Biosecurity risks to New Zealand's plantation forests and the rationale for pathway risk management

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Abstract

Insect pests and pathogens can cause considerable damage to trees. While our planted forests have been affected by comparatively few pests and pathogens so far, many such species occur overseas and their arrival in New Zealand could have devastating consequences. This article provides an overview of the more important insect pests and pathogens of pines and other tree species planted in New Zealand and some of the known overseas threats. While we have a good understanding of the risks posed by many overseas pests and pathogens, experience indicates that there are many threats that are unknown, either because their behaviour in a new environment differs from that in their native range or because they are unknown to science. We therefore conclude that pathway risk management that addresses pests and pathogens in a more general way, irrespective of their identity, is critical to protecting New Zealand's forest biosecurity.

Background

Perhaps the greatest risk for forestry in New Zealand is the threat of invasive pathogens and insect pests and their potential impacts on our forests and access to markets. New Zealand enjoys the status of having comparatively few forest pests and pathogens, but there is a vast number of species in other countries that are known to cause considerable damage to trees including pines, Douglas fir, eucalypts and many other exotic and native tree species that are important in this country. Surveys of insect pests and pathogens associated with pines in their native region in the northern hemisphere and in other countries where pines are cultivated have revealed hundreds of species (see below) of which most are not present in New Zealand.

International trade has been growing at a phenomenal rate in New Zealand and worldwide, and never before has there been a time when as many goods arrive at our shores as today. An unwanted by-product of international trade is the opportunity for pests and pathogens to be transported to other countries where they have previously not occurred. This has resulted in the establishment of thousands of pests and pathogens outside their native range. In the United States alone more than 450 exotic insects and many pathogens attacking trees have been detected in the last 150 years, of which some cause considerable damage (Aukema et al., 2010) or, in the worst case, have huge economic impacts and cause the near extinction of their host tree species (Aukema et al., 2011).

There have been some incursions of potential high-impact species in New Zealand, but the arrival and establishment rate of such invaders appears to be lower in this country than elsewhere. This is likely to be the result of New Zealand's comparatively stringent border biosecurity policy. Nevertheless, the threat of biological invasions remains a major concern in New Zealand, and as researchers, foresters and policy-makers we need to do our utmost to reduce the arrival and establishment of unwanted insect pests and pathogens further.

The objectives of this paper are to:

- provide an overview of insect pests and pathogens associated with pines (and some other tree species) that are present in New Zealand or found overseas
- clarify the distinction between managing pests versus pathways
- provide an overview of approaches and methods to prevent and manage invasions
- and draw conclusions about the overall risk to New Zealand's forests from overseas pests and pathogens.

Risks and threats

Scion has a list (as at June 2014) of over 1,000 pests and pathogens recorded on conifers overseas, of which over 600 have been recorded on *Pinus radiata*. This is a very large number of known threats, even before considering the threats to other tree species. However, few economically important exotic forest pests have established in New Zealand so far. Between the beginning of plantation forestry in the late 19th century and forestry quarantine inspections starting in 1948, only a few economically important pests were detected.

After forestry quarantine inspections at ports and forest health surveillance had begun, serious pests and pathogens continued to establish infrequently as shown in Table 1. Overall, 292 new insect pests and fungi have been recorded on woody plants in New Zealand from 1950 to 2014 (Carter 1989; Unpublished Scion records). However, most of these are of no significance because they cause little or no damage, and some could be native to New Zealand.

Table 1: Economically important exotic forest and tree pests and pathogens established in NZ

