Biosecurity Risk to New Zealand Forestry

D.A. Herron, L.S. Bulman, R. Turner, …

Report information sheet

Report title	Biosecurity Risk to New Zealand Forestry
Authors	D.A. Herron, L.S. Bulman, R. Turner
Client	Forest Growers Research
Client contract number	0000-00
MBIE contract number	
PAD output number	
Signed off by	
Date	28 May 2020
Confidentiality requirement	Confidential (for client use only)
Intellectual property	
Disclaimer	The information and opinions provided in the Report have been prepared for the Client and its specified purposes. Accordingly, any person other than the Client uses the information and opinions in this report entirely at its own risk. The Report has been provided in good faith and on the basis that reasonable endeavours have been made to be accurate and not misleading and to exercise reasonable care, skill and judgment in providing such information and opinions. Neither Scion, nor any of its employees, officers, contractors, agents or other persons acting on its behalf or under its control accepts any responsibility or liability in respect of any information or opinions provided in this Report.

Cover photo: Pines from the Basque Country believed to be affected by *Lecanosticta acicola*. November 2018, Photo credit: Basoa.

Published by: Scion, 49 Sala Street, Private Bag 3020, Rotorua 3046, New Zealand. www.scionresearch.com

Executive summary

The problem

The Forest Growers Science and Innovation Strategy and the Forest Biosecurity Committee Forest Biosecurity Strategy to 2030 both recognise that the NZ forest industry is highly reliant on radiata pine and to a lesser extent, Douglas-fir. The biosecurity risk associated with monoculture[1] forestry in New Zland has not been evaluated, recently. This has resulted in uncertainty around the need for risk mitigations such as species diversification and the extent and timing of adoption of those mitigations.

Client initiatives

The industry wants an evaluation of the current biosecurity risk facing the radiata pine and Douglas-fir estates. In particular, whether the risk is increasing compared with previous estimates.

This project

This project comprises three main parts:

1. A collation and review of previous risk assessments that have been undertaken.

2. An assessment of key threats to our radiata pine forest estate.

3. An overall assessment as to whether the level of risk has increased to the extent that further mitigating steps need to be taken by the sector.

A second project or phase 2 will cover an in depth look at biosecurity risk mitigating strategies that could be put in place along with the relative merits/effectiveness and practicality of these mitigations. That may include a review of possible alternatives, genetic resources existing in NZ and their security, seed availability and key information/capability constraints that would need to be overcome, as well as technologies to reduce introductions and assist with eradication.

Key results

It is well established that the main pathway for the spread of invasive pests and pathogens around the world is through human-mediated activities, such as trade and travel. Over the last 100 years, we have seen an increase in the number of goods and people moving around the world and with it the increased movement of invasive pests and pathogens. As the world takes stock and decides how to move on from the SARS-CoV-2 (COVID-19) pandemic, we will likely see some changes to how we trade and the amount of trade over the next few years. This could slow the movement of pests and pathogens, at least for the short term.

The list of potential pest and pathogens that could invade and cause damage to our radiata and Douglas-fir stands is long. It is also incomplete because there are many undiscovered species or species that have never been seen on these hosts before but could cause disease if they were ever introduced. For New Zealand, it appears that the number of introduced pests and pathogens establishing is stabilising despite increased trade. There are a number of reasons for this, including a pest/pathogen's inability to survive the journey and the current biosecurity measures in place. Our biosecurity protocols are likely to keep pace with the increase in trade; however, pathway management will be critical for the detection, prevention and management of a wide variety of invasive pests and pathogens.

[1] Monoculture – plantings of one species in a forest

A number of new technologies are being explored that will improve surveillance, pathogen detection and management, including the use of modelling, pathogen detectors and targeted spraying technologies. In addition to this, forest diversification can add value to further reduce risk but one needs to look at the cost to benefit. Monocultures were presumed to be at risk from invasion because of their diminished genetic diversity compared with forestry comprised of multiple species. The risks have been debated; however, there was little evidence to support the idea. Over the last 60 years, New Zealand has only seen four high impact pathogens, and no high impact pests, establish in radiata pine or Douglas-fir plantations. None have been devastating. Today, we have more data from other countries that demonstrate the benefits of mixed forests[1] over monocultures when it comes to risk from invasions. These studies are quite specific with regards to the species, pathogen and pest and regions and one must be cautious about making any generalisations.

Implications of results for the client

Switching from monocultures to mixed forests or stands has many benefits, which will need to be explored before any formal decision is made. Fortunately, with our current biosecurity measures, the changes in trade trends and the exploration and implementation of improved technologies for biosecurity, there is time to investigate whether forest diversification makes sense. Forest diversification may involve replacement of radiata pine or Douglas-fir with alternative species, deployment of mixed species (with or without the current two main species) in stands or forests, and a broadening of the gene pool within one species. One form of diversification may be more feasible or attractive to growers than another. If current biosecurity measures, including pathway management are being continually updated, we could limit the risk associated with the ever increasing list of pest and pathogen threats. While we are able to limit the invasion of many of these pests and pathogens already, some may slip through and forest diversification may be an additional strategy that could further safeguard our estates.

Further work

If mixed forests or stands are considered from a forest management perspective, we would need to look at a number of factors:

1. Which tree species could we use as an alternative species? This would depend on the industry's needs (wood properties, growth, form, etc.), their suitability to various sites, and their susceptibility to pests and pathogens already in New Zealand.
2. Where can germplasm for breeding and massive propagation be sourced?
3. Where and how to deploy these species – alternate species in monoculture or in mixed stands?
4. Will all our stands be mixed or can we look at mixed stands as buffers to pathways?

An adoption of this strategy will require planning and a number of pilot studies to answer some of these questions. Models are also useful to help test certain scenarios and make predictions to save time, money and effort. To save time, we should explore the use of alternate species to supplement or replace radiata while improvements are made to our current biosecurity frameworks.

Diversification is only one approach to mitigate biosecurity risk. Technologies to reduce pest establishment and reduce impact is another. Both will be described and evaluated in the phase 2 report.

[1] Mixed forests – a mosaic of single species stands mixed with stands of different species within a forest. Mixed stands – single stands comprising more than one species.

Biosecurity Threats to New Zealand Forestry

Table of contents

Introduction

Risk is a word that is used in different ways. It is a noun “Travelling to a country with malaria without taking precautions is a risk”, or “pitch canker poses a risk to radiata pine”; and a verb “They risked their health by travelling…”, or “importing pine seed from California risks introducing *Fusarium circinatum*”. The formal definition of risk is exposure to danger, harm or loss. We take “biosecurity risk” in this report to be the likelihood of forest pests or pathogens entering and establishing in New Zealand and the potential for them to cause damage and loss.

Pinus radiata and *Pseudotsuga menziesii* (Douglas-fir) were first introduced to New Zealand over 170 years ago and have been planted for forestry purposes for over 100 years. Over that time a large number of exotic insects and fungi have been recorded on those species, but few have caused serious problems. There are a range of factors that influence the frequency of pest and pathogen arrivals and establishments. Key factors are:

1. pathways by which pests enter,
2. suitability of conditions for establishment, and
3. interventions to avoid pest establishment.

Specifically, the amount, origin and composition of cargo or packaging; number of visitors and immigrants; abundance of suitable hosts on which to establish, environmental conditions and biosecurity interventions all affect the number and type of new forest pest and pathogens.

Those influences are changing due to globalisation, climate change, and policy. This review will examine previous risk assessments, trends and current threats, and from that evaluate whether the biosecurity risk to radiata pine and Douglas-fir plantations is stable or likely to increase or decrease. The risk evaluation will help the forest industry determine the need for diversification and the pros and cons of doing so.

Previous risk assessments

There is a very large body of literature on diversification and its effect on risk. This section is confined largely to reviews carried out on New Zealand forestry because they are more relevant to the New Zealand situation of well-managed, fast growing, largely healthy production forests established in an isolated country. It also discusses diversification to contrast risk to monoculture forestry with biosecurity risk to a mixed species forestry.

Several assessments on the risk to forest monocultures in New Zealand were carried out in the 1980s. Bain (1981) and Chou (1981) both concluded that monocultures were commonly considered more risky than mixed species stands or natural forests, but there were few examples in the literature to support that view. They stated that serious diseases and insect problems occurred in mixed forests, while there was no clear evidence that outbreaks in monocultures were a result of lack of species diversity.

Sweet and Burdon (1983) agreed that New Zealand had a monoculture of radiata pine grown over large areas (over 800,000 ha at that time) in even-aged stands. They also pointed out that there was a widely accepted adverse view of monocultures because it was thought that risk from pests, diseases, and abiotic disturbance was incurred by deploying an exotic single species planted over consecutive rotations in even aged stands. However, they contended risk was overstated and while risk existed, it was not necessarily higher than that of native forests or forests of mixed species or uneven-aged stands. This counter view was taken because of a general lack of distinction between monocultures and clonal forests, lack of widespread damage in New Zealand forest monocultures to date, and radiata pine's low vulnerability if correctly sited. A move away from radiata pine to increased diversity may incur cost and create new risk. They concluded that the best approach was to maintain a genetically diverse radiata pine estate but have alternative species research ready and available for production if an extreme event occurred.

Sweet (1989) reviewed the health of New Zealand's exotic radiata monoculture between the 1950s and 1980s. Based on his observations of needle retention, comparisons of radiata in New Zealand and it native range as well as in Europe where pollution was higher, it was found that New Zealand stands were unhealthy. Infections from pests and pathogens, climate change, pollution, poor site-species matching has and continues to reduce the health of these stands. Furthermore, unhealthy stands are more vulnerable to other infections that take advantage of reduced resistance/stress, such as *Armillaria* and *Dothistroma*. Sweet agreed that monocultures – with a broad genetic base – were at no greater risk than mixed species; however, considering the continued decline of radiata pine, he suggested that finding alternate species to replace radiata should be considered for the long-term.

~~Gadgil and Bain (1999) compa~~red the relative vulnerability of plantation forests (within and outside of their natural range) and natural forests to biotic and abiotic stress. They argued that native forests have a larger component of pests and pathogens than exotic tree species, and that both native and exotic forests are vulnerable to new pests and pathogens. Table 1 (updated from Gadgil and Bain, 1999) shows a larger list of pests[1] on radiata pine and Douglas-fir growing in their native areas compared with those species planted in countries outside their native range. For example, radiata pine growing in its native range in California suffers from 10 native pests and three exotic pests, by contrast radiata pine in New Zealand suffers from three native pests and five exotic pests. That trend is even more pronounced for Douglas-fir. They also cited six examples concerning yield loss in exotic plantations where five of those were thought to be a result of poor matching of tree species to site.

[1] Pests and pathogens

Table 1 – Significant indigenous and exotic pests of radiata pine and Douglas-fir from indigenous and exotic geographic areas (updated, after Gadgil and Bain, 1999

		As an Indigenous Species			As an Exotic Species	
	Geographic Area	**Indigenous**	**Exotic**	**Geographic Area**	**Indigenous**	**Exotic**
Pinus radiata	**California**	*Coleosporium madiae* *Cronartium comptoniae* *Cyclaneusma minus* *Endocronartium harknessii* *Arceuthobium campylopodum* *Armillaria* spp. *Heterobasidion annosum* *Toumeyella pinicola* *Ips paraconfusus* *Phytophthora pluvialis*	*Dothistroma septosporum* *Fusarium circinatum* *Rhyacionia frustrana*	**New Zealand** **Chile**	*Armillaria* spp. *Pseudocoremia sauvis* *Phytophthora kernoviae*	*Dothistroma septosporum* *Cyclaneusma minus* *Diplodia pinea* *Neonectria fuckeliana* *P. pluvialis* *Sirex noctilio* *D. septosporum* *D. pinea* *N. fuckeliana* *Rhyacionia buoliana*
		Indigenous	**Exotic**		**Indigenous**	**Exotic**
Pseudotsuga menziesii	**NW North America**	*Phaeocryptopus gaeumannii* *Rhabdocline pseudotsugae* *Arceuthobium douglasii* *Phacidiopycnis pseudotsugae* *Armillaria* spp *Heterobasidion annosum* *Phellinus weirii* *P. pluvialis* *Leptographium wageneri* *Dioryctria abietivorella* *Choristoneura occidentalis* *Orygia pseudotsugata* *Buprestis aurulenta* *Dendroctonus pseudotsugae*	*Fusarium circinatum*	**New Zealand**	*P. sauvis*	*P. gaeumannii* *P. pseudotsugae* *P. pluvialis*

More recently, MacPherson et al. 2017 discussed species diversification as a strategy to reduce the impact of pests and pathogens on plantations. They suggested diversification in production forests is an “insurance hypothesis”. Growing more than one species spreads risk (Loreau et al., 2001, Pautasso et al., 2005) because many new pests or pathogens only attack a single host species or genus. Several studies found that increased species diversity reduced pest/pathogen damage: modelling studies showed *Heterobasidion annosum* damage was lower when *Picea* stands were mixed with *Pinus* (Thor et al., 2005); *Armillaria* spread reduced with increased tree diversity (Gerlach et al. 1997); greater species diversity reduced disease risk of *Phytophthora ramorum* in California (Haas et al. 2011); field experiments showed that tree diversity reduced disease in *Tilia cordata* and *Quercus petraea* (Hantsch et al. 2014); and Guyot et al. (2016) in a multi country study showed pest resistance increased with tree species diversity.

Brockerhoff et al. (2017) stated meta-analyses demonstrated that damage by defoliating insects was more severe in pure stands than in mixed stands. However, this was complicated because most stand scale studies involved native insects. Tree species composition appeared to be more important than diversity *per se*, i.e. species with very dissimilar characteristics provided greater resistance than stands with more diverse but similar species.

Liu et al. (2018) cited studies that showed monocultures provided ideal habitat for pests and pathogens, due to their uniform genetics and closeness of tree species, resulting in rapid population increase and spread (Hartley, 2002; Bowyer, 2006; Carnus et al., 2006; Brockerhoff et al., 2013; Moghaddam, 2014), whereas mixed plantations were more resistant to damage from storms, insects or diseases (Hartley, 2002; Nichols et al., 2006; Griess and Knoke, 2011).

Summary

Early studies in New Zealand concluded that the risk from monoculture forestry was considered by many to be high; however, there was little evidence to support that view. Also, over the last 60+ years, very few damaging pests and pathogens have caused any serious damage. More recent overseas studies concluded that monocultures are more prone to pest attack than mixed stands, however this is largely determined by the species, their use and the pests and pathogens they are likely to encounter.

Threats

There are over 1,000 overseas conifer pests of which over 600 have been recorded on radiata pine (Scion internal records). Several attempts have been made to determine the most serious of those pest threats to New Zealand plantation forestry. Table 2 lists a selection of what are considered to be high impact pests. This selection is made difficult by several reasons.

Firstly, selection is subjective. One group of pathologists and entomologists will inevitably select a different list than another group.

Secondly, it is difficult to predict how a pest will behave in its new environment. Some seemingly benign organisms such as *Neonectria fuckeliana* caused considerable initial damage before a successful control was developed.

Thirdly, the pest may be new to science, for example *Phytophthora pluvialis*, the cause of red needle cast. Carter (1989) estimated that for every two known pests there was one equally likely to establish. That could be a result of the pest being new to science or because it has never been introduced to radiata pine or Douglas-fir before.

