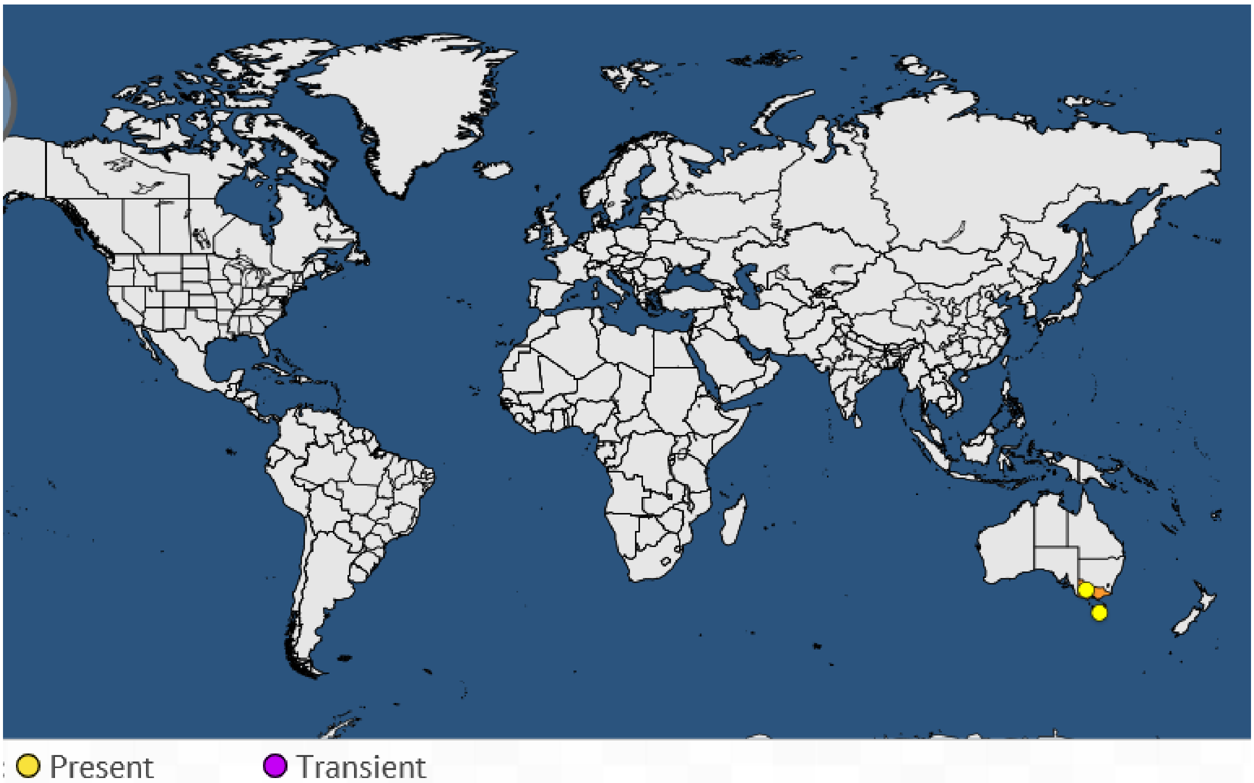

Fig. 8. Distribution of *Paropsisterna bimaculata*. EPPO Global Database.

Signs and symptoms: Severely infested trees are stripped of all young leaves and shoots, leaving just midribs, giving rise to a twiggy broom like appearance to tree tops (:broom topping"). Larval feeding, which produces a scalloping pattern lo leaf margins, differs from that of adults. Adults and larvae are morphologically distinctive.

Impact: *Paropsisterna bimaculata* is endemic in Tasmania where it has spread to plantations of exotic *Eucalyptus nitens* and also to eucalypt plantations in Victoria. It has increased in significance as the plantation areas of *E*. *nitens* and *E*. *globulus* have expanded. Damage is caused by defoliation and consequent growth loss (e.g. voracious feeding on *E*. *nitens* and up to 30% wood volume reduction in *E*. *regnans* in Tasmania; Edgar 2011; EPPO 2014). Most defoliation is caused by the larger, older instar larvae. Young trees are especially vulnerable after age three years. Severe infestation over successive seasons causes poor tree development and dieback, and sometimes even mortality.