Pest	Year recorded	Type	Damage	Main host	Likely origin
Sirex noctilio	1900	Wood wasp	Occasional tree death, quarantine pest	*Pinus radiata*	Eurasia
Diplodia pinea	1900	Stem pathogen	Branch/crown dieback	*Pinus radiata*	North America
Cyclaneusma spp.	1900	Needle pathogen	Defoliation	*Pinus radiata*	North America
Seiridium cardinale	1900	Stem pathogen	Branch/crown dieback	*Cupressus macrocarpa*	North America
Paropsis charybdis	1916	Leaf beetle	Defoliation	*Eucalyptus nitens*	Australia
Hylastes ater	1929	Bark beetle	Occasional seedling death, quarantine pest	*Pinus radiata*	Europe
Phaeocryptopus gaeumannii	1959	Needle pathogen	Defoliation	*Pseudotsuga menziesii*	North America
Colletotrichum acutatum f.sp. pineum	1963	Shoot pathogen	Top dieback	*Pinus radiata*	North America
Arhopalus ferus	1963	Wood and bark borer (beetle)	Quarantine pest	*Pinus radiata*	Europe
Dothistroma septosporum	1964	Needle pathogen	Defoliation	*Pinus radiata*	North America
Hylurgus ligniperda	1974	Bark beetle	Quarantine pest	*Pinus radiata*	Europe
Ophiostoma novo-ulmi	1989	Stem pathogen	Tree death – Dutch elm disease	*Ulmus spp*	Europe
Scolytus multistriatus	1989	Bark beetle	Vector of *O. novo-ulmi*	*Ulmus spp*	Europe
Neonectria fuckeliana	1996	Stem pathogen	Stem malformation	*Pinus radiata*	North America
Orgyia thyellina (eradicated)	1996	Moth	Defoliation	*Many*	Asia
Teia anartoides (eradicated)	1999	Moth	Defoliation	*Many*	Asia
Phytophthora pluvialis	2008	Needle pathogen	Defoliation	*Pinus radiata*	North America

Known threats

The list of known insect pests and pathogens that could threaten plantation forests in New Zealand, but are not yet present in this country, is much too long to present here. However, the following are examples of species that could cause serious damage to plantation trees if they established here.

Pitch canker disease, caused by *Fusarium circinatum*, is probably native to Central America from where it has spread to the United States, Mexico, South Africa, Spain, Italy, France, Japan and Chile. In the United States it has caused considerable losses in several pine species, including highly susceptible *Pinus radiata*. In trees of any age it can affect most structures. Tree crowns can show dieback and multiple infections may cause tree death. Climatic conditions in many areas in New Zealand are suitable for the establishment of *F. circinatum*, but Ganley (2007) concluded that with the absence of a vector and cooler conditions in many forest growing regions, pitch canker may not be the serious threat some anticipated.

Western gall rust caused by *Endocronartium harknessii* leads to galls that girdle pine branches or stems, resulting in death or growth loss as shown in the first photo. It is worst in highly managed, young forests because of its life-cycle and the susceptibility of young host tissue. In an unthinned *Pinus contorta* stand in Alberta, it caused 30 per cent mortality. Western gall rust has not been recorded outside its natural range, and Ramsfield et al. (2007) concluded that although its threat (potential impact) was high, the risk (likelihood of establishment) of it reaching New Zealand and establishing here was low.

Phytophthora pinifolia causes the foliage disease of *Pinus radiata* known as Daño Foliar del Pino (DFP) in Chile. Its origin is unknown and it was first recorded in 2003 from a small area. The disease is capable of causing severe defoliation in areas prone to mist and low sunlight as shown in the second photo. Sometimes repeated defoliation has weakened trees so much that they have died from secondary attack by pathogens such as *Diplodia pinea*. In addition, some countries imposed trade restrictions on Chilean forest produce following the discovery of this *P. pinifolia* (see also

Pawson et al., this issue). Although DFP has not been a serious problem in Chile since 2006, because of the replacement of *Pinus radiata* with *Eucalyptus* in susceptible areas and unfavourable weather for disease development, *Phytophthora pinifolia* is considered a significant threat and risk to New Zealand forestry.

Armillaria species are decay fungi of woody debris, but they also cause root disease in living trees. The degree of pathogenicity depends on the species of *Armillaria* and the host. *Armillaria* species already present in New Zealand have been responsible for growth loss through root damage. Other Armillaria species in Europe, North America and Asia, especially *A. ostoyae* and *A. mellea*, can cause significant mortality of conifers. In Australia, *A. luteobubalina* is an important primary pathogen in eucalypt forests. The genus is capable of establishing in new areas, for instance, *A. mellea* and *A. gallica* have been found causing tree disease in South Africa where they were probably introduced with potted plants from Europe during colonisation (Coetzee et al., 2003).