Finally, risk is determined by the potential for damage plus the pest's ability to survive the journey and establish. For instance, the pine shoot moth, *Rhyacionia buoliana*, may cause serious damage to radiata pine in New Zealand but it is highly unlikely that it will ever establish because the pathways by which it could be transported to New Zealand (stems or shoots of live pine plants) are well controlled. It is therefore a significant threat but an extremely low risk.

This is further complicated by the fact that we live in a constantly changing world with regards to land cover, land use, climate change, etc. It is difficult to predict how pests will adapt and change, especially under climate change. Generally, it seems that a changing climate is going to make it easier for some pests to access environments that were not considered a risk, previously. This means that the status of each and every pest would need to be re-evaluated, over time, when information is available, such as new outbreaks, host shifts, range shifts, etc.

Details on potential high impact pests and pathogens are provided in Appendix A.

Table 2 – A selection of high impact pests drawn from known threats

Type*	Pest	Type, Potential damage	Host
P	*Armillaria* species	Root disease, mortality	*P. radiata*
P	*Cronartium coleosporioides*	Stem rust, mortality, malformation	*P. radiata*
P	*Cronartium comptoniae*	Stem rust, mortality, malformation	*P. radiata*
P	*Cronartium quercuum*	Stem rust, mortality, malformation	*P. radiata*
P	*Cronartium quercuum* f. sp. *fusiforme*	Stem rust, mortality, malformation	*P. radiata*
P	*Elytroderma deformans*	Witches broom, defoliation	*P. radiata*
P	*Endocronartium harknessii*	Stem rust, mortality, malformation	*P. radiata*
P	*Endocronartium pini*	Stem rust, mortality, malformation	*P. radiata*
P	*Fusarium circinatum*	Stem bleeding, dieback, defoliation, mortality	*P. radiata*
P	*Heterobasidion annosum* sensu stricto	Root and butt rot, mortality	*P. radiata,* D.-fir
P	*Lecanosticta acicola*	Needle blight, defoliation	*P. radiata*
P	*Leptographium wageneri*	Root and butt rot, mortality	*P. radiata*
P	*Lophodermium seditiosum*	Needlecast, defoliation	*P. radiata*
P	*Mycosphaerella dearnesii*	Needle blight, defoliation	*P. radiata*
P	*Phelinus weirii*	Root rot	D.-fir
P	*Phytophthora pinifolia*	Needlecast, defoliation	*P. radiata*

P	*Pseudocercospora pini-densiflorae*	Needle blight, defoliation	*P. radiata*
	Rhabdocline pseudotsugae	Needle blight, defoliation	D.-fir
P	*Sirococcus conigenus*	Shoot blight, seedling mortality	*P. radiata*
I	*Dendroctonus ponderosae*	Bark beetle, mortality	*P. radiata*
I	*Dendroctonus pseudotsugae*	Bark beetle, mortality	D.-fir
I	*Dendroctonus valens*	Bark beetle, mortality	*P. radiata*
I	*Dioryctria abietella*	Cone and shoot borer, growth loss	*P. radiata*
I	*Diprion pini*	Defoliator, growth loss, tree mortality	*P. radiata*
I	*Hylobius abietis*	Bark beetle, mortality	*P. radiata*
I	*Ips grandicollis*	Bark beetle, mortality	*P. radiata*
I	*Ips paraconfusus*	Bark beetle, mortality	*P. radiata*
I	*Ips sexdentatus*	Bark beetle, mortality	*P. radiata*
I	*Lymantria monacha*	Defoliator, growth loss, tree mortality	*P. radiata*
I	*Neodiprion sertifer*	Defoliator, growth loss, tree mortality	*P. radiata*
I	*Oligonychus milleri*	Defoliator, growth loss	*P. radiata*
I	*Rhyaciona buoliana*	Shoot moth, deformation	*P. radiata*
I	*Synanthedon sequoiae*	Borer, top breakage	*P. radiata*
I	*Thaumetopoea pityocampa*	Defoliator, growth loss	*P. radiata*
I	*Tomicus piniperda*	Bark beetle, growth loss	*P. radiata*
I	*Zadiprion falsus*	Defoliator, growth loss, mortality	*P. radiata*

* P – pathogen; I - insect

Summary

There are over 1,000 pests recorded on conifers, of which many could affect radiata pine or Douglas-fir. There are many more overseas that we don't know about because they haven't been discovered or radiata pine and/or Douglas-fir are not present in their current range. Many of these organisms may have the ability to cause significant economic impact if they established in New Zealand, but due to their biology are only able be transported via well controlled pathways and therefore should be ignored for current risk assessments. Climate change will likely make pathways more accessible for pests and could make conditions in New Zealand more favourable – meaning that pests currently considered unlikely to establish could do so in future.

Risk

As discussed above, there are a number of threats to forestry outside of the country. The risk associated with these threats is determined by the likelihood of arrival, the pest's probability of establishment, rate of spread and the damage it causes.

Pathways

Bain aptly said "It is unwise to focus too much attention on individual organisms. More importantly, we should be maintaining a broad knowledge base and cleaning up pathways so that pests of all kinds are prevented from entering the country in the first place" (Forest Research 2003). Others have since echoed these views: Webber (2010) concluded that limiting plant pathogen establishment is best achieved by regulating and managing pathways than focussing on risk analysis of specific pathogens; and Brockerhoff and Bulman (2014) also suggested that pest lists are not particularly useful, and risk is best mitigated through identification and management of pathways. In 2003, pathway management resulted in the successful detection and destruction in quarantine of imported Douglas-fir material infected by *Fusarium circinatum*, the causal agent of pitch canker. This avoided the establishment of a potentially serious radiata pine pathogen in New Zealand. Pathways by which pests may enter include wood packaging (dunnage, crates, pallets), air and sea containers, imported vehicles and live plants. The volume of imports through seaports and airports is increasing by year (Figure 1).

A study of all known plant pathogen associations recorded in New Zealand on 131 economically important plant species over the last 133 years was conducted to look at the rate at which new fungal species were found (Sikes et al. 2018). Sikes et al (2018) estimate 5.9 new species a year are establishing in New Zealand across all sectors. While it appears that the overall number of new pathogens has stabilised despite increasing imports; the number is increasing in the forestry and fruit tree sector. Possible explanations for this include differences in uptake of biosecurity and emphasis on pre-border control over the years, recent developments in international phytosanitary standards and differences in pathogens between crops and trees with regards to their epidemiology and vectors. This study included 42 species of woody plants in the forestry sector and was based on one data source. While their broad conclusions on increasing rate of new pathogen establishment for woody plants matches that for radiata pine and Douglas-fir (Table 9), it doesn't condider the significance of those pathogens. Only one new pathogen record on radiata pine and Douglas-fir since 1996 has been economically significant.

Westphal et al. (2008), using socioeconomic, ecological and biogeographic variables, modelled the arrival of invasive species. In summary, it was found that the best predictor for the number of invasive species in a country is the level of international trade (not the type of trade but the overall degree of trade). To further explain these invasions, Chapman et al. (2017) used network-based models that consider connectivity indices (climate, imports from source countries, spatial, etc.) and found that invasions are more likely when importing from countries that share an established trade network, climate, and have the unwanted pest present. These kinds of models, using trade data and other indices, can help predict pathways, source countries and the kinds of species most likely to invade (Paini et al. 2016), which can improve import health standards.

Import health standards are one means of controlling pest pathways by specifying appropriate treatments and imposing restrictions on imports or conditions of entry, for instance the material needs to be held under quarantine to ensure it is pest free before being released into the environment. In 2016 Scion reviewed national import health standards from the forestry perspective. Import health standard specifications were found

to be adequate overall, but there were some exceptions. For example, the heat treatment prescribed in the wood packaging standard (IPSM 15) is only partially effective against *F. circinatum*, the causal agent of pitch canker.

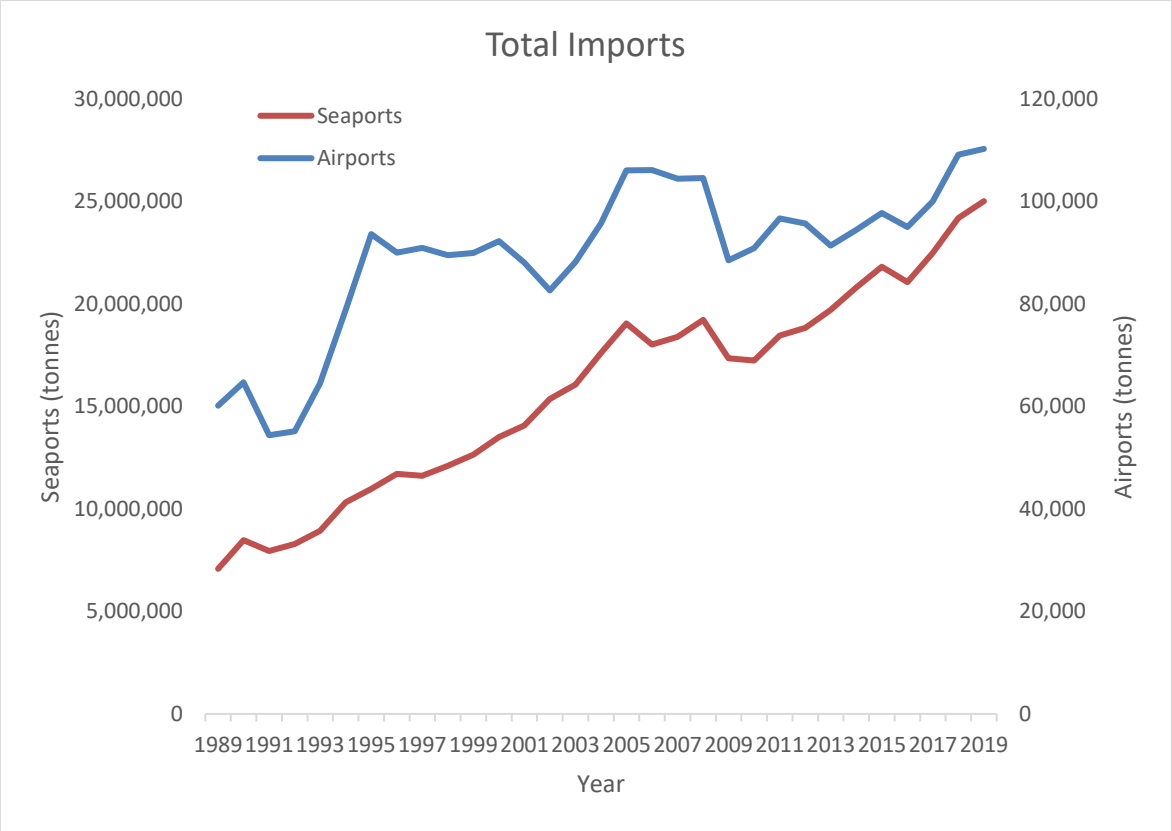

Figure 1 – import volumes from 1989 to 2019 from Overseas cargo statistics Stats NZ

Conditions for Establishment

Probability of establishment is governed by the availability of pathways to transport the pest and its ability to survive on them, the volume of material carried on the pathways, suitability of conditions for establishment, and also interventions put in place to disrupt establishment arrival (e.g. the ISPM15 standard). Klapwijk et al. (2016) discussed the challenge of maintaining trade while still protecting against pest invasion. They suggested prevention, rapid response and enlisting public support as means of protecting against invasive forest pests while still maintaining trade. That was in a European setting, it should be easier to achieve in New Zealand due to its isolation and lower volume of imported goods and material.

There are a number of barriers that affect pest establishment success. Generally, an invading pest needs to survive product processing, treatment, packaging, transport, biosecurity checks, life in a new environment, etc. When a pest or pathogen does, and many don't, overcome all of those barriers it may result in a new epidemic of a newly emerging disease (Santini et al. 2018). For tree pathogens, connectivity is an important factor to consider as it increases the probability of transmission of an infection from one area to another. Models that predict invader spread in the US have shown that entry locations and host distribution are good predictors of pest spread (Hudgins et al. 2017).

Connectivity does not only refer to spatial proximity but also how inoculum is spread between areas, such as streams, wind, fog, animals (including insects) or human mediated activities (Roberts et al. 2020). While studies looking at these pathways are limited to specific pathogens in certain areas on certain hosts (reviewed by Roberts et al.

2020), the findings do show that well connected forests, where these pathways exist, can lead to increased incidence of disease. The escape of some pests into our forests using these pathways should be identified. There are some New Zealand examples of invasive forest pests (*Cardiaspina fiscella* and *Phylacteophaga froggattii*) and pathogens (*Pseudoplagiostoma eucalypti* (=*Cryptosporiopsis eucalypti*) and *Cladosporium* sp.) that were found in close proximity to an airport, which suggest that invasive organisms do escape and can establish in non-plantation forest locations (Gadgil et al. 2002).

Identifying and managing the means/pathways by which pests can move from a port of entry into forests is more important from a forest management standpoint when compared to the makeup of a stand or forest (i.e. monoculture vs mixed stands). However, the makeup of a stand is important when considering the pests likely to be encountered in future, the ecosystem services provided by the stand, the financial implications, etc. While the species planted may not determine whether a pest will establish or not, the susceptibility and distribution of those planted species will play a significant role in spread and damage observed.

As outlined in previous risk assessments, monocultures, like mixed stands or forests, suffer from disease caused by pests and pathogens; however, there was little evidence to suggest that monocultures were more at risk because of their lower genetic diversity. In more recent literature, we know that monocultures do not benefit from any “associational resistance” (Barbosa et al. 2009), where plant species are not as vulnerable to, or easily detected by, pests in a community of different plant species (Stenberg 2017). This will not include stands of monocultures that have been bred for resistance. Breeding for resistence may confer some cross resistance to other pathogens (Ismael, Scion unpublished data). Woodcock et al 2018 review the deployment of resistant trees to mitigate impact of pests and discuss the potential to breed for resistance to a range of biotic threats. They suggest it is generally advisable to maintain genetic variability within a single species breeding proigramme even though genetically variable and similar populations can both suffer pest outbreaks. They state there few studies that compare pest resistance amongst single species populations that differ in genetic diversity.

The consensus from a number of studies is that a higher species diversity does reduce damage caused by invasive forest pathogens (reviewed by Roberts et al. 2020). In mixed stands, the accessibility of hosts is reduced and they are further apart which can reduce secondary transmission (Bauhus et al. 2017; Jactel et al. 2017; Prospero and Cleary, 2017) and mixed stands may provide additional habitats for natural biocontrol (Bauhus et al. 2017). However, the mechanisms behind this resilience depends on the species composition and the type of pest and pathogen encountered.

Pest Interceptions and Interventions

Since 2000, we have seen a change in the interception frequencies of insect families containing potential forest pests (Figure 2, Table 3). These changes are linked to the implementation of phytosanitary policies, such as ISPM15; differences in how inspections at the borders are managed; and a shift in pathway focus pre- and post-2000. Wood products and packaging no longer make up a large portion of interceptions, instead fresh produce make up the bulk.— only 506 out of 74082 interceptions are listed as on wood in the 2000-2018 dataset. As a consequence *Naupactus cervinus*, a pest of citrus, is currently the most intercepted Curculionidae.

In the 2000-2018 dataset, the most frequently intercepted insect order is Hemiptera, which has increased in yearly interception frequency since the mid-2010s (Figure 3). Part of this increase is due to increased interceptions of the brown marmorated stink bug (BMSB) and related species, following our increased awareness of BMSB global spread in the early

2010s. Note that the rapid increase in BMSB interceptions is influenced by an increase in inspection intensity on relevant pathways and improvements in diagnostic capabilities.