Identification: Like *Paropsis charybdis* (eucalyptus tortoise beetle), *Paropsisterna beata* (eucalyptus leaf beetle) and the recently introduced *Paropsisterna variicollis* (eucalyptus variegated beetle), all being now present in New Zealand, *P*. *bimaculata* is a chrysomelid beetle (family Chrysomelidae, order Coleoptera). The adult beetle is up to 1 cm long. It is distinguished (especially from the similar *Paropsisterna agricola*, also present in Tasmanian *E*. *nitens* plantations) by two distinctive black marks (and often two adjacent faded ones) on the forward shield covering of the thorax and by generally pale patterns on the wing cases. Colours vary; a red brown colour when adults appear after their winter hibernation changes to a pale green with a faint gold repeating pattern during summer.

Potential pathways: *Paropsisterna bimaculata* was intercepted four times at the UK border during 2004 as a "hitchhiker" on tree ferns (*Dicksonia antarctica*) imported from Australia (EPPO 2014). This led to its temporary inclusion on the EPPO Alert List for over three years. A UK pest risk analysis is available. Adults fly, but natural dispersal across the Tasman to New Zealand seems unlikely (it has not occurred to date). It is not known how the related eucalyptus leaf beetle (*Paropsisterna beata*) reached New Zealand, but it was suggested that adults may have been present overwintering in a shipping container. It was first found in 2012 near Upper Hutt and subsequently on firewood collected at Waikanae. The eucalyptus variegated beetle (*P*. *variicollis*) was first found in Hawke's Bay in 2016, where a survey at that time revealed that it was relatively widespread in the region (BNZ), but it is apparently also not known how it arrived. Meurise et al. (2018) indicate that interceptions have revealed a number of potential pathways for Coleoptera, including wood packaging, logs, and processed wood, containers, vehicles and machinery, and international mail.

Import health standards:

Relevant import health standards for *P*. *bimaculata* include *Nursery Stock*, *Poles*, *Piles*, *Rounds and Sleepers from all Countries*, *Wood Packaging Material from all Countries*, *Vehicles, Machinery and Equipment*, *Sea Containers from all Countries* and *Air Containers from all Countries*. According to the *Plants Biosecurity Index* and the Nursery Stock standard, eucalypt plants may be imported from Australia, but must undergo level 3B post entry quarantine for a six months' minimum period prior to release, during which time any eggs, larvae or adults of this pest should be detectable. In addition, the basic requirements for whole plants and cuttings, which includes cleanliness, a requirement for an import permit, and a phytosanitory certificate declaring that professional pre-export inspection and potentially a chemical treatment if required has been undertaken, should ensure no chance incursion of this insect. These basic conditions, which include a period of post entry quarantine for a minimum of three months or as specified under special entry conditions, apply to all permitted plant imports, and should adequately address the movement of *P*. *bimaculata* on genera other than *Eucalyptus*. As for the other insect pests discussed above, wood products must be bark free and contamination by extraneous material in vehicles, machinery, and in and on shipping containers should be effectively covered under the relevant standards.

Conclusion:

In theory, the measures in place ensure there is a low risk of an incursion by *P*. *bimaculata*. However, the variety of potential pathways, the demonstrated movement of living *P*. *bimaculata* half way around the world, the proximity of the present pest range to New Zealand, and the lack of information on the manner in which two other species of *Paropsisternum* have already reached this country, all engender some uncertainty and emphasize that the requirements outlined in these standards be implemented as thoroughly as possible.

Discussion:

The legal framework enabling MPI and others to keep harmful and unwanted organisms out of New Zealand[16] is the Biosecurity Act 1993. Under this Act, import health standards prescribe the regulations and protocols designed to prevent unintentional incursions by pests and pathogens via a variety of international trade and commodity pathways. The protocols are revised as new information becomes available. Deliberate imports of new organisms for specific purposes are approved, or not, through the Hazardous Substances and New Organisms (HSNO) Act 1996 which provides a vehicle for assessing and managing the environmental and safety risks involved.

The import health standards evaluated in this study were generally considered to be adequate in blocking the entry of six exotic insect pests and pathogens of forest plantations, but for some there are a number of details that could be improved upon. These are itemised under the respective organisms and in the Executive Summary. However, it became apparent during the study that assessing the standards in this way has an element of subjectivity, being based on limited and generally qualitative information. This may explain why opinions on the importance of different pathways may vary (compare, for instance, viewpoints under the subheading "potential pathways" for *Fusarium circinatum* and *Rhyacionia buoliana*). It is true that we now have valuable data from studies quantifying shipping container contamination (Gadgil et al. 2000, 2002; MAF 2000; BNZ 2006; refer App. 1) and from analyses of international interception data that reveal which insects are travelling by different pathways (e.g. Meurisse 2018)[17]. Nevertheless, the abilities of pathogens and pests to travel may not coincide with their capacity to establish. Brockerhoff et al. (2006) found that New Zealand data on interception frequency for bark beetles was not clearly related to their establishment in the forest.