Nun moth, *Lymantria monacha*, is a serious defoliator of conifers as shown in the third photo. The larvae are voracious feeders and have defoliated and killed large areas of forest in Poland. The preferred hosts are *Picea abies* and *Pinus sylvestris*, but Withers and Keena (2001) showed that *Pinus radiata* can be attacked. *Lymantria monacha* has been intercepted on used vehicles at New Zealand ports (Armstrong et al., 2003), and there should be no climatic barrier to its establishment in this country. This insect, along with other *Lymantria* species, is a serious risk and threat to New Zealand forestry.

The bark beetle, *Ips grandicollis*, attacks the vascular tissue of pines and transmits blue-stain fungi. Recently felled trees or slash are preferred, but apparently healthy trees are also attacked, as shown in the fourth photo, both in its native area in North America and in Australia where it was detected in 1943. In Australia, many apparently healthy *P. radiata* trees are killed regularly in mass attacks (Neumann & Morey, 1984). Other *Ips* species have established in parts of Europe and Asia. *Ips grandicollis* and related species are considered a significant risk and threat.

Mountain pine beetle, *Dendroctonus ponderosae*, is one of the most destructive insects in the pine forests of western North America (Creeden et al., 2014). Severe economic damage is most common in *Pinus contorta*, and millions of trees may be killed each year. At least 13 other pine species are attacked by *D. ponderosae* in its native range. *Pinus radiata* is likely to be a suitable host. *Dendroctonus* species have been intercepted alive at New Zealand ports, and some are known invaders. However, *D. ponderosae* is probably a weak invader, and therefore it is considered a significant threat but a low risk.

The European pine shoot moth, *Rhyaciona buoliana*, is considered the most destructive pest of *P. radiata* plantations in Chile. It is native to Eurasia but has invaded parts of the United States and Canada and was also introduced into Argentina, Uruguay and Chile. The insect affects height growth of young pines and causes stem deformation and multiple leaders. Although it represents a significant threat to pines in New Zealand, its establishment is unlikely because of this country's regulations on the importation of live pine material, which is considered the main pathway.

Unknown threats and the fallacy of pest lists

A greater risk to New Zealand's forests may be posed by the 'known unknowns' and 'unknown unknowns'. Carter (1989) suggested that based on historical records, for every two known threats there is one unknown

Western gall rust causing stem deformation on *Pinus contorta var. latifolia* in Canada

A young radiata pine tree in Chile affected by DFP (caused by *Phytophthora pinifolia*), with a severely affected older stand in the background

equally likely to be introduced. The last two serious established pathogens of *P. radiata*, *Neonectria fuckeliana* (causing nectria flute canker) and *Phytophthora pluvialis* (Red Needle Cast) would never have been on any New Zealand list of unwanted organisms.

Prior to its arrival in this country, *N. fuckeliana* was known as a wound invading fungus on spruce and fir. It had never been recorded as a pest of pines, let alone *P. radiata*. *Phytophthora pluvialis* was even more obscure. In 2008, it was a completely new undescribed organism and it was later also found in Oregon in the United States. There are several lessons to be learnt. First, while it is useful to select some key pest threats and have contingencies for them, reliance on pest lists is dangerous. Secondly, the 'unknown unknowns' may be even more damaging than the expected or even unexpected species because their behaviour is more unpredictable. Unknowns may therefore pose a greater threat to market access because of the uncertainty they provide to trading partners.

Pathways

Insect pests and pathogens can arrive in New Zealand by a number of pathways that are associated with human activities, primarily involving international trade and overseas travel of people. Natural dispersal of species is thought to be a comparatively rare event, but some organisms such as fungal spores can be blown across the sea over long distances by strong winds. A well-documented case of this is the poplar rust pathogens (*Melampsora* species), which arrived in New Zealand, apparently carried by the wind from Eastern Australia some 2,000 kilometres away (Close et al., 1978). Subsequently poplar rust caused considerable damage in New Zealand (Spiers, 1989). However, based on border interception records in New Zealand and elsewhere, most pathogens and insect pests were evidently introduced by sea freight, air freight and in association with passengers and their baggage (for example, Ridley et al., 2000; Brockerhoff et al., 2006; McCullough et al., 2006).