NZ has a world class reputation for biosecurity, but we are still limited by the extensive effort required to inspect and identify contamination at the border. This is where border inspection data from other regions around the world can be used to supplement our knowledge of what may be arriving in NZ. For example, the NZ 2000-2018 interception dataset contains only one interception of the granulated ambrosia beetle, *Xylosandrus crassiusculus*. However, among eight international interception datasets of border interceptions collected between 1995-2019 (Australia, Canada, USA, Japan, South Korea, UK, and the European and Mediterranean region) there were 96 *Xylosandrus crassiusculus* records, providing a great deal more information on the global movement of this species.

Global trade volumes are on the rise as are imports into New Zealand. While border security will keep pace with increasing import volumes it will not reduce risk over time; understanding and managing the pathways through trade connectivity will. Over the next few years, we will see a reduction in trade due to the COVID-19 (SARS-Cov-2) pandemic that has placed restrictions on movement and social distancing. The World Trade Organisation (WTO) has made some predictions about the virus' impact on trade and what the rebound may look like compared to the 2008/09 financial crisis (Figure 4). The reduction in trade and the return to pre-COVID-19 trends will take some time, which will affect the movement and arrival of pests. Passenger travel to New Zealand is likely to be reduced more than trade but for forest pests, passengers are a less important pathway than imported goods.

Table 3 – Statistics for Curculionidae intercepted at the border for the 18 years pre and post 2000.

	1982-2000 BUGS database	2000-2018 MPI
Number of Curculionidae species	122	76
Number of Curculionidae interceptions	1087	1345
Percentage of Curculionidae border interceptions identified as *Naupactus cervinus* (most intercepted species in the 2000-2018 MPI dataset)	0%	56%
Percentage of Curculionidae border interceptions identified as *Xyleborus perforans* (most intercepted species in the 1982-2000 BUGS database)	12%	4%
Percentage of interceptions from the Northern hemisphere.	69%	51%

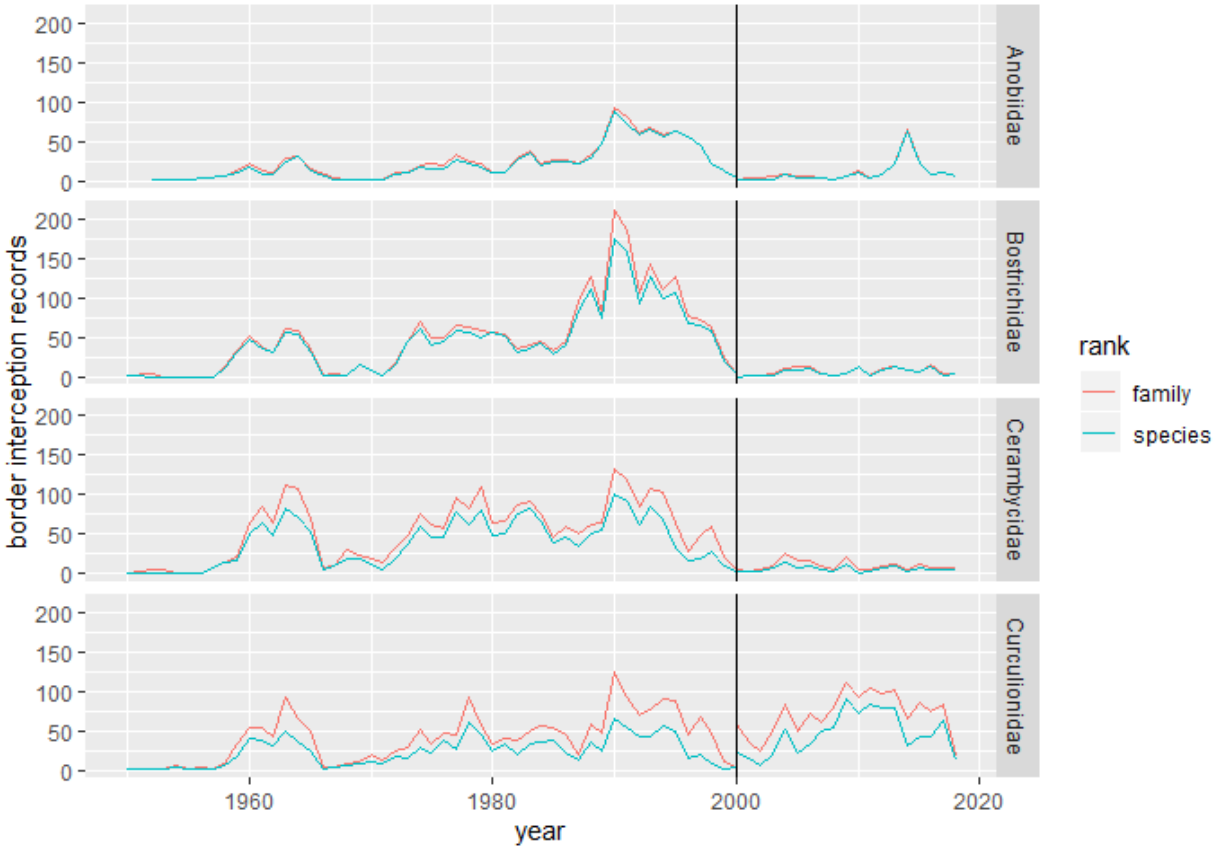

Figure 2. NZ yearly border interception frequencies of four Coleoptera families, including those identified down to species level, or all interceptions identified to at least family level. The black line at the year 2000 marks the transition from period of specifically trained forestry inspectors at the border inspecting wood packaging and related products, to the present-day system of generalist inspectors, and the allowance for importers to opt directly for treatment instead of sending samples to diagnostics.

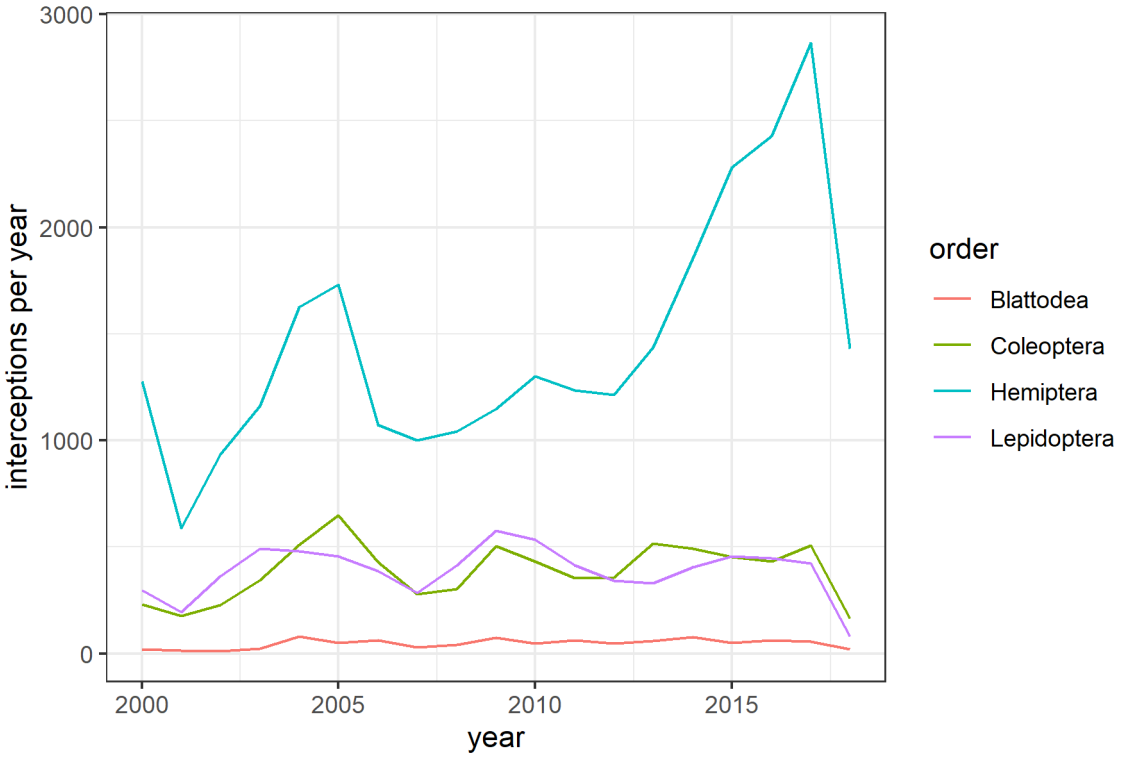

Figure 3. Yearly border interception frequency of different insect orders, on all pathways.

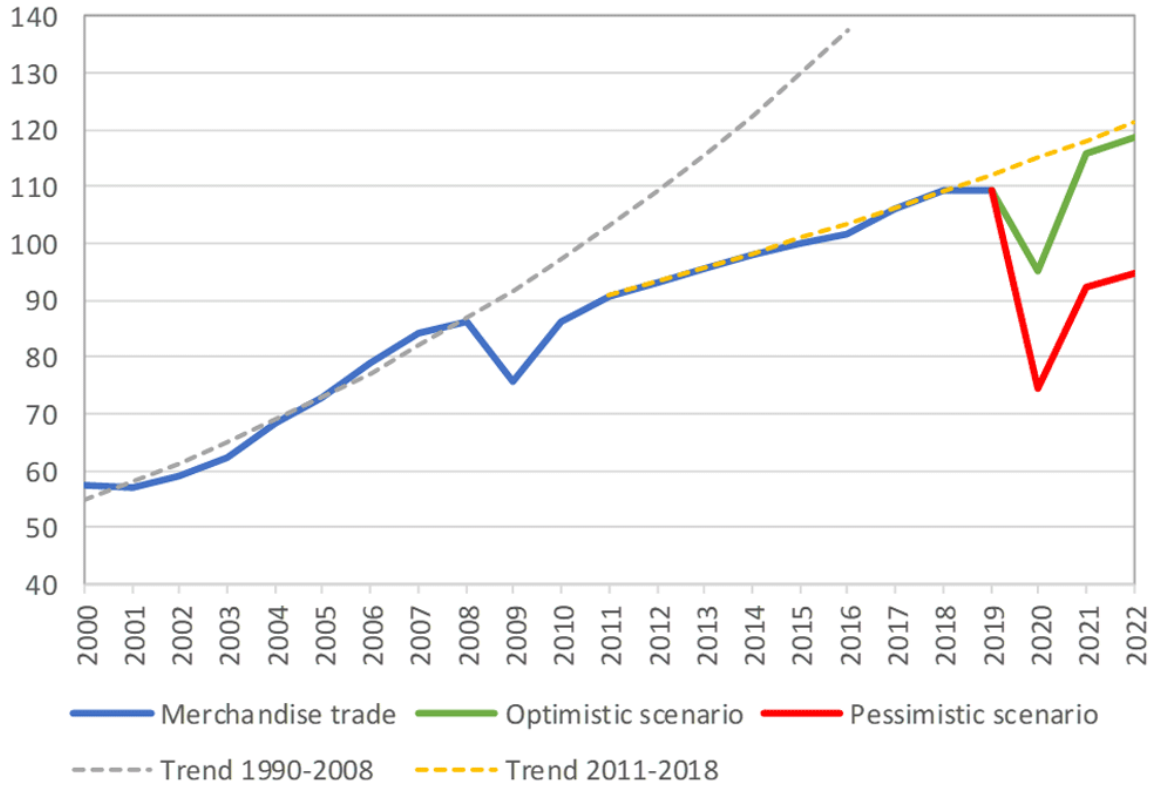

Figure 4. World merchandise trade volume, 2000 – 2022. Source: WTO Secretariat

Summary

The arrival or invasive pests and pathogens is set to continue with the trade and movement of plants and plant products as well as used equipment, vehicles and containers. The implementation of certain phytosanitary practices, such as ISPM15, has reduced the risk associated with the movement of wood products and allowed us to put more effort into inspecting other pathways; however, there is still some residual risk. An increase in trade might increase in the number of pests, however, it will stretch our capacity to effectively inspect cargo, of various types, which will increase the risk of certain threats entering the country. Identifying these pests, their pathways (including interception records) with up to date information and data from other countries will help inform pre and post border monitoring as well as the management of invasion pathways (Andow 2003; Ruiz and Carlton. 2003). This information will also give some ideas as to the impact expected and the management options available post border.

Trends

Pests and pathogens established in New Zealand

Of the organisms introduced over the past 60 years or so, only four pathogens have caused significant damage (Table 9). No insect has caused significant damage. For radiata pine, *Dothistroma septosporum* is the most significant recent pathogen introduction, followed by *Phytophthora pluvialis* and *Neonectria fuckeliana*. The latter causes depressions in the stem of affected trees associated with pruning large branches. It is recorded only in the lower half of the South Island and is now well controlled by stand management procedures that avoid large branches and pruning in winter. *Nothophaeocryptopus gaeumannii*, the cause of Swiss needle cast, is the most significant pathogen to establish on Douglas-fir. *Phytophthora pluvialis* also causes significant defoliation of Douglas-fir in certain locations. Of the insect introductions none cause

damage to growing plantation trees; *Arhopalus* and *Hylurgus* are considered quarantine pests. The last new insect records on radiata pine or Douglas-fir were made over 20 years ago (Table 5)

Overall, there have been few arrivals of major significance to radiata pine or Douglas-fir plantation forestry in New Zealand over the past 60 years and solutions have been found for those of importance, with the possible exception of Swiss needle cast. Two of the four pathogens that caused significant damage were unknown on radiata pine or Douglas-fir before being recorded in New Zealand. *Phytophthora pluvialis* was new to science in 2008. *Neonectria fuckeliana* until recently was considered a wound colonising fungus of spruce and fir in the Northern Hemisphere. It now appears to be causing damage there, possibly due to climate change.

New to New Zealand forestry records 1960 to 2020

Table 9 – Fungi affecting *Pinus radiata* and/or *Pseudotsuga menziesii*

Year	Name of organism	Effect*	Disorder	Location	Bio
1959	*Nothophaeocryptopus gaeumannii*	H	Needle cast	Taupo	WO
1962	*Dothistroma septosporum*	H	Needle blight	Kinleith Forest	WO
1963	*Colletotrichum acutatum* f.sp. *pineum*	L	Dieback	Woodhill Forest	AK
1981	*Cylindrocarpon retaudii*	L	Needle lesions	Puhipuhi	ND
1985	*Arbotiporus biennis*	L	Decay	Titirangi Auckland	AK
1985	*Hapalopilus nidulans*	L	Decay	Kaahu, Kinleith	TO
1995	*Sistotrema brinkmania*	L	Wood rot	Kinleith Forest	TO
1996	*Neonectria fuckeliana*	H	Canker	Tokoiti Forest	DN
1998	*Coleophoma cylindrospora*	L	Leaf damage	Endean Forest	BP
2003	*Cylindocladium* aff. hurae	L	Needle blight	Waipu Forest	ND
2008	*Gyrostroma* sp.	L	Dieback	Simmons Hill	MK
2008	*Phytophthora pluvialis*	H	Needle cast	Wharerata	GB
2013	*Pseudozyma aphidis*	L	No damage	Rotoaira	TO
2016	*Pezicula eucrite*	L	No damage	Ngaumu Forest	WA
2018	*Gyrodontium sacchari*	L	No damage	Rotorua	BP
2018	*Postia balsamea*	L	No damage	Western Springs	AK

Table 10 – Insects affecting *Pinus radiata* and/or *Pseudotsuga menziesii*

Year	Name of organism	Effect*	Disorder	Location	Bio
1961	*Xyleborinus saxesenii*	L	Wood borer	Mamaranui	ND
1963	*Arhopalus ferus*	L	Wood borer	Orua Bay	AK
1972	*Ambrosiodmus compressus*	L	Wood borer	Kawerau	BP
1974	*Hylurgus ligniperda*	L	Bark beetle	Whitford	AK
1998	*Essigella californica*	L	Sapsucker	Whangarei	ND

L – Low impact
M- Medium impact
H – High Impact

Appendix I lists all insects and fungi found on radiata pine and Douglas-fir in New Zealand. Most are exotic and nearly all cause little damage. Many were introduced before strict quarantine restrictions were imposed, i.e. before the late 1940s.