The fact is that we do not know how many (most?) of our significant pests and pathogens actually entered and became established in this country. Even where likely pathways can be conjectured, the details of precisely how exotic organisms breached the security net, migrated to and established in production forests are almost completely lacking. Such information, could it be obtained, would be of inestimable value in focussing and streamlining particular procedures outlined in the present standards. For instance, even if needles infected with, say, a different strain of *Dothistroma*, arrive on or in a container, what are the chances that this new pathogen will establish in a plantation or that it will simply die without dispersing? In the absence of such information potential pathways must be dealt with using a broad brush approach, which by necessity results in a not insignificant national biosecurity monetary investment (Sikes et al. 2018).

In undertaking this study, it was also necessary (as with the earlier review: Hood 2016) to consider potential non-forestry invasion routes, such as imports of cultivated plants, that are not linked directly to imports of forest produce or to items contaminated by material from forest sources. This is challenging when not all non-forestry hosts or carriers of pests and pathogens may be known (e.g. see under *Fusarium circinatum*). A comprehensive workshop earlier this decade highlighted many of the biosecurity issues relevant to the importing of cultivated plants, which could potentially affect forestry, directly or indirectly (Dawson 2010). The workshop incidentally also drew attention to a number of shortcomings in the *Plants Biosecurity Index*, which provides information on the biosecurity status for imports of different plant species (Dickson 2009). There are various organism lists which vary in quality and are not all equally up to date, as became apparent when working through the selected organisms in the present review.

As presented, this review deals with the relevant import health standards without taking into account the degree to which the respective pathways are actively functioning, which also has a bearing on the level of

[16] As well as for responding to those that do breach the border and for the management of any that become effectively established.

[17] Interceptions of exotic decay fungi in wood, and whether they are still alive and able to fruit and spread, are recorded less frequently, possibly because of difficulties with identification, but there are some examples. For instance, J.W. Gilmour in the Forest Research Institute Annual Report for March, 1957 (p. 54), regarding *Porodaedalea pini* (synonyms: *Phellinus pini*, *Fomes pini*): "*Fomes pini*: The important red ring rot of Douglas fir in North America has again been identified in crates imported from Canada". Most decay fungi are not pathogenic, but there are some that also cause root diseases e.g. certain species of *Armillaria*, *Heterobasidion* and *Phellinidium*. BNZ (2003, 2006) provide lists of fungi and insects identified on material contaminating sea containers.

risk of a new incursion. One would expect greater risk with more trade and some informative (if disparate) more recent import information is provided in Appendices 2-6. On the other hand, a single contaminated import item may be all that is necessary for a new incursion event to occur. Additionally, with time the patterns of importing may change, with a corresponding adjustment to the relative pathway risk. It is helpful to compare biosecurity measures undertaken in this country with those practiced elsewhere in the world. Meurise et al (2018) have reviewed international management and policy procedures and in particular, the global International Standards for Phytosanitary Measures (ISPMs) set by the International Plant Protection Convention (IPPC). These include, for example, ISPM 15, which deals with wood packaging material, ISPM 39 which gives guidelines for other types of wood commodity and ISPM 36 (plants for planting). By international norms, New Zealand is especially active in the biosecurity field.

A recent, comprehensive paper on national biosecurity concluded that the annual rate of detection of new exotic forest pathogens had increased in recent years in New Zealand despite a reduction in related import volume (Sikes et al. 2018). This was in contrast to an opposite trend with pathogens of crop and pasture species. These authors suggested a number of reasons, including the possibility that less emphasis had been placed on pre-border biosecurity relevant to forestry items than with the crop and pasture sectors. They did note, however, that forest pathogens are able to use additional commodity pathways that involve material such as wood packaging, which may account for some of the increase, and suggested that greater biosecurity stringency for this pathway was relatively recent (see below). This does indicate, though, that while it is essential to ensure that the import health standard regulations are such as to plug all pathway gaps, it is at least equally as important that their protocols are effectively and fully administered, a challenge that cannot be underestimated. Recent analyses of interception data from international sources, including some from New Zealand, have revealed just how frequently exotic insect pests are transported by means of different pathways (Meurisse 2018; cf. Wingfield et al. 2015). This raises questions as to numbers that may be missed in obscure corners and crevices, and reaffirms the difficulties of detection by inspection alone (MAF 2000; BNZ 2006).