The main pathways for forest pests and pathogens are thought to be imports of live plant material, wooden materials (especially wood packaging), and contaminants of used cars and machinery, air and sea containers, and ships themselves (Ridley et al., 2000; Liebhold et al., 2012). Wood packaging such as pallets, dunnage and case wood is thought to be responsible for the unwanted establishment of important tree pests such as pine bark beetles, the burnt pine longhorn, and the sirex woodwasp, respectively, which are well-known forest pests in New Zealand. Elsewhere the introduction of highly damaging species, such as the emerald ash borer which is killing most if not all ash trees it encounters in the Eastern United States, were linked to wood packaging materials (Poland & McCullough, 2006).

Shipping containers have taken international trade by storm, and today most products are shipped using containers (Levinson, 2008). They are practical and efficient for transporting goods, but shipping containers

Defoliation of Scots pine in Germany caused by the caterpillar of nun moth (*Lymantria monacha*) – see inset. It is also capable of defoliating radiata pine and other conifers. Source: Hannes Lemme for main photo and Stanislaw Kinelski for inset, both www.bugwood.org

are also an easy mode of transport for all kinds of stowaways. Approximately 500,000 containers arrive annually in New Zealand. A survey by the Ministry of Agriculture and Forestry (MAF, 2003) found that approximately 17 per cent of shipping containers that were surveyed contained biosecurity risk cargo, of which many required cargo treatments such as fumigation or incineration. Some kind of contamination, mostly on the inside but also on the outside of shipping containers, affected over 20 per cent of containers (MAF, 2003).

An earlier assessment by Ridley et al. (2000) documented various items of biosecurity concern associated with containers including scale insects, moths, plant material with aphid damage, and egg masses of several invertebrate species, as well as plant debris with sporulating fungi (for example, *Fusarium*) and *Phytophthora* species which may represent serious plant pathogens.

Air containers also appear to be a significant risk pathway. Many new establishments near Auckland Airport point to this.

Used vehicle and machinery imports are another important pathway for the potential introduction of unwanted species. One of the best known cases is the frequent arrival of egg masses of gypsy moth and other tussock moths on used cars imported from North-East Asia (Armstrong et al., 2003). These species are ferocious defoliators, can cause considerable damage and even tree mortality, and they are proven invaders.

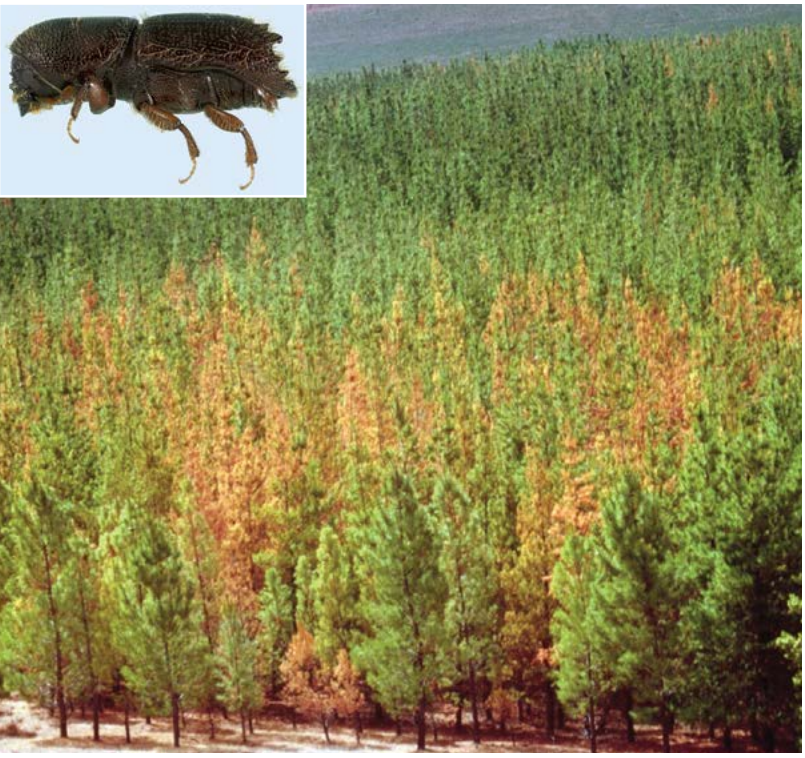
Finally, the live plant trade is known to be particularly risky. This is because insect pests and pathogens are imported on plants that are destined for propagation, not consumption, which implies that the plants are kept alive and harsh pesticides or other treatments cannot be applied. Furthermore, undetected infestations can easily be spread with host plants, which makes potential incursion responses difficult. In

the United States it has been estimated that imported live plants were responsible for almost 70 per cent of introductions of damaging forest insects and pathogens in the last 150 years (Liebhold et al., 2012).