Industry Views on Biosecurity Risk

Between 7 and 15 May an online survey was sent to forest growers and others with a direct stake in forest biosecurity. Scion researchers were also invited to participate as a "control" group who are knowledgeable on forest biosecurity but don't have a direct commercial interest in forestry. The aim was to gauge views on future risk, trends and biosecurity awareness. As at 20 May, 140 people responded; 13 were biosecurity specialists, 19 were growers of large forests, 90 were farm foresters and there were 18 others.

Overall, just over half the respondents (52%) considered it likely or highly likely that a serious pest would establish within the next 10 years. Fewer (26%) thought that would happen within five years. Only 8% of respondents thought it unlikely that a serious pest would establish in the next 10 years.

Table 4 - How likely is it that a serious new radiata pine or Douglas-fir insect pest or pathogen will establish in NZ within the next 10 years?

Response	Forester	Other	FFA	Expert	Total	Forester	Other	FFA	Expert	Total
Highly likely		1	4		5	0%	6%	4%	0%	4%
Likely	4	2	24	2	32	21%	11%	27%	15%	23%
Somewhat likely	10	12	49	7	78	53%	67%	54%	54%	56%
Unlikely	4	2	9	4	19	21%	11%	10%	31%	14%
	1	1	4		6	5%	6%	4%	0%	4%
Grand Total	**19**	**18**	**90**	**13**	**140**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 5 - How likely is it that a serious new radiata pine or Douglas-fir insect pest or pathogen will establish in NZ within the next 5 years?

Response	Forester	Other	FFA	Expert	Total	Forester	Other	FFA	Expert	Total
Highly likely		1	4		5	0%	6%	4%	0%	4%
Likely	4	2	24	2	32	21%	11%	27%	15%	23%
Somewhat likely	10	12	49	7	78	53%	67%	54%	54%	56%
Unlikely	4	2	9	4	19	21%	11%	10%	31%	14%
Highly unlikely	1	1	4		6	5%	6%	4%	0%	4%
Grand Total	**19**	**18**	**90**	**13**	**140**	**100%**	**100%**	**100%**	**100%**	**100%**

In terms of change over time, most respondents (74%) considered that the threat of a serious forest pest incursion had increased over the past 10 years and would continue to increase over the next 10 years (78%). Industry views differed significantly from the specialists where 75% of industry respondents thought the threat had increased over the past 10 years compared with 46% of specialist respondents. Both groups had similar views on future threat. In order of priority, increased international good trade, climate change, tourism/overseas pest outbreaks were considered the most important drivers of biosecurity risk over the next 10 years. Single species dominance in NZ production forestry was considered among the top three drivers for 12 respondents but only three listed reduced genetic diversity in NZ production forests among their top three. Sub-optimal pathway control at the border was the most common additional driver listed. Several respondents mentioned unapproved seed importation, others listed mail and parcels, economic drivers to import machinery, and the border inspection focus on agriculture not forestry.

Table 6 - Over the past 10 years, do you consider the threat of a serious new radiata pine or Douglas-fir pest or pathogen establishment has:

Response	Forester	Other	FFA	Expert	Total	Forester	Other	FFA	Expert	Total
Increased	12	13	43	4	72	63%	72%	48%	31%	51%
Increased significantly		2	27	2	31	0%	11%	30%	15%	22%
Reduced	1		2	2	5	5%	0%	2%	15%	4%
Remained about the same	6	3	18	5	32	32%	17%	20%	38%	23%
Grand Total	**19**	**18**	**90**	**13**	**140**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 7 - Over the next 10 years, do you consider the threat of a serious new radiata pine or Douglas-fir pest or pathogen establishment will:

Response	Forester	Other	FFA	Expert	Total	Forester	Other	FFA	Expert	Total
Increase	13	11	50	8	82	68%	61%	56%	62%	59%
Increase significantly		4	22	1	27	0%	22%	24%	8%	19%
Reduce			2	1	3	0%	0%	2%	8%	2%
Remain about the same	6	3	16	3	28	32%	17%	18%	23%	20%
Grand Total	**19**	**18**	**90**	**13**	**140**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 8 - Over time, New Zealand's future ability to stop serious forestry pests and pathogens at the border will:

Response	Forester	Other	FFA	Expert	Total	Forester	Other	FFA	Expert	Total
Increase	3	5	20	5	33	16%	28%	22%	38%	24%
Increase significantly		1	1	1	3	0%	6%	1%	8%	2%
Reduce	3	5	28	5	41	16%	28%	31%	38%	29%
Reduce significantly		1	8		9	0%	6%	9%	0%	6%
Remain about the same	13	6	33	2	54	68%	33%	37%	15%	39%
Grand Total	**19**	**18**	**90**	**13**	**140**	**100%**	**100%**	**100%**	**100%**	**100%**

Goods and packaging arriving on sea containers was considered the most important pathway with 51 respondents listing it in their top three, followed by used forestry machinery (42 respondents) and recreational forest visitors (32). Given those pathways and drivers, respondents were unsure on whether our ability to stop serious pests at the border would increase or reduce. More respondents (36%) thought our ability to stop pests would reduce or reduce significantly over time compared with the 26% who thought it would increase or increase significantly. Farm foresters were less optimistic, with almost half (46%) thinking our ability to stop pests would reduce. The split in opinion is understandable. Those who thought our ability to stop pests would reduce listed reduced border control due to Covid, inability to handle increased import volumes, shift from protection to production, and climate change. Those who thought our ability to stop pests would increase listed technology advances, increased awareness of biosecurity through Covid, and fewer tourists. Those who were split and thought our ability would remain about the same thought the positive and negative drivers would balance out.

Biosecurity awareness was high with 77% of respondents and 56% of respondents having heard of pitch canker and mountain pine beetle, respectively. Just over a third knew of western gall rust. Pitch canker, western gall rust and the pine Phytophthora disease in Chile DFP were of most concern. Four respondents listed the "unknowns" and two listed brown marmorated stick bug even though it isn't a forestry pest.

General statements included points around biosecurity risk being more than productivity loss, licence to operate in terms of domestic and international trade may be of greater concern. Several respondents suggested pathogens were a larger risk than insects because historicall they caused more damage, were more difficult to detect early and were more challenging to eradicate.

Summary

The industry view is that it is likely or highly likely a pest will establish within the next 10 years but understandably, the likelihood of that happening within the next 5 years is lower. Most considered that biosecurity risk is increasing because of increased trade, climate change and pest outbreaks overseas. Opinion was evenly divided on our future ability to stop pests at the border. Factors such as increased trade and climate change would hinder our ability but technology advances and increased awareness may improve our ability to control pests at the border. We should consider loss of licence to operate forestry business along with productivity loss when considering impact of forest pest incursions.

Factors that influence risk

A number of new technologies are being explored that will help optimise and improve biosecurity. These include the Trans-Tasman Atmospheric Transport Pathway (ATP) model, which will improve forecasting so that we can survey locations where pests are likely to show up; pathogen sensors are also being developed to identify infections before visual symptoms appear, which will help with earlier detection and eradication; the use of UAVs for not only surveillance but also for targeted spraying applications that will reduce economic, environmental and social impacts. These technologies will be expanded on under phase 2.

For the purpose of this review, under phase 1, we discuss the use of mixed species – as a comparison to biological risk to radiata pine and/or Douglas-fir plantings. Widespread planting of a single species (monoculture) with favourable growth and wood properties for timber production is an attractive and profitable approach for many forest managers; however, with the increased movement of pests and pathogens, forest managers need to balance those benefits with therisk linked to invasion and consider other options, one of which is forest diversification. We discuss the potential for forest diversification to reduce biosecurity risk below.

Forest diversification is a widely debated topic that has and will continue to be explored in studies and papers around the world. The argument for the planting of more than one species is often referred to the “insurance policy” (Loreau et al. 2001; Pautasso et al. 2005) or the “dilution effect” (Guo et al. 2019; Huang et al. 2016) where the risk of an attack, at the forest level, is spread between the species planted. As most invasive pathogens are species- or genus-specific, mixed stands can reduce the effects of susceptibility and spread (Macpherson et al. 2017) as modelled in the example of *Heterobasidion annosum* on mixed *Pinus* and *Picea* stands (Thor et al. 2005).

The use of models allows us to test a number of variables and their effects on a scenario, which can help us make predictions and decisions. MacPherson et al. (2017) developed a framework to determine the potential impact of a pest so various management approaches to mitigate risk could be evaluated. Their bioeconomic model considered the arrival of a pathogen in a stand with only two planted species–a susceptible and a resistant species. While the model does demonstrate that the planting of two species does reduce the economic loss caused by a pathogen, the results are sensitive to the characteristics of the pathogen, i.e., probability of arrival, time of arrival and rate of spread. It is also sensitive to the losses based on the level of susceptibility to the pathogen and the timber loss from the less desirable, yet resistant species.

There are many benefits to diversification, including non-timber benefits, such as water regulation and carbon sequestration (Bauhis et al. 2011) and the expansion of ecosystem services (Gamfeldt et al. 2013); however, the benefits are often generalised as studies focus on specific examples (Macpherson et al. 2017). It is also important to mention that there are conflicting results that show that diversification may yield negative results, such as increased logging costs, reduction in production, increased management complexity, etc. (Chen et al. 2003; Griess and Knoke 2011; Felton et al. 2016). The outcomes, positive or negative, will depend largely on the species selected and the productivity of the site (Felton et al. 2016). Ultimately, decisions on diversifications will need to look at the empirical data and the meta-analyses of that data to understand effects for a scenario but it does seem that risk from a pathogen will determine the optimal planting proportion (Macpherson et al. 2017).

Based on feeback received from various stakeholders regarding the first draft of the review, it seems unlikely that foresters would replace radiata, at least in the immediate

future, with mixed stands and with good reason. A decision such as this will have long-term consequences for the industry and needs to be thoroughly investigated, trialled and tested before it is even debated. We refer back to the review concerning the health of plantation forestry by Sweet (1989) where he suggested, then, that we look at alternate species to replace radiata. Maintaining the health of the estate will need increased investment, changes in policy, upgrades to biosecurity and thoughts around the future of radiata. We think a long-term strategy that considers alternative species can help reduce the risk to radiata and to the estate as a whole. This could be done in phases where we use alternate species in stands around and near ports of entry to act as buffers to slow invasions. The use of alternative species is by no means a silver bullet and will still require world-class biosecurity measures to protect the estate.

Summary

Over the past 60 years a number of exotic pests and pathogens have established in New Zealand's radiata pine and Douglas-fir plantations. Only four fungi have been problematic and two of those were impossible to predict and prepare for. There are a number of high profile threats as shown in the previous section and the unknowns may be of equal importance. While a list of pests and pathogens is useful; information about their biology, distribution, host range, likelihood of spread and known pathways is more important when quantifying risk. For well-studied organisms it is easier to make some predictions when compared to relatively unknown species, organisms that are new to science or unknown on a host of importance.

It will be difficult to predict which pests and pathogens (known or unknown) are likely to invade; however, many are likely to be detected within our current biosecurity framework. To this point, we can prepare for the more likely pests that are capable of causing damage and develop or use strategies and models around those. They could be quite general as many of these organisms share similar pathways or something more specific, such as forest diversification. Whatever the choice, we will need to consider risk holistically to make an informed decision.

Conclusion

The risk of a serious new pest or pathogen is reasonably low based on experience over the past 60 years. However, the risk is not null; and globalisation, increasing import volumes and climate change have increased biosecurity risk compared with 60 years ago. It is prudent to have risk mitigation measures in place given the value of the estate and potential loss that may be suffered.

Phase 2: What's next?

This review has dealt with risk and highlighted some of the trends we are likely to see going forward. Understanding risk is important if we are to think of innovative ways to manage risk with effective mitigation strategies. In phase 2 we will explore, in more detail, various mitigation strategies to reduce risk, including improvements to border security, the use of new and exciting surveillance and eradication technologies, diversification at various levels, etc. Together, these reports should give a nice overview of where we are and where we are going in terms of plantation health. It will also help us identify gaps and the needs of the industry to better secure our estates.

Acknowledgements

We thank Forest Growers Research for funding this project and the many forest growers who responded to the survey and/or provided feedback on this report.

References

Andow DD. 2003. Pathways-based risk assessment of exotic species invasions. In: Invasive Species: Vectors and management strategies. Ruiz GM, Carlton JT (Eds) Island Press: Washington, DC, USA. 439-455.

Bain, J., 1981. Forest monocultures — how safe are they? An entomologist's viewpoint, N.Z. J For., 26: 37-42.

Barbosa P, Hines J, Kaplan I, Martinson H, Szczepaniec A, Szendrei Z. 2009. Annual Review of Ecology, Evolution and Systematics 40:1-20.

Bauhus J, Forrester D, Gardiner B, Jactel, H, Vallejo R, Pretzsc, H. 2017. Ecological stability of mixed-species forests, in Mixed-Species Forests - Ecology and Management, (eds) H. Pretzsch, D. I. Forrester, and J. Bauhus Verlag: Heidelberg), 337–382.

Bauhus J, Van der Meer P, Kanninen M. 2011. Ecosystem Goods and Services. from Plantation Forests. Routledge, London.

Brockerhoff E.G., Bulman L.S. 2014. Biosecurity risks to New Zealand's plantation forests and the rationale for pathway risk management. New Zealand Journal of Forestry 59: 3–8.

Brockerhoff, E.G., Barbaro, L., Castagneyrol, B.*et al.* 2017. Forest biodiversity, ecosystem functioning and the provision of ecosystem services. Biodivers Conserv 26:3005–3035. https://doi.org/10.1007/s10531-017-1453-2

Burdon, R. D., 1982. Monocultures — how vulnerable? N.Z. Forest Service. Forest Research Institute, What's New? No. 115.

Chapman D, Purse BV, Roy HE, Bullock JM. 2017. Global trade networks determine the distribution of invasive non-native species. Global Ecology and Biogeography 26: 907-917.

Chen HY, Klinka K, Mathey AH, Wang X, Varga P, Chourmouzis C. 2003. Are mixed-species stands more productive than single-species stands: an empirical test of three forest types in British Columbia and Alberta. Canadian Journal of Forest Research 33:1227-1237.

Chou, C. K. S., 1981. Monocultures, species diversification and disease hazards in forestry. N.Z. Jl For., 26: 20-36.

Felton A, Nilsson U, Sonesson J, Felton AM, Roberge JM, Ranius T, Ahlström M, Bergh J, Björkman C, Boberg J, Drössler L, Fahlvik N, Gong P, Holmström E, Keskitalo ECH, Klapwijk M, Laudon H, Lundmark T, Niklasson M, Nordon A, Pettersson M, Stenlid J, Sténs A, Walertz K. 2016. Replacing monocultures with mixed-species stands: ecosystem service implications of two production forest alternatives in Sweden. Ambio 45:124-139.