In a detailed report following an evaluation survey conducted in 2006 it was found that accredited persons were still reporting only 8% of internally contaminated sea containers and even less of those known to be externally contaminated, despite changes to the import health standard as a result of recommendations following an earlier (2001-2002) survey (BNZ 2003, 2006). This shortfall for the sea container pathway was second only to that reported for imported used vehicles (App. 1). The contamination included undocumented wood packaging in one third of the loaded containers (noncompliance). This information is disconcerting and strengthens the importance of maintaining the additional import health standard procedures such as fumigation or chemical treatment and post entry quarantine. As a result of the 2006 sea container survey, recommendations were developed which will have been incorporated into a revised *Sea Containers from all Countries* import health standard, which dates to 2018 (and presumably the import health standard *Wood Packaging Material from all Countries*, which dates to 2009). There is clear benefit in conducting periodic field studies of different import pathways, including pathogens as well as insect pests, in order to quantify the level of effectiveness of the procedures required by the relevant import health standards in meeting their intended purpose.

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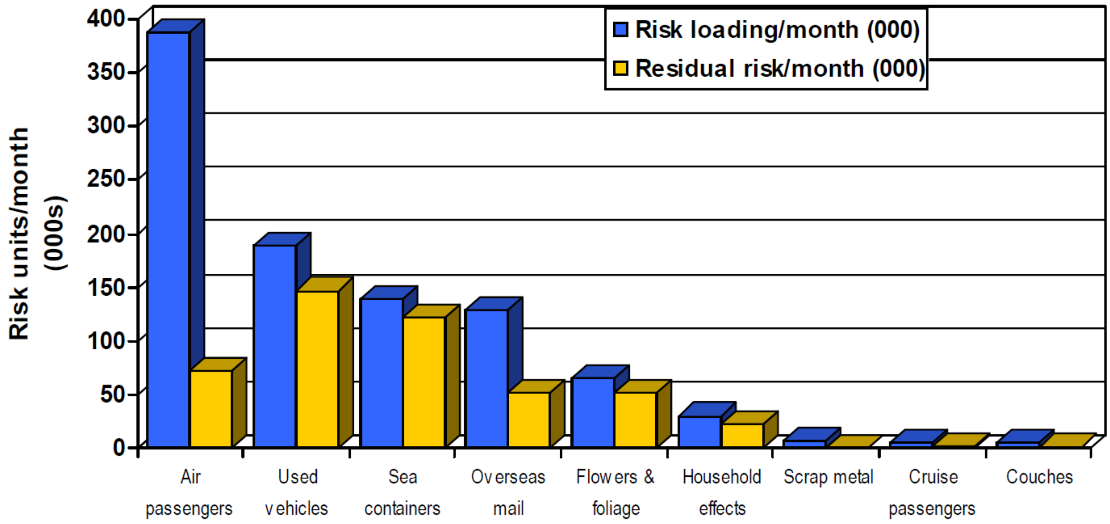
Appendix 1

Risk loading and residual risk by pathway, as in 2006.



Taken from BNZ (2006). Risk loading is the biosecurity risk before, and residual risk that after, risk mitigation measures (risk management) have been taken. Risk units are an estimate determined in order to compare the level of biosecurity risk between pathways, consignments and time. In 2006, measures to reduce risk were judged to be effective for air passengers and international mail, and not very effective for used vehicles and sea containers, which showed the highest absolute levels of risk after biosecurity processing.