Pathway risk management

Managing pathway risks rather than focusing on individual pest and pathogen species has many advantages. While biosecurity experts all know about particular unwanted pest and pathogen species that we want to keep out of the country, it is not really feasible to predict which species are the next to arrive that should deserve our attention to prevent their introduction. So-called pest lists which have been compiled for the forestry and other sectors have a purpose, but managing entire pathways has the benefit of addressing many potential invaders, not only those that we know about. This is highly relevant because, as explained above, a large proportion of the invasive insect pests and pathogens that were detected in New Zealand in the past were not expected or even known to science.

Pathway risk management has long been practised by New Zealand's border biosecurity agency, the Ministry for Primary Industries, and its predecessors. Along with a range of programmes targeted at individual pests that are known to be a threat, a number of approaches are being used that reduce invasive species threats for entire pathways. An excellent example is the early adoption of the International Standard for Phytosanitary Treatments No. 15, known as ISPM 15 (IPPC, 2011). This standard regulates treatments of wood packaging materials, typically by heat or fumigation, to avoid the presence of live pests that may occur in wood or bark. ISPM 15 has been implemented by 78 countries, of which New Zealand was the first to do so. The treatments are effective against a wide range of insect pests (Haack et al., 2014) and even some pathogens (Ramsfield et al., 2010), and the policy appears to be useful. However, a small proportion of wood packaging materials with live insects remains (Haack et al., 2014).



Radiata pine stand in Australia with trees killed by the eastern five-spined ips bark beetle (*Ips grandicollis*) shown in inset. Source: Dennis Haugen for main photo and Natasha Wright, Florida Department of Agriculture and Consumer Services, for inset, both www.bugwood.org

Another pathway that is well-managed in New Zealand is the live plant trade, which is considered particularly risky as mentioned above. While it is acceptable in most countries to import large quantities of a wide range of plants, including for wholesale purposes, New Zealand has implemented a stringent system of post-entry quarantine, whereby live plants undergo a period of isolation in a quarantine facility or an otherwise safe area, depending on the expected risk associated with particular plants (MAF 2010).

Worldwide, only New Zealand and Australia have implemented such a safe system. It proved its worth when a batch of Douglas fir seedlings was found to be infected with the pitch canker pathogen. Because the seedlings were contained in a quarantine facility when the infection was detected, the pathogen was not released into the wild (Ormsby 2004). Furthermore, the discovery led to new, tighter regulations.

Pathway risk management for sea containers is much more difficult, and probably not as effective, because of the sheer volume of containers entering the country. Furthermore, measures that interfere with the processing and on-shipping of containers are problematic because of concerns about interference with trade. While some containers are inspected thoroughly (for example MAF, 2003), it is impossible to do this comprehensively. The utility of such inspections is therefore more to provide information about pathway risks and to act as a deterrent against negligence with regard to pest and pathogen infestation of shipments.

Conclusions

New Zealand's stringent border biosecurity and forest biosecurity systems have been relatively successful, despite the large increase in international trade. However, there is no reason for complacency. Forestry is by its nature at significant risk from biotic threats. Once planted, 30 or more years pass until trees are harvested, and switching tree species because of an emerging pest or disease problem is not as easy as with annual crops. There are numerous known pests and diseases that are not present in New Zealand, and we can do our best to manage and anticipate these threats. However, many examples of pests and diseases appearing that were previously unknown highlight that it is critical to adopt measures that are effective at managing pathways to prevent the arrival and establishment of such unwanted and often highly damaging species.

While most pathways are well-managed, research could assist policy-makers and regulators make further improvements. Robust data on the infestation rates and risks posed by all pathways would help target inspections and other mitigation measures more efficiently and effectively.

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