Forest research. 2003. New Zealand's least wanted. Forest research, Executive brief No. 10

Gadgil, P.D., Bain, J., 1999. Vulnerability of planted forests to biotic and abiotic disturbances. *New Forests* 17, 227–238.

Gadgil PD, Bulman LS, Glassey KL. 2002. Quarantine risk associated with air cargo containers. New Zealand Journal of Forest Science 32: 28-47.

Gamfeldt L, Snäll T, Bagchi R, Jonsson M, Gustafsson L, Kjellander P,Ruiz-Jaen MC, Fröberg M, Stendahl J, Philipson CD, Mikusi´nski G, Andersson E, Westerlund B, Andrén H, Moberg F, Moen J, Bengtsson J. 2013. Higher levels of multiple ecosystem services are found in forests with more tree species. Nature Communication 4:1340.

Gerlach J., Reich P., Puettmann K., Baker T. Species, diversity, and density affect tree seedling mortality from Armillaria root rot. Can. J. Forest Res. 1997;27(9):1509–1512.

Griess V.C., Knoke T. Growth performance, windthrow, and insects: meta-analyses of parameters influencing performance of mixed-species stands in boreal and northern temperate biomes. Canadian Journal of Forest Research 41:1141-1159.

Guo Q, Fei S, Potter KM, Liebhold AM, Wen J. 2019. Tree diversity regulates forest pest invasion. PNAS 116:7382-7386.

Guyot V., Castagneyrol B., Vialatte A., Deconchat M., Jactel H. Tree diversity reduces pest damage in mature forests across Europe. Biol. Lett. 2016;12(4):20151037.

Haas S.E., Hooten M.B., Rizzo D.M., Meentemeyer R.K. Forest species diversity reduces disease risk in a generalist plant pathogen invasion. Ecol. Lett. 2011;14(11):1108–1116.
Hantsch L., Bien S., Radatz S., Braun U., Auge H., Bruelheide H. Tree diversity and the role of non-host neighbour tree species in reducing fungal pathogen infestation. J. Ecol. 2014;102(6):1673–1687.
Huang ZYX, van Landgevelde F, Estrada-Peňa A, Suzán G, De Boer WF. 2016. The diversity-disease relationship: evidence for and criticism of the dilution effect. Parasitology 143:1075-1086.
Hudgins EJ, Liebhold AM, Leung B. 2017. Predicting the spread of all invasive forest pests in the United States. Ecology Letters 20:426-435.
Klapwijk, M. J., Hopkins, A. J., Eriksson, L., Pettersson, M., Schroeder, M., Lindelöw, Å., Rönnberg, J., Keskitalo, E. C., & Kenis, M., 2016. Reducing the risk of invasive forest pests and pathogens: Combining legislation, targeted management and public awareness. *Ambio*, *45 Suppl 2*(Suppl 2), 223–234. https://doi.org/10.1007/s13280-015-0748-3
Jactel H, Bauhus J, Boberg J, Bonal D, Castagneyrol B, Gardiner B, Gonzalez-Olabarria JR, Koricheva J, Meurisse N, Brockeroff EG. 2017. Tree diversity drives forest stand resistance to natural disturbances. Current Forestry Reports 3:223-243.
Liu, C.L.C., Kuchma, O., Krutovsky, K.V., 2018. Mixed-species versus monocultures in plantation forestry: Development, benefits, ecosystem services and perspectives for the future. Gl. Ec. and Cons. 15, e00419.https://doi.org/10.1016/j.gecco.2018.e00419.
Loreau M., Naeem S., Inchausti P., Bengtsson J., Grime J., Hector A., Hooper D., Huston M., Raffaelli D., Schmid B., Tilman D., Wardle D. Biodiversity and ecosystem functioning: current knowledge and future challenges. Science. 2001;294(5543):804–808
Macpherson, M. F., Kleczkowski, A., Healey, J. R., Quine, C. P., & Hanley, N. (2017). The effects of invasive pests and pathogens on strategies for forest diversification. *Ecological modelling*, *350*, 87–99. https://doi.org/10.1016/j.ecolmodel.2017.02.003
Paini DR, Sheppard AW, Cook DC, De Barro PJ, Worner SP, Thomas MB. 2016. Global threat to agriculture from invasive species. PNAS 27: 7575-7579
Pautasso M., Holdenrieder O., Stenlid J. Susceptibility to fungal pathogens of forests differing in tree diversity. In: Scherer-Lorenzen M., Körner C., Schulze E.-D., editors. Forest Diversity and Function. vol. 176. Springer; Berlin: 2005. pp. 263–289.
Prospero S, Cleary M. 2017. Effect of host variability on the spread of invasive forest diseases. Forests 8:80-91.
Roberts M, Gilligan CA, Kleczkowski A, Hanley N, Whalley AE, Healey JR. 2020. The effect of forest management options on forest resilience to pathogens. Frontiers in Forests and Global Change 3: 1-21.
Ruiz GM, Carlton JT (Eds). 2003. Invasive species: Vectors and management strategies. Island Press, Washington, DC, USA.
Santini A, Liebhold A, Migliorini, Woodward S. 2018. Tracing the role of human civilization in the globalization of plant pathogens. International Society for Microbial Ecology 12:647-652.
Stenberg JA. 2017. A conceptual framework for Integrated Pest Management. Trends in Plant Science 22:759-769.
Sweet, G.B. and Burdon, R.D. 1983. The radiata pine monoculture: an examination of the ideologies. New Zealand Journal of Forestry 28: 325-6.
Thor M., Ståhl G., Stenlid J. Modelling root rot incidence in Sweden using tree, site and stand variables. Scand. J. Forest Res. 2005;20(2):165–176.
Westphal MI, Browne M, MacKinnon, K, Noble I. 2008. The link between international trade and the global distribution of invasive alien species. Biological Invasions 10: 391-398.
Woodcock P, Cottrell JE, Buggs RJA, Quine CP. 2018. Mitigating pest and pathogen impacts using resistant trees: a framework and overview to inform development and deployment in Europe and North America. Forestry: An International Journal of Forest Research 91:1–16. https://doi.org/10.1093/forestry/cpx031

Appendix I – Pests and Pathogens recorded on Radiata Pine and Douglas-fir in New Zealand

Organism	Host	Type	No.	First Record
Acremonium sp	Pinus radiata	Fungus	7	13-Nov-92
Agaricomycete	Pinus radiata	Fungus	1	18-Apr-16
Agrocybe praecox	Pinus radiata	Fungus	1	03-Apr-96
Aleuria aurantia	Pinus radiata	Fungus	1	10-Jul-07
Allantophomopsiella pseudotsugae	Pinus radiata	Fungus	38	11-May-84
Allantophomopsis lycopodina	Pinus radiata	Fungus	1	11-Aug-16
Allantophomopsis sp	Pinus radiata	Fungus	9	12-Aug-10
Alternaria sp	Pinus radiata	Fungus	46	27-Apr-65
Amanita muscaria	Pinus radiata	Fungus	1	03-Jun-94
Amanita nehuta	Pinus radiata	Fungus	1	06-Jul-99
Amanita sp	Pinus radiata	Fungus	1	21-Jun-91
Amylostereum areolatum	Pinus radiata	Fungus	6	06-Aug-63
Antrodia albida	Pinus radiata	Fungus	1	05-Jul-19
Apiocrea chrysosperma	Pinus radiata	Fungus	1	06-Feb-97
Apiotrichum sp.	Pinus radiata	Fungus	1	11-Sep-19
Arbortiporus biennis	Pinus radiata	Fungus	2	08-Apr-91
Arcyria ferruginea	Pinus radiata	Fungus	1	12-Aug-96
Armillaria novae-zelandiae	Pinus radiata	Fungus	146	28-Apr-93
Aspergillus sp	Pinus radiata	Fungus	1	14-Aug-19
Athelia sp	Pinus radiata	Fungus	1	16-Jun-97
Aureobasidium pullulans	Pinus radiata	Fungus	4	23-Oct-68
Aureobasidium sp	Pinus radiata	Fungus	65	04-Dec-78
Beauvaria sp	Pinus radiata	Fungus	2	14-Jan-98
Boeremia exigua var. exigua	Pinus radiata	Fungus	2	30-Jul-19
Boletus luteus	Pinus radiata	Fungus	1	23-Apr-70
Boletus orovillus	Pinus radiata	Fungus	1	31-Mar-70
Boletus sp	Pinus radiata	Fungus	1	27-Apr-16
Botryosphaeria sp	Pinus radiata	Fungus	29	14-May-90
Botrytis cinerea	Pinus radiata	Fungus	97	04-Sep-73
Botrytis sp	Pinus radiata	Fungus	76	30-Apr-80
Calocera sp	Pinus radiata	Fungus	1	11-May-96
Calonectria pacifica	Pinus radiata	Fungus	1	25-Nov-19
Cephalosporiopsis sp	Pinus radiata	Fungus	1	02-Nov-93
Cephalosporium lecanii	Pinus radiata	Fungus	1	04-Jul-74
Cephalosporium sp	Pinus radiata	Fungus	2	22-Sep-78
Ceratocystis sp.	Pinus radiata	Fungus	1	03-May-17
Ceuthospora sp	Pinus radiata	Fungus	93	15-Dec-87
Ceuthospora sp.	Pinus radiata	Fungus	3	05-Oct-08
Chaetomium globosum	Pinus radiata	Fungus	1	06-Oct-93
Chaetomium trigonosporum	Pinus radiata	Fungus	1	25-Jul-08
Chaetoporus sp	Pinus radiata	Fungus	7	06-Sep-85
Chalciporus piperatus	Pinus radiata	Fungus	1	12-Mar-15
Chlorococcus sp	Pinus radiata	Fungus	2	23-Jun-78
Chondrostereum purpureum	Pinus radiata	Fungus	1	04-Jun-98
Cladosporium cladosporioides	Pinus radiata	Fungus	2	01-May-00
Cladosporium oxysporum	Pinus radiata	Fungus	2	26-Jan-01
Cladosporium sp	Pinus radiata	Fungus	44	19-Jul-78
Clavulina sp	Pinus radiata	Fungus	1	12-May-00
Clitocybe aff. dealbata	Pinus radiata	Fungus	1	20-May-98
Clonostachys rosea	Pinus radiata	Fungus	1	12-Jul-15
Clonostachys sp.	Pinus radiata	Fungus	2	19-May-16

Coleophoma cylindrospora	Pinus radiata	Fungus	4	26-Jun-00
Colletotrichum acutatum	Pinus radiata	Fungus	15	20-Dec-83
Colletotrichum acutatum f.sp. pineum	Pinus radiata	Fungus	18	13-Mar-90
Colletotrichum gloeosporioides	Pinus radiata	Fungus	1	25-Jul-08
Colletotrichum sp	Pinus radiata	Fungus	1	04-Feb-02
Collybia sp	Pinus radiata	Fungus	1	23-Mar-98
Coniophora arida	Pinus radiata	Fungus	1	04-Jul-94
Coniophora olivaceae	Pinus radiata	Fungus	1	23-May-95
Coniophora puteana	Pinus radiata	Fungus	1	07-Aug-90
Coniothyrium sp	Pinus radiata	Fungus	3	15-Jan-79
Coprinus patoillardi	Pinus radiata	Fungus	1	16-Apr-97
Coprinus sp	Pinus radiata	Fungus	1	20-Sep-94
Cordyceps sinclairii	Pinus radiata	Fungus	1	06-May-98
Cortinarius sp	Pinus radiata	Fungus	5	19-May-93
Coryneum sp	Pinus radiata	Fungus	1	21-Feb-79
Crucibulum laeve	Pinus radiata	Fungus	1	16-Sep-94
Cryptosporiopsis sp	Pinus radiata	Fungus	4	26-Jun-92
Cyathus olla	Pinus radiata	Fungus	1	13-May-96
Cyclaneusma minus	Pinus radiata	Fungus	1345	07-Dec-79
Cyclaneusma niveum	Pinus radiata	Fungus	34	11-Mar-74
Cyclaneusma sp	Pinus radiata	Fungus	228	12-May-82
Cylindrocarpon didymum	Pinus radiata	Fungus	7	15-Sep-03
Cylindrocarpon lucidum	Pinus radiata	Fungus	1	31-Jan-94
Cylindrocarpon obtusisporum	Pinus radiata	Fungus	1	05-Jun-08
Cylindrocarpon sp	Pinus radiata	Fungus	121	27-Feb-92
Cylindrocarpon spp	Pinus radiata	Fungus	6	08-Jul-96
Cylindrocladium aff hurae	Pinus radiata	Fungus	3	06-May-03
Cylindrocladium scoparium	Pinus radiata	Fungus	39	04-Mar-82
Cylindrocladium sp	Pinus radiata	Fungus	6	01-Oct-81
Cylindrodendrum album	Pinus radiata	Fungus	1	22-Nov-19
Cystoderma sp	Pinus radiata	Fungus	2	12-Apr-96
Cytospora sp	Pinus radiata	Fungus	5	15-Jun-83
Dacrymyces stillatus	Pinus radiata	Fungus	1	30-Jun-03
Dacryopinax spathularia	Pinus radiata	Fungus	2	30-Nov-01
Dasyscypha caliciformis	Pinus radiata	Fungus	1	10-Dec-63
Dermocybe sp	Pinus radiata	Fungus	1	31-May-76
Dextrinocystidium sacratum	Pinus radiata	Fungus	1	02-Nov-09
Diaporthe sp	Pinus radiata	Fungus	1	11-Dec-19
Didymella glomerata	Pinus radiata	Fungus	1	17-Feb-20
Diplodia sapinea	Pinus radiata	Fungus	1440	06-May-92
Diplodia scrobiculata	Pinus radiata	Fungus	1	19-Jun-07
Diplodia sp	Pinus radiata	Fungus	7	15-Aug-09
Discula sp	Pinus radiata	Fungus	1	02-Mar-96
Dothistroma septosporum	Pinus radiata	Fungus	935	19-Nov-64
Elongisporangium anandrum	Pinus radiata	Fungus	1	05-Nov-19
Elongisporangium undulatum	Pinus radiata	Fungus	8	07-May-08
Endophragmiella dingleyae	Pinus radiata	Fungus	1	17-Jan-00
Entoloma procerum	Pinus radiata	Fungus	1	12-Mar-15
Entoloma readiae var. sulphureum	Pinus radiata	Fungus	1	12-Mar-15
Entoloma sp	Pinus radiata	Fungus	1	01-Apr-96
Entomophthora sp	Pinus radiata	Fungus	1	17-Apr-02
Epicoccum purpurascens	Pinus radiata	Fungus	43	28-May-92
Epicoccum sp	Pinus radiata	Fungus	6	02-Oct-08
Epithyrium sp	Pinus radiata	Fungus	1	25-Sep-89
Exidia sp.	Pinus radiata	Fungus	1	16-Aug-18
Exophiala sp	Pinus radiata	Fungus	1	13-May-97
Favolaschia calocera	Pinus radiata	Fungus	1	07-May-92
Fibuloporia donkii	Pinus radiata	Fungus	2	16-Oct-92
Flammulina velutipes	Pinus radiata	Fungus	1	25-Feb-98
Flyspeck fungus	Pinus radiata	Fungus	2	15-Nov-77