Appendix 2

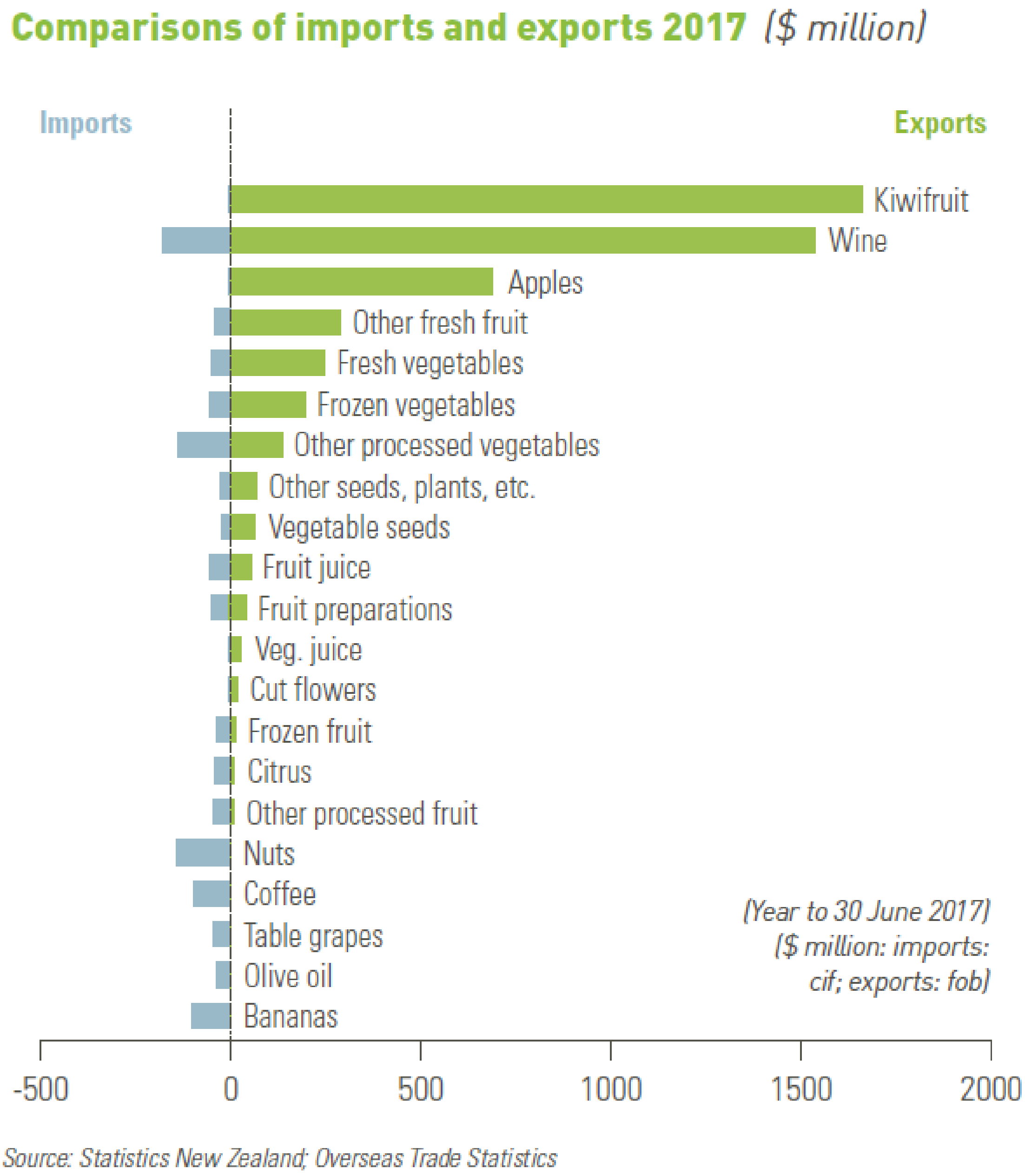
Quantities of forestry products imports, years ended 31 December 2012 to 2017.