Fuligo septica	Pinus radiata	Fungus	2	25-Sep-98
Fusarium acuminatum	Pinus radiata	Fungus	4	03-Mar-99
Fusarium avenaceum	Pinus radiata	Fungus	27	02-Aug-99
Fusarium cerealis	Pinus radiata	Fungus	2	30-Jul-19
Fusarium cortaderiae	Pinus radiata	Fungus	1	30-Jul-19
Fusarium equiseti	Pinus radiata	Fungus	5	05-Mar-99
Fusarium graminum	Pinus radiata	Fungus	1	10-Aug-03
Fusarium lateritium	Pinus radiata	Fungus	2	20-Mar-93
Fusarium moniliforme	Pinus radiata	Fungus	1	23-May-74
Fusarium moniliforme var subglutinans	Pinus radiata	Fungus	1	06-Jun-73
Fusarium oxysporum	Pinus radiata	Fungus	84	30-Jun-86
Fusarium sambucinum	Pinus radiata	Fungus	13	13-May-96
Fusarium semitectum	Pinus radiata	Fungus	2	13-Feb-95
Fusarium solani	Pinus radiata	Fungus	15	07-May-92
Fusarium sp	Pinus radiata	Fungus	239	12-Nov-85
Fusarium spp	Pinus radiata	Fungus	10	08-Nov-71
Fusarium sulphureum	Pinus radiata	Fungus	1	16-Jul-17
Fusicoccum sp	Pinus radiata	Fungus	20	19-Dec-85
Fusicolla merismoides	Pinus radiata	Fungus	1	12-Sep-19
Galerina patagonica	Pinus radiata	Fungus	2	03-May-93
Galerina sp	Pinus radiata	Fungus	4	12-Apr-96
Ganoderma applanatum	Pinus radiata	Fungus	2	28-Oct-03
Ganoderma applanatum sensu wakef	Pinus radiata	Fungus	1	09-Jan-07
Ganoderma mastoporum	Pinus radiata	Fungus	1	10-Jun-92
Ganoderma sp	Pinus radiata	Fungus	6	27-Aug-96
Geastrum sp	Pinus radiata	Fungus	2	21-Jun-91
Genatobotrys simplex	Pinus radiata	Fungus	1	15-May-00
Geniculosporium sp	Pinus radiata	Fungus	1	19-Dec-85
Geotrichum sp	Pinus radiata	Fungus	1	06-Dec-93
Gliocladium sp	Pinus radiata	Fungus	4	06-Dec-93
Gliocladium viride	Pinus radiata	Fungus	1	11-Mar-03
Gliophorus ostrinus	Pinus radiata	Fungus	1	21-May-99
Globisporangium sp.	Pinus radiata	Fungus	1	25-Jul-19
Gloeocystidiellum sacratum	Pinus radiata	Fungus	77	03-Aug-87
Gloeopeniophorella sacrata	Pinus radiata	Fungus	2	08-Dec-11
Gloeophyllum abietinum	Pinus radiata	Fungus	1	14-Aug-19
Gloeophyllum sepiarium	Pinus radiata	Fungus	6	11-May-96
Gloeosporium sp	Pinus radiata	Fungus	7	08-Mar-82
Graphium sp	Pinus radiata	Fungus	21	21-Sep-92
Grifola rosulata	Pinus radiata	Fungus	1	07-Mar-78
Grosmannia huntii	Pinus radiata	Fungus	45	14-Nov-88
Grosmannia radiaticola	Pinus radiata	Fungus	4	12-Dec-03
Grosmannia sp.	Pinus radiata	Fungus	4	24-May-18
Gymnopilus junonius	Pinus radiata	Fungus	16	01-May-91
Gymnopilus sp	Pinus radiata	Fungus	7	11-Apr-96
Gyromitra esculenta	Pinus radiata	Fungus	1	24-Jun-00
Gyromitra infula	Pinus radiata	Fungus	1	08-Apr-06
Gyrostroma sp	Pinus radiata	Fungus	1	13-Jun-08
Hapalopilus nidulans	Pinus radiata	Fungus	10	23-May-85
Harzia sp	Pinus radiata	Fungus	1	11-Mar-04
Hebeloma sp	Pinus radiata	Fungus	1	14-Jun-89
Hirsutella sp	Pinus radiata	Fungus	1	29-Apr-04
Hjortstamia crassa	Pinus radiata	Fungus	1	23-Jun-06
Hohenbuehelia podocarpinea	Pinus radiata	Fungus	3	14-Apr-86
Hohenbuehelia sp.	Pinus radiata	Fungus	6	28-Sep-95
Hormonema sp	Pinus radiata	Fungus	1	15-May-05
Humicola sp	Pinus radiata	Fungus	1	02-Apr-04
Hygrophoropsis aurantiaca	Pinus radiata	Fungus	1	13-Jun-97
Hymenochaete sp	Pinus radiata	Fungus	1	06-Nov-19
Hyphodontia sp	Pinus radiata	Fungus	2	07-Aug-90

Hypholoma acutum	Pinus radiata	Fungus	1	11-May-96
Hypholoma fasciculare	Pinus radiata	Fungus	8	18-Apr-78
Hypholoma sp	Pinus radiata	Fungus	4	21-Nov-97
Hyphomycete	Pinus radiata	Fungus	11	02-Apr-09
Hypoderma sp	Pinus radiata	Fungus	1	17-Oct-79
Hysterium sp	Pinus radiata	Fungus	1	09-Oct-79
Ileodictyon cibarius	Pinus radiata	Fungus	2	23-May-97
Ilyonectria crassa	Pinus radiata	Fungus	1	25-Nov-19
Ilyonectria destructans	Pinus radiata	Fungus	1	22-Nov-99
Ilyonectria mors-panacis	Pinus radiata	Fungus	2	16-Dec-19
Ilyonectria sp.	Pinus radiata	Fungus	3	28-Jun-14
Inocybe sp	Pinus radiata	Fungus	8	11-Apr-96
Inocybe sp aff. corydalina	Pinus radiata	Fungus	1	29-Apr-99
Irpex sp	Pinus radiata	Fungus	1	06-Jun-16
Junghuhnia vincta	Pinus radiata	Fungus	24	15-Apr-86
Kneiffiella sp	Pinus radiata	Fungus	1	29-Apr-92
Laccaria laccata	Pinus radiata	Fungus	1	04-Mar-92
Laccaria sp	Pinus radiata	Fungus	5	17-Jul-81
Lachnellula calyciformis	Pinus radiata	Fungus	2	19-Jun-03
Lachnellula pseudotsugae	Pinus radiata	Fungus	1	24-Nov-17
Lachnellula sp	Pinus radiata	Fungus	20	23-Mar-92
Lachnellula subtilissima	Pinus radiata	Fungus	9	21-Jun-04
Lachnellula suecica	Pinus radiata	Fungus	1	24-May-94
Lactarius rutus	Pinus radiata	Fungus	1	05-Feb-12
Lenzites betulina	Pinus radiata	Fungus	1	07-Jun-96
Lenzites sp.	Pinus radiata	Fungus	1	18-Oct-13
Lepidoderma sp	Pinus radiata	Fungus	2	24-Apr-98
Lepiota sp	Pinus radiata	Fungus	4	23-Mar-98
Leptoderma sp	Pinus radiata	Fungus	1	15-Aug-95
Leptographium alethinum	Pinus radiata	Fungus	2	06-Mar-05
Leptographium lundbergii	Pinus radiata	Fungus	19	17-Apr-86
Leptographium lundbergii?	Pinus radiata	Fungus	1	11-Jun-92
Leptographium procerum	Pinus radiata	Fungus	13	08-Feb-90
Leptographium sp	Pinus radiata	Fungus	119	15-May-91
Leptostroma sp	Pinus radiata	Fungus	25	21-Jan-83
Leptoxyphium sp	Pinus radiata	Fungus	1	18-Apr-02
Leucoagaricus naucinus	Pinus radiata	Fungus	1	23-Apr-98
Leucogyrophana sp.	Pinus radiata	Fungus	1	29-May-14
Libertella sp	Pinus radiata	Fungus	1	18-Nov-81
Licea sp	Pinus radiata	Fungus	1	31-Oct-83
Lophium mytilinum	Pinus radiata	Fungus	1	12-Jul-91
Lophium sp	Pinus radiata	Fungus	3	06-Sep-79
Lophodermium conigenum	Pinus radiata	Fungus	186	25-Sep-84
Lophodermium nitens	Pinus radiata	Fungus	1	15-Oct-98
Lophodermium pinastri	Pinus radiata	Fungus	76	27-Nov-76
Lophodermium sp	Pinus radiata	Fungus	393	11-Jun-86
Lycogala epidendrum	Pinus radiata	Fungus	3	15-Feb-01
Lycoperdon perlatum	Pinus radiata	Fungus	3	14-Mar-91
Macrolepiota dolichaula	Pinus radiata	Fungus	1	28-Apr-94
Marasmius sp	Pinus radiata	Fungus	1	09-Apr-96
Mariannaea elegans	Pinus radiata	Fungus	2	14-Apr-97
Meiorganum curtisii	Pinus radiata	Fungus	1	08-Mar-07
Melanospora sp	Pinus radiata	Fungus	2	26-Sep-94
Melanotus hepatochrous	Pinus radiata	Fungus	2	20-Sep-96
Microsphaeropsis olivacea	Pinus radiata	Fungus	1	24-May-94
Microsphaeropsis sp	Pinus radiata	Fungus	2	12-Oct-94
Monodictys sp	Pinus radiata	Fungus	1	28-Sep-99
Mortierella sp.	Pinus radiata	Fungus	3	14-Aug-19
Mucor sp	Pinus radiata	Fungus	15	27-Jul-81
Mycena flavescens	Pinus radiata	Fungus	1	30-Jun-01

Mycena minirubra	Pinus radiata	Fungus	1	17-Dec-01
Mycena pura	Pinus radiata	Fungus	1	30-Jun-01
Mycena sp	Pinus radiata	Fungus	4	12-Apr-96
Naemospora sp	Pinus radiata	Fungus	2	07-Dec-93
Naucoria sp	Pinus radiata	Fungus	1	20-Jun-95
Nectria cinnabarina	Pinus radiata	Fungus	8	04-Feb-92
Nectria sp	Pinus radiata	Fungus	5	01-Aug-83
Neoascochyta paspali	Pinus radiata	Fungus	1	30-Jul-19
Neocatenulostroma abietis	Pinus radiata	Fungus	11	16-Sep-77
Neofusicoccum luteum	Pinus radiata	Fungus	6	20-Jun-07
Neofusicoccum parvum	Pinus radiata	Fungus	2	28-Jan-88
Neolentinus lepideus	Pinus radiata	Fungus	6	08-Feb-91
Neonectria fuckeliana	Pinus radiata	Fungus	32	05-Dec-00
Neonectria sp	Pinus radiata	Fungus	3	22-May-13
Neurospora intermedia	Pinus radiata	Fungus	1	30-Oct-08
Neurospora sp	Pinus radiata	Fungus	1	08-Aug-13
Nigraspora sp	Pinus radiata	Fungus	4	04-Nov-08
Nigrospora	Pinus radiata	Fungus	1	06-Apr-82
Nigrospora oryzae	Pinus radiata	Fungus	1	20-Feb-20
Nothophaeocryptopus gaeumannii	Pinus radiata	Fungus	1	28-Sep-17
Oidiodendron sp	Pinus radiata	Fungus	1	10-Mar-94
Oligoporus sp	Pinus radiata	Fungus	1	14-Nov-95
Ophiostoma floccosum	Pinus radiata	Fungus	1	11-Dec-19
Ophiostoma ips	Pinus radiata	Fungus	2	01-May-19
Ophiostoma piceae	Pinus radiata	Fungus	6	17-Dec-92
Ophiostoma sp	Pinus radiata	Fungus	22	06-Dec-84
Ophiostomataceae	Pinus radiata	Fungus	3	23-Oct-19
Paecilomyces sp	Pinus radiata	Fungus	1	30-May-94
Paxillus panuoides	Pinus radiata	Fungus	8	20-Feb-86
Penicillium sp	Pinus radiata	Fungus	14	30-Jun-93
Peniophora sp	Pinus radiata	Fungus	12	15-Aug-83
Pesotum sp	Pinus radiata	Fungus	4	16-Apr-91
Pestalotia sp	Pinus radiata	Fungus	136	21-Jan-86
Pestalotiopsis clavispora	Pinus radiata	Fungus	1	07-Dec-07
Pestalotiopsis funerea	Pinus radiata	Fungus	16	06-Apr-72
Pestalotiopsis pinastri	Pinus radiata	Fungus	1	26-Mar-98
Pestalotiopsis sp	Pinus radiata	Fungus	191	20-Dec-99
Pestalotiopsis stevensonii	Pinus radiata	Fungus	6	30-Jun-00
Pezicula eucrita	Pinus radiata	Fungus	3	23-May-19
Pezicula sp.	Pinus radiata	Fungus	1	06-Sep-16
Phacidiaceae	Pinus radiata	Fungus	1	13-Jun-19
Phacidiopycnis sp	Pinus radiata	Fungus	27	14-Oct-92
Phaeolus schweinitzii	Pinus radiata	Fungus	7	07-Apr-08
Phallobata alba	Pinus radiata	Fungus	1	14-Jun-00
Phanerochaete sordida	Pinus radiata	Fungus	1	14-Apr-08
Phialocephala fortinii	Pinus radiata	Fungus	1	14-Aug-19
Phialophora sp	Pinus radiata	Fungus	5	26-May-98
Phlebiopsis gigantea	Pinus radiata	Fungus	11	21-Sep-61
Pholiota sp	Pinus radiata	Fungus	1	30-Jan-08
Phoma leveillei	Pinus radiata	Fungus	2	28-May-92
Phoma sp	Pinus radiata	Fungus	35	27-Jun-72
Phoma? Sp	Pinus radiata	Fungus	48	12-Sep-84
Phomopsis sp	Pinus radiata	Fungus	143	07-Nov-89
Phragmidium violaceum	Pinus radiata	Fungus	1	04-Apr-95
Phyllachora sp	Pinus radiata	Fungus	1	11-Nov-99
Phyllosticta sp	Pinus radiata	Fungus	1	15-Sep-67
Physalospora sp	Pinus radiata	Fungus	1	31-May-04
Phytophthora aleatoria	Pinus radiata	Fungus	4	15-Aug-19
Phytophthora cactorum	Pinus radiata	Fungus	42	04-Aug-00
Phytophthora chlamydospora	Pinus radiata	Fungus	1	16-Oct-19

Phytophthora cinnamomi	Pinus radiata	Fungus	135	13-Oct-89
Phytophthora citricola	Pinus radiata	Fungus	6	11-Nov-99
Phytophthora citrophthora	Pinus radiata	Fungus	1	18-Jul-96
Phytophthora cryptogea	Pinus radiata	Fungus	6	23-Feb-12
Phytophthora gonapodyides	Pinus radiata	Fungus	1	22-Nov-16
Phytophthora kernoviae	Pinus radiata	Fungus	83	17-Nov-06
Phytophthora multivora	Pinus radiata	Fungus	4	26-Apr-11
Phytophthora pluvialis	Pinus radiata	Fungus	279	02-Jul-08
Phytophthora sp	Pinus radiata	Fungus	315	21-May-66
Phytopythium litorale	Pinus radiata	Fungus	1	11-Oct-17
Phytopythium vexans	Pinus radiata	Fungus	1	14-Jun-19
Pithomyces sp	Pinus radiata	Fungus	2	30-May-94
Pleiochaeta sp	Pinus radiata	Fungus	1	30-Jun-93
Pleospora herbarum	Pinus radiata	Fungus	2	25-Oct-78
Pleospora sp	Pinus radiata	Fungus	4	01-May-69
Pleurococcus baegelii	Pinus radiata	Fungus	5	16-Mar-01
Pleurococcus sp	Pinus radiata	Fungus	5	22-Apr-92
Pleurotus decorus	Pinus radiata	Fungus	1	08-May-70
Pleurotus purpureoolivaceus	Pinus radiata	Fungus	1	11-Jun-97
Pleurotus sp	Pinus radiata	Fungus	1	06-May-98
Podoscypha petalodes subsp. floriformis	Pinus radiata	Fungus	1	25-Jun-98
Polyporus sp	Pinus radiata	Fungus	1	14-Jun-01
Poria sp	Pinus radiata	Fungus	2	26-May-94
Postia balsamea	Pinus radiata	Fungus	1	22-Jun-18
Postia dissecta	Pinus radiata	Fungus	1	05-Nov-13
Potebniomyces pyri	Pinus radiata	Fungus	1	23-Apr-12
Psathyrella sp	Pinus radiata	Fungus	2	22-May-98
Pseudohydnum gelatinosum	Pinus radiata	Fungus	1	09-Aug-96
Pseudomonas sp	Pinus radiata	Fungus	4	25-Nov-80
Pseudomonas syringae	Pinus radiata	Fungus	32	30-May-85
Pseudomonas syringae pv. syringae	Pinus radiata	Fungus	2	06-May-88
Pseudozyma aphidis	Pinus radiata	Fungus	1	26-Jun-13
Pullularia sp	Pinus radiata	Fungus	1	27-Mar-69
Punctularia strigoso-zonata	Pinus radiata	Fungus	1	14-Apr-16
Pythium acanthicum	Pinus radiata	Fungus	1	01-Oct-93
Pythium dissotocum	Pinus radiata	Fungus	1	13-Aug-18
Pythium echinulatum	Pinus radiata	Fungus	6	13-Apr-99
Pythium irregulare	Pinus radiata	Fungus	3	22-Apr-97
Pythium macrosporum	Pinus radiata	Fungus	1	19-Sep-16
Pythium paroecandrum	Pinus radiata	Fungus	1	10-Jul-72
Pythium senticosum	Pinus radiata	Fungus	1	13-Jun-19
Pythium sp	Pinus radiata	Fungus	22	22-Apr-82
Pythium ultimum	Pinus radiata	Fungus	2	15-Jul-96
Resinicium bicolor	Pinus radiata	Fungus	6	18-May-99
Reticularia lycoperdon	Pinus radiata	Fungus	2	04-Nov-19
Rhizoctonia solani	Pinus radiata	Fungus	9	05-Apr-93
Rhizoctonia sp	Pinus radiata	Fungus	15	29-May-91
Rhizopogon rubescens	Pinus radiata	Fungus	1	12-Feb-00
Rhizosphaera kalkhoffii	Pinus radiata	Fungus	5	31-Mar-09
Rhizosphaera sp	Pinus radiata	Fungus	4	15-Apr-91
Rigidoporus sp	Pinus radiata	Fungus	1	07-Jul-83
Rosellinia radiciperda	Pinus radiata	Fungus	4	24-Mar-65
Rosellinia sp	Pinus radiata	Fungus	30	11-Mar-91
Rosulomyces sp	Pinus radiata	Fungus	1	28-Apr-95
Russula sp	Pinus radiata	Fungus	2	12-Mar-15
Sarea resinae	Pinus radiata	Fungus	13	01-Jan-92
Schizophyllum commune	Pinus radiata	Fungus	7	20-May-98
Scleroderma australe	Pinus radiata	Fungus	1	20-May-98
Scleroderma bovista	Pinus radiata	Fungus	7	09-May-91
Scleroderma sp	Pinus radiata	Fungus	6	23-Mar-98

Sclerodermatales	Pinus radiata	Fungus	1	26-Apr-98
Sclerophoma sp	Pinus radiata	Fungus	326	26-Feb-76
Scutellinia kerguelensis	Pinus radiata	Fungus	1	11-Apr-96
Scytalidium sp	Pinus radiata	Fungus	1	29-Aug-06
Seimatosporium sp	Pinus radiata	Fungus	1	04-Jun-10
Septoria sp	Pinus radiata	Fungus	2	14-Apr-69
Sirodothis? Sp	Pinus radiata	Fungus	1	03-Sep-86
Sistotrema sp	Pinus radiata	Fungus	1	27-Jun-03
Skeletocutis amorpha	Pinus radiata	Fungus	2	07-Aug-90
Skeletocutis sp	Pinus radiata	Fungus	1	22-Jun-01
Sordaria sp	Pinus radiata	Fungus	1	17-Sep-08
Sphaeropsis sp	Pinus radiata	Fungus	1	04-Jun-15
Sporothrix inflata	Pinus radiata	Fungus	1	30-May-14
Sporothrix sp	Pinus radiata	Fungus	4	04-Mar-93
Stemonitis splendens	Pinus radiata	Fungus	1	14-Dec-95
Stemphylium botryosum	Pinus radiata	Fungus	1	25-Apr-00
Stemphylium sp	Pinus radiata	Fungus	20	09-May-75
Stereum sanguinolentum	Pinus radiata	Fungus	8	11-Mar-95
Stereum sp	Pinus radiata	Fungus	2	17-May-96
Stereum vellereum	Pinus radiata	Fungus	1	17-Sep-19
Stictis sp	Pinus radiata	Fungus	1	05-May-03
Stilbella sp	Pinus radiata	Fungus	1	30-Apr-01
Strasseria carpophila	Pinus radiata	Fungus	1	30-Aug-77
Strasseria geniculata	Pinus radiata	Fungus	334	22-Feb-79
Strasseria sp	Pinus radiata	Fungus	104	18-May-84
Strobilurus sp	Pinus radiata	Fungus	1	21-May-98
Stropharia rugosoannulata	Pinus radiata	Fungus	1	17-Nov-95
Sydowia polyspora	Pinus radiata	Fungus	144	23-Feb-93
Thelephora terrestris	Pinus radiata	Fungus	18	10-Jun-92
Thelonectria discophora	Pinus radiata	Fungus	35	02-Nov-76
Thelonectria sp.	Pinus radiata	Fungus	5	10-Apr-15
Thelonectria torulosa	Pinus radiata	Fungus	1	05-Dec-19
Thelonectria trachosa	Pinus radiata	Fungus	1	27-May-14
Thelonectria veuillotiana	Pinus radiata	Fungus	13	15-May-11
Tomentella ferruginea	Pinus radiata	Fungus	1	16-Jun-16
Tomentella pilosa	Pinus radiata	Fungus	1	31-Jan-74
Torula sp	Pinus radiata	Fungus	4	30-Aug-89
Trametes coccinea	Pinus radiata	Fungus	12	05-Sep-84
Trametes sp	Pinus radiata	Fungus	1	28-Jul-99
Trametes versicolor	Pinus radiata	Fungus	1	02-Jun-14
Trichoderma ghanense	Pinus radiata	Fungus	1	21-Mar-19
Trichoderma sp	Pinus radiata	Fungus	68	03-Jan-60
Trichoderma viride	Pinus radiata	Fungus	13	27-Mar-92
Tricholoma pessundatum	Pinus radiata	Fungus	3	19-Apr-00
Tricholoma sp	Pinus radiata	Fungus	2	09-Jul-85
Tricholoma terreum	Pinus radiata	Fungus	2	24-Jun-98
Tricholomopsis rutilans	Pinus radiata	Fungus	5	04-May-81
Trichothecium crotocinigenum	Pinus radiata	Fungus	1	18-Sep-19
Trichothecium roseum	Pinus radiata	Fungus	2	13-Nov-00
Trimmatostroma sp	Pinus radiata	Fungus	5	24-Apr-13
Truncatella sp	Pinus radiata	Fungus	1	30-Jun-10
Tubercularia sp	Pinus radiata	Fungus	2	29-Nov-83
Tubercularia vulgaris	Pinus radiata	Fungus	22	11-Nov-84
Tyromyces atrostrigosus	Pinus radiata	Fungus	1	07-May-99
Tyromyces setiger	Pinus radiata	Fungus	4	14-Apr-86
Umbelopsis sp.	Pinus radiata	Fungus	1	25-Jun-18
Uromyces trifolii	Pinus radiata	Fungus	1	10-May-84
Usnea sp	Pinus radiata	Fungus	1	21-May-91
Valsaria rubricosa	Pinus radiata	Fungus	30	17-Apr-13
Verticillium sp	Pinus radiata	Fungus	4	01-Oct-81

Verticimonosporium sp	Pinus radiata	Fungus	1	07-Dec-93
Weraroa erythrocephala	Pinus radiata	Fungus	1	31-Jul-60
Xerocomus chrysenteron	Pinus radiata	Fungus	1	15-Mar-95
Xylobolus illudens	Pinus radiata	Fungus	1	12-Dec-01
Zythiostroma sp	Pinus radiata	Fungus	10	15-Jan-97
Zythiostroma? Sp	Pinus radiata	Fungus	2	13-Oct-82
?Doryctes sp	Pinus radiata	Insect	1	18-Feb-93
?Ernobius mollis	Pinus radiata	Insect	1	27-Sep-94
?Hylastes/hylurgus	Pinus radiata	Insect	1	08-Dec-95
?Somatidia sp	Pinus radiata	Insect	1	16-Mar-94
?Strongylopterus chathamensis	Pinus radiata	Insect	1	15-Nov-93
?Thrips	Pinus radiata	Insect	2	22-May-95
?Torostoma apicale	Pinus radiata	Insect	1	24-Oct-95
Acalles sp	Pinus radiata	Insect	1	30-Oct-98
Acanthoxyla sp	Pinus radiata	Insect	2	19-May-65
Acroceridae	Pinus radiata	Insect	1	11-Feb-98
Adalia bipunctata	Pinus radiata	Insect	1	18-Feb-85
Aderidae	Pinus radiata	Insect	1	24-Nov-09
Adoxia sp	Pinus radiata	Insect	1	09-Nov-17
Aenictopecheidae	Pinus radiata	Insect	1	07-Mar-19
Agapanthida pulchella	Pinus radiata	Insect	2	29-Apr-94
Agastegnus sp	Pinus radiata	Insect	2	24-Jan-72
Agonocheila antipodum	Pinus radiata	Insect	5	18-Feb-85
Agrotis ipsilon aneituma	Pinus radiata	Insect	1	12-Nov-02
Agrypnus vandepolli	Pinus radiata	Insect	3	05-May-93
Agrypnus variabilis	Pinus radiata	Insect	1	03-May-16
Aletia ?moderata	Pinus radiata	Insect	1	23-Jan-98
Alticini	Pinus radiata	Insect	1	12-Nov-08
Amarygmus sp	Pinus radiata	Insect	1	10-Aug-04
Amarygmus watti	Pinus radiata	Insect	3	02-Mar-95
Amasa truncata	Pinus radiata	Insect	1	04-Apr-90
Ambeodontus tristis	Pinus radiata	Insect	2	06-Jan-93
Amblyopone australis	Pinus radiata	Insect	9	25-Feb-82
Amphipsalta sp	Pinus radiata	Insect	13	29-May-99
Anagotus helmsi	Pinus radiata	Insect	4	19-Feb-80
Ancistrocerus gazella	Pinus radiata	Insect	2	14-Apr-94
Aneurus zealandensis	Pinus radiata	Insect	1	22-Nov-18
Anisolabis littorea	Pinus radiata	Insect	1	10-Jan-95
Annelidea	Pinus radiata	Insect	1	22-Apr-97
Anobiidae	Pinus radiata	Insect	14	02-Dec-87
Anthicidae	Pinus radiata	Insect	1	14-Mar-17
Anthocoridae	Pinus radiata	Insect	1	07-Mar-90
Anthribidae	Pinus radiata	Insect	3	27-Nov-84
Anthribidae?	Pinus radiata	Insect	1	27-Nov-84
Anthribus sp	Pinus radiata	Insect	2	07-Aug-64
Apanteles glomeratus	Pinus radiata	Insect	1	12-Mar-70
Apanteles sp	Pinus radiata	Insect	3	07-Mar-85
Aphididae	Pinus radiata	Insect	21	11-Jan-95
Aphis sp	Pinus radiata	Insect	3	05-Mar-99
Aphodius tasmaniae	Pinus radiata	Insect	1	02-Mar-95
Apis mellifera	Pinus radiata	Insect	1	27-Nov-03
Aradidae	Pinus radiata	Insect	3	24-Dec-12
Araecerus palmaris	Pinus radiata	Insect	2	21-Feb-95
Aranea	Pinus radiata	Insect	1	15-May-01
Araneae	Pinus radiata	Insect	3	06-Mar-19
Archaeoglenes costipennis	Pinus radiata	Insect	1	17-Dec-18
Arhopalus ferus	Pinus radiata	Insect	158	11-Nov-76
Arhopalus sp.	Pinus radiata	Insect	2	23-Oct-75
Arion hortensis	Pinus radiata	Insect	1	07-Jul-78
Arthropoda	Pinus radiata	Insect	1	07-Nov-14

Artystona erichsoni	Pinus radiata	Insect	1	19-Aug-96
Artystona rugiceps	Pinus radiata	Insect	6	09-Feb-95
Artystona sp	Pinus radiata	Insect	14	18-Feb-85
Arytainilla spartiophila	Pinus radiata	Insect	1	21-Nov-14
Ascetoderes sp.	Pinus radiata	Insect	1	28-May-15
Asilidae	Pinus radiata	Insect	1	20-Nov-03
Asynonychus cervinus	Pinus radiata	Insect	10	30-Mar-89
Atrichatus aeneicollis	Pinus radiata	Insect	1	10-Nov-86
Aucklandella sp	Pinus radiata	Insect	5	29-Mar-93
Baculipalpus strigipennis	Pinus radiata	Insect	2	21-Feb-79
Baculipennis mollis	Pinus radiata	Insect	2	24-Nov-11
Balcus niger	Pinus radiata	Insect	3	18-Jan-95
Balcus sp	Pinus radiata	Insect	2	18-Dec-97
Barea confusella	Pinus radiata	Insect	1	21-Jun-91
Bethelium diversicorne	Pinus radiata	Insect	2	18-Feb-92
Bibionidae	Pinus radiata	Insect	5	13-Dec-95
Bitoma insularis	Pinus radiata	Insect	5	30-Sep-09
Bitoma rugosa	Pinus radiata	Insect	1	14-May-93
Bitoma sp	Pinus radiata	Insect	5	25-Mar-04
Bitoma sp.	Pinus radiata	Insect	4	02-Apr-15
Blosyropus spinosus	Pinus radiata	Insect	2	16-May-84
Blosyropus? spinosus	Pinus radiata	Insect	1	16-Jan-85
Bothrideres sp	Pinus radiata	Insect	1	09-Sep-87
Bothrideridae	Pinus radiata	Insect	3	20-Mar-13
Brachymopus sp	Pinus radiata	Insect	1	01-Mar-06
Brachynopus rufus	Pinus radiata	Insect	1	04-Jan-05
Braconidae	Pinus radiata	Insect	3	16-Jul-08
Bradysia sp	Pinus radiata	Insect	1	03-Nov-10
Brontopriscus pleuralis	Pinus radiata	Insect	5	12-Mar-96
Brontopriscus sp.	Pinus radiata	Insect	1	15-Jul-15
Browse	Pinus radiata	Insect	1	16-Oct-01
Byrrhidae	Pinus radiata	Insect	2	09-Mar-06
Cacephatus incertus	Pinus radiata	Insect	1	25-Feb-20
Cacephatus sp	Pinus radiata	Insect	1	12-Mar-13
Caedicia simplex	Pinus radiata	Insect	1	28-Feb-90
Cambridgea sp	Pinus radiata	Insect	1	23-Jun-05
Campoplex sp	Pinus radiata	Insect	1	08-Dec-06
Carabidae	Pinus radiata	Insect	4	27-Jul-98
Carystoterpa sp	Pinus radiata	Insect	1	07-Feb-12
Catoptes binodis	Pinus radiata	Insect	2	23-Feb-72
Catoptes censorius	Pinus radiata	Insect	1	01-Nov-83
Catoptes sp	Pinus radiata	Insect	1	08-Nov-85
Cebysa leucotelus	Pinus radiata	Insect	1	19-Feb-19
Celatoblatta sp	Pinus radiata	Insect	1	26-Apr-06
Centipede	Pinus radiata	Insect	1	13-Oct-05
Cerambycidae	Pinus radiata	Insect	9	15-Jan-74
Ceratopogonidae	Pinus radiata	Insect	1	24-Jul-09
Cercopidae	Pinus radiata	Insect	1	01-Jan-01
Cermatulus nasalis nasalis	Pinus radiata	Insect	6	17-Nov-98
Ceroplastes sinensis	Pinus radiata	Insect	1	20-Jun-85
Certonotus fractinervis	Pinus radiata	Insect	1	05-Mar-73
Chaetedus sp	Pinus radiata	Insect	1	16-Jun-00
Chinamiris sp	Pinus radiata	Insect	3	09-May-13
Chiracanthium stratioticum	Pinus radiata	Insect	1	16-Mar-01
Chrysodeixis eriosoma	Pinus radiata	Insect	1	18-Jan-89
Chrysomela hyperici	Pinus radiata	Insect	2	27-Apr-98
Chrysomelidae	Pinus radiata	Insect	2	24-Oct-01
Cicadellidae	Pinus radiata	Insect	1	14-Dec-16
Cicadidae	Pinus radiata	Insect	2	12-Nov-91
Cicindela sp	Pinus radiata	Insect	1	20-Jan-16