Product	2012	2 013	2 014	2 015	2 016	2017 (provisional)
Timber						
Logs and poles (000 m^3)	5	6	6	4	4	5
Sleepers (000 m^3)	3	2	6	3	2	3
Sawn timber - hardwoods (000 m^3)	20	25	22	19	35	29
- softwoods (000 m^3)	16	27	26	50	40	40
Total sawn timber and sleepers (000 m^3)[1]	40	54	54	73	78	72
Total timber (000 m^3)	**45**	**60**	**60**	**77**	**82**	77
Roundwood equivalent (000m^3(r))[2]	93	125	124	165	175	164
Wood pulp						
Chemical (tonnes)	15 690	10 382	41 320	50 634	49 158	48 137
Mechanical (tonnes)	424	386	254	652	608	570
Total wood pulp (tonnes)	**16 114**	**10 767**	**41 574**	**51 285**	**49 766**	48 707
Roundwood equivalent (000m^3(r))[2]	78	52	203	250	242	237
Paper and paperboard						
Newsprint (tonnes)	13 609	18 760	13 612	13 217	9 775	8 049
Other paper and paperboard (tonnes)[3]	398 351	424 034	429 520	424 893	455 510	447 819
Total paper and paperboard (tonnes)	**411 961**	**442 794**	**443 132**	**438 110**	**465 285**	455 868
Roundwood equivalent (000m^3(r))[2]	1 892	2 028	2 037	2 145	2 145	2 104
Panel products[4]	Figures currently being revised.					
Other forest products[5]	Data not available.					
Source						
Statistics New Zealand. Compiled by Sector Data and Analysis, Ministry for Primary Industries.						
Notes						
1 Total sawn timber and sleepers includes hardwoods, softwoods, sleepers and other sawn timber not able to be classified.						
2 Roundwood equivalent (m^3(r)) has been estimated using recognised conversion factors.						
3 Includes all other paper and paperboard imported but not manufactures of paper and paperboard.						
4 Comprising fibreboard, plywood, veneer, particleboard.						
5 Includes continuously shaped wood (mouldings, etc), manufactures of paper and paperboard, wooden furniture and furniture parts, fuelwood and charcoal, waste paper,						
	wood and cork manufactures and woodchips.					

Source: Ministry for Primary Industries. Accessed 26 November, 2018.

Appendix 3

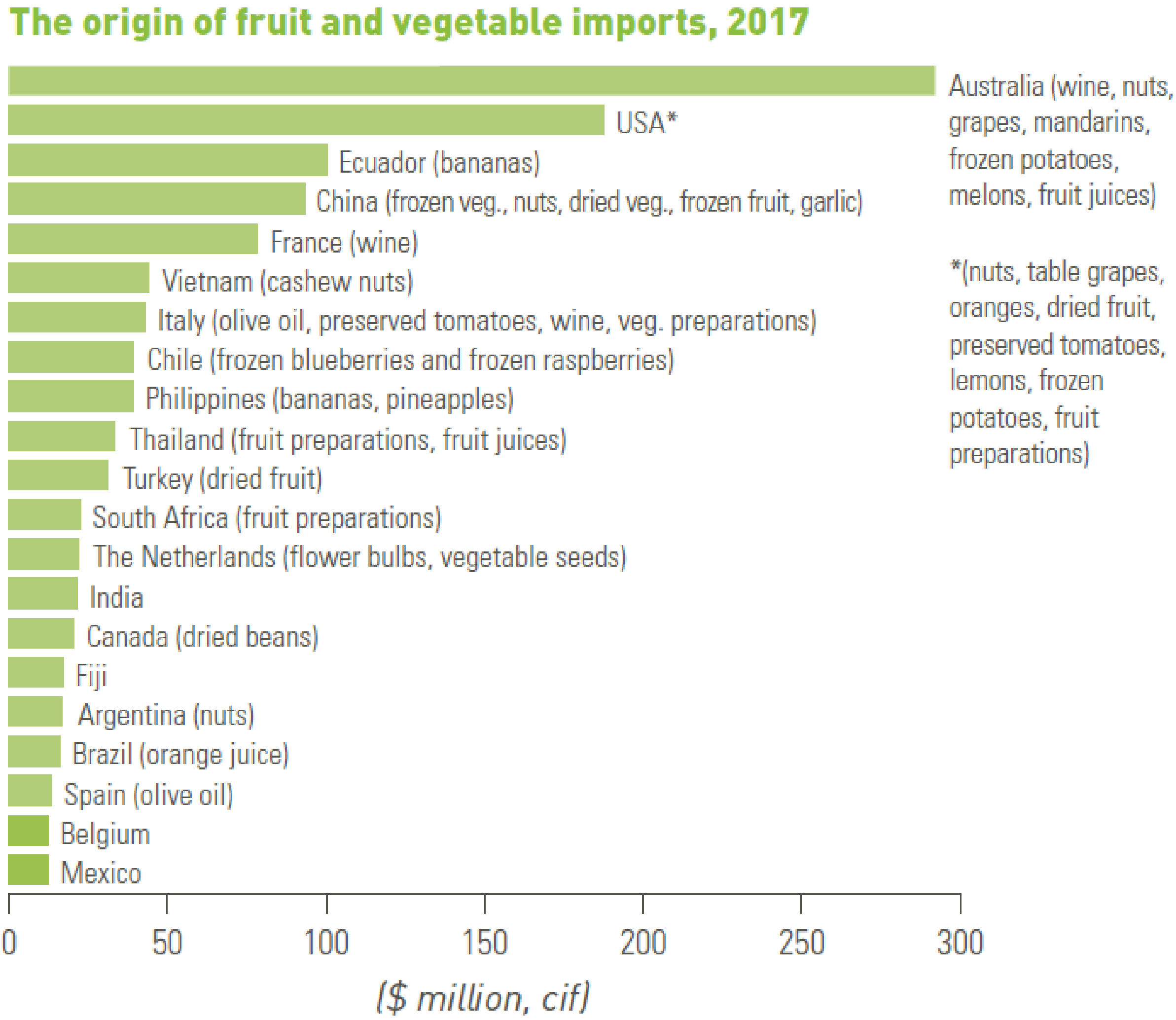
Imports and exports of fruit, vegetables and cut flowers, 2017, by item.



Source: New Zealand Horticulture/Plant and Food Research. Accessed 26 November, 2018.

Appendix 4

Imports of fruit and vegetables, 2017, by origin.



The countries listed in this diagram send us more than $10m (cif) of fruit and vegetables.

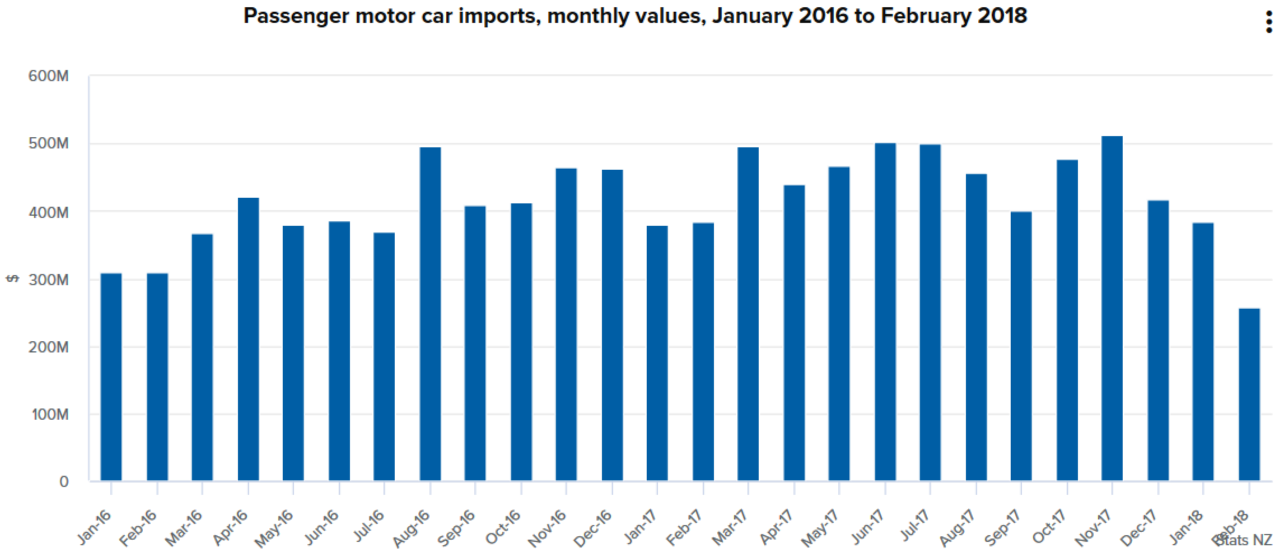
Many of these crops are not grown in New Zealand. Others complement availability gaps in New Zealand's own seasonal production. Products named when import value exceeds $5m.

Source: Statistics New Zealand; Overseas Trade statistics for year ended June 2017.

Source: New Zealand Horticulture/Plant and Food Research. Accessed 26 November, 2018.

Appendix 5

Passenger motor car imports 2016-2018.



Source: Stats NZ**.** Units: $ million. The drop in February, 2018, was caused by a delay in the unloading of vehicles due to the discovery of brown marmorated stink bugs (*Halyomorpha halys*) on the carrying vessels (see MPI).

Appendix 6

Biosecurity risk pathways, 2009-2010.

PATHWAY	RISK ITEM	NUMBER OF ITEMS
International mail	Letters, parcels	36 600 000
Air	Passengers	4 790 000
Shipping	Sea containers	610 000
Imported goods	Used vehicles and machinery	91 300

Source: Stevens et al. 201