Cicindela tuberculata	Pinus radiata	Insect	2	11-Mar-97
Cicindelidae	Pinus radiata	Insect	1	12-Jan-17
Cinara sp	Pinus radiata	Insect	1	20-Jan-99
Cleopus japonicus	Pinus radiata	Insect	1	26-Feb-20
Cleridae	Pinus radiata	Insect	1	11-Jun-11
Clitarchus sp	Pinus radiata	Insect	1	18-Apr-85
Coccidae	Pinus radiata	Insect	1	02-Oct-03
Coccinella leonina	Pinus radiata	Insect	3	03-Dec-82
Coccinellidae	Pinus radiata	Insect	3	17-Aug-05
Coccus hesperidum	Pinus radiata	Insect	13	18-Mar-65
Coccus longulus	Pinus radiata	Insect	1	12-Jun-19
Coccus sp	Pinus radiata	Insect	1	04-Sep-04
Coelostomidia pilosa	Pinus radiata	Insect	1	14-Feb-99
Coelostomidia wairoensis	Pinus radiata	Insect	1	27-Jul-84
Col.corylophidae	Pinus radiata	Insect	1	23-May-00
Coleoperous larvae	Pinus radiata	Insect	1	17-Jan-85
Coleoptera	Pinus radiata	Insect	6	20-Apr-95
Collembola	Pinus radiata	Insect	9	15-Sep-96
Colpodes sp	Pinus radiata	Insect	1	27-Jun-06
Coptomma variegatum	Pinus radiata	Insect	2	22-Oct-04
Corylophidae	Pinus radiata	Insect	2	20-Apr-98
Cossonid sp	Pinus radiata	Insect	1	07-Sep-76
Cossoninae	Pinus radiata	Insect	5	27-Mar-96
Costelytra sp	Pinus radiata	Insect	1	17-Oct-17
Costelytra zealandica	Pinus radiata	Insect	3	14-May-99
Cotes sp	Pinus radiata	Insect	1	25-Sep-19
Crabronidae	Pinus radiata	Insect	1	03-Mar-18
Crambidae	Pinus radiata	Insect	1	16-Feb-17
Crisius binotatus	Pinus radiata	Insect	2	15-Sep-81
Cryphalus wapleri	Pinus radiata	Insect	1	28-Sep-99
Cryptamorpha brevicornis	Pinus radiata	Insect	1	20-Nov-19
Cryptamorpha desjardinsi	Pinus radiata	Insect	1	20-Nov-19
Cryptarcha optanda	Pinus radiata	Insect	3	25-May-00
Cryptarcha sp.	Pinus radiata	Insect	1	27-Apr-19
Cryptocheilus australis	Pinus radiata	Insect	1	11-Mar-96
Cryptomorpha brevicornis	Pinus radiata	Insect	2	16-Jun-97
Cryptomorpha sp	Pinus radiata	Insect	2	25-Jun-00
Cryptophagidae	Pinus radiata	Insect	2	08-Apr-98
Cryptophagus sp	Pinus radiata	Insect	1	05-Apr-72
Cryptorhynchinae	Pinus radiata	Insect	1	15-Feb-19
Cryptorhynchini	Pinus radiata	Insect	1	14-Jun-14
Ctenopseustis obliquana	Pinus radiata	Insect	52	09-Feb-89
Cucujidae	Pinus radiata	Insect	8	21-Nov-91
Culicidae	Pinus radiata	Insect	1	27-Jan-15
Curculionidae	Pinus radiata	Insect	64	08-Mar-90
Cutworm damage	Pinus radiata	Insect	1	27-May-82
Cynipoidea	Pinus radiata	Insect	1	12-May-99
Cyphon sp	Pinus radiata	Insect	1	11-Nov-04
Dasytes minuta	Pinus radiata	Insect	1	19-Nov-03
Dasytes sp	Pinus radiata	Insect	3	11-Dec-85
Declana floccosa	Pinus radiata	Insect	20	03-Jun-93
Degithina decepta	Pinus radiata	Insect	2	30-Jun-00
Deladenus siricidicola	Pinus radiata	Insect	4	09-Jan-92
Dermestidae	Pinus radiata	Insect	1	19-Oct-92
Diadegma sp	Pinus radiata	Insect	2	27-Mar-96
Diagrypnodes wakefieldi	Pinus radiata	Insect	2	08-Mar-78
Diaspididae	Pinus radiata	Insect	1	20-Jul-99
Dicranosterna semipunctata	Pinus radiata	Insect	2	03-Nov-03
Dilophus nigrostigma	Pinus radiata	Insect	1	08-Dec-03
Diplodia sapinea	Pinus radiata	Insect	1	10-Dec-12

Diptera	Pinus radiata	Insect	21	22-Oct-93
Dolomedes minor	Pinus radiata	Insect	1	17-Apr-01
Dryocora howitti	Pinus radiata	Insect	9	26-Jul-04
Dumbletonius characterifer	Pinus radiata	Insect	1	25-Nov-93
Eburida quadriguttata	Pinus radiata	Insect	1	27-Mar-95
Eburida sublineata	Pinus radiata	Insect	1	29-Jun-83
Eburilla sericea	Pinus radiata	Insect	3	06-Aug-96
Echthromorpha intricatoria	Pinus radiata	Insect	1	22-Sep-98
Eiratus parvulus	Pinus radiata	Insect	1	16-Oct-17
Elateridae	Pinus radiata	Insect	34	12-Mar-92
Empicorcis rubromaculatus	Pinus radiata	Insect	1	23-Feb-72
Enarsus bakewelli	Pinus radiata	Insect	2	20-Aug-96
Ephestia sp	Pinus radiata	Insect	1	28-Mar-95
Epiphyas postvittana	Pinus radiata	Insect	35	16-Apr-85
Epuraea sp	Pinus radiata	Insect	2	26-Oct-17
Epuraea zealandica	Pinus radiata	Insect	1	28-Jun-06
Epyaxa rosearia	Pinus radiata	Insect	1	12-Jun-97
Eriophora pustulosa	Pinus radiata	Insect	2	26-Feb-99
Ernobius mollis	Pinus radiata	Insect	16	18-Feb-93
Erotylidae	Pinus radiata	Insect	2	13-Nov-09
Erymneus sp.	Pinus radiata	Insect	1	22-Dec-17
Essigella californica	Pinus radiata	Insect	89	19-May-98
Etnalis spinicollis	Pinus radiata	Insect	1	01-Oct-17
Eucinetus stewarti	Pinus radiata	Insect	1	24-Dec-19
Euciodes suturalis	Pinus radiata	Insect	2	14-Dec-95
Eucolaspis brunnea	Pinus radiata	Insect	15	25-Jun-92
Eucolaspis sp	Pinus radiata	Insect	7	01-Mar-85
Eugnomus antennalis	Pinus radiata	Insect	1	23-Feb-93
Eugnomus fasciatus	Pinus radiata	Insect	3	27-Oct-72
Eugnomus maurus	Pinus radiata	Insect	1	14-Dec-72
Eugnomus sp	Pinus radiata	Insect	5	03-Dec-13
Eulachnus brevipilosus	Pinus radiata	Insect	11	21-May-98
Eulachnus sp	Pinus radiata	Insect	1	05-May-94
Euophryum confine	Pinus radiata	Insect	3	08-Jan-13
Euophryum rufum	Pinus radiata	Insect	1	23-Feb-72
Euophryum sp	Pinus radiata	Insect	2	09-Nov-76
Exapion ulicis	Pinus radiata	Insect	1	19-Feb-97
Formicidae	Pinus radiata	Insect	3	06-Apr-98
Gasteruptiidae	Pinus radiata	Insect	1	21-Nov-14
Gelinae	Pinus radiata	Insect	1	22-Apr-97
Gellonia dejectaria?	Pinus radiata	Insect	1	11-Dec-95
Gellonia pannularia	Pinus radiata	Insect	1	06-Aug-99
Geometridae	Pinus radiata	Insect	7	19-Nov-08
Glaucias amyoti	Pinus radiata	Insect	3	22-Mar-96
Glyptotermes brevicornis	Pinus radiata	Insect	1	16-Aug-19
Gracillariidae	Pinus radiata	Insect	1	22-Feb-99
Graphania mutans	Pinus radiata	Insect	3	02-Apr-93
Graphania? Sp	Pinus radiata	Insect	2	05-Apr-93
Guiglia schauinslandi	Pinus radiata	Insect	2	17-Nov-04
Gymnobathra hyetodes	Pinus radiata	Insect	1	14-Jan-18
Gymnobathra parca	Pinus radiata	Insect	1	10-Nov-99
Hadrobregmus magnus	Pinus radiata	Insect	3	01-Mar-95
Harmonia axyridis	Pinus radiata	Insect	2	12-Feb-19
Helicoverpa armigera conferta	Pinus radiata	Insect	17	16-Apr-85
Heliothrips haemorrhoidalis	Pinus radiata	Insect	83	26-Jun-70
Heliothrips sp	Pinus radiata	Insect	1	08-Oct-98
Helmoreus sharpi	Pinus radiata	Insect	1	19-Apr-19
Hemerobiidae	Pinus radiata	Insect	1	16-Dec-15
Hemiptera	Pinus radiata	Insect	6	13-Dec-95
Hepialidae	Pinus radiata	Insect	1	07-Nov-19

Heteronychus arator	Pinus radiata	Insect	3	09-Oct-93
Hexatricha pulverulenta	Pinus radiata	Insect	44	28-Nov-91
Hierodoris atychioides	Pinus radiata	Insect	23	06-Oct-88
Hierodoris sp	Pinus radiata	Insect	2	28-Nov-19
Histeridae	Pinus radiata	Insect	2	15-Mar-93
Holcaspis sp	Pinus radiata	Insect	1	07-Jan-72
Hoplocneme hookeri	Pinus radiata	Insect	3	24-Sep-98
Hoplocneme punctatissima	Pinus radiata	Insect	1	11-Dec-79
Hybolasius crista	Pinus radiata	Insect	3	21-Mar-00
Hybolasius modestus	Pinus radiata	Insect	1	17-Nov-99
Hybolasius sp	Pinus radiata	Insect	4	02-Mar-92
Hybolasius vegetus	Pinus radiata	Insect	1	26-Feb-05
Hydnangium carneum	Pinus radiata	Insect	1	09-Jan-12
Hydriomena deltoidata	Pinus radiata	Insect	1	25-Jan-01
Hylaeidae	Pinus radiata	Insect	1	31-Mar-87
Hylaeus sp	Pinus radiata	Insect	1	03-May-10
Hylastes ater	Pinus radiata	Insect	188	18-Mar-64
Hylastes sp	Pinus radiata	Insect	2	14-Jan-11
Hylastes/hylurgus?	Pinus radiata	Insect	1	01-Jun-94
Hylesininae	Pinus radiata	Insect	1	13-Jan-82
Hylurgus ligniperda	Pinus radiata	Insect	189	17-Nov-93
Hylurgus sp	Pinus radiata	Insect	1	24-Nov-94
Hymenoptera	Pinus radiata	Insect	3	28-Jan-03
Hymenopterous larvae	Pinus radiata	Insect	1	16-Oct-63
Ibalia leucospoides	Pinus radiata	Insect	9	16-Feb-81
Ibalia sp	Pinus radiata	Insect	7	31-Jan-84
Icerya purchasi	Pinus radiata	Insect	1	12-Sep-96
Ichneumon promissorius	Pinus radiata	Insect	3	20-Jan-99
Ichneumonidae	Pinus radiata	Insect	5	01-Sep-89
Idolothrips spectrum	Pinus radiata	Insect	1	13-Sep-07
Ischalis fortinata	Pinus radiata	Insect	1	26-Oct-94
Ischalis variabilis	Pinus radiata	Insect	1	26-Mar-04
Izatha sp	Pinus radiata	Insect	2	28-May-90
Kalasiris perforata	Pinus radiata	Insect	1	03-Sep-01
Kalotermes banksiae	Pinus radiata	Insect	3	29-Jan-88
Kalotermes brouni	Pinus radiata	Insect	46	21-Jan-92
Kalotermitidae	Pinus radiata	Insect	1	27-Jun-19
Kept for rearing	Pinus radiata	Insect	1	03-May-93
Kupeus sp	Pinus radiata	Insect	1	07-Feb-07
Lamiinae	Pinus radiata	Insect	3	20-Jun-74
Lasiorhynchus barbicornis	Pinus radiata	Insect	1	09-Mar-14
Lathridiidae	Pinus radiata	Insect	1	23-May-94
Lathridus sp	Pinus radiata	Insect	1	07-Mar-90
Leanobium flavomaculatum	Pinus radiata	Insect	2	19-Jan-96
Leanobium flavomaculatum?	Pinus radiata	Insect	1	19-Apr-90
Lebiinae	Pinus radiata	Insect	1	16-Oct-95
Leioproctus sp	Pinus radiata	Insect	2	10-Nov-18
Lepidoptera	Pinus radiata	Insect	25	02-Apr-93
Lepidoscia sp. nr lainodes	Pinus radiata	Insect	1	22-Aug-18
Leptachrous strigipennis	Pinus radiata	Insect	7	26-Jan-84
Lindingaspis rossi	Pinus radiata	Insect	5	22-Oct-85
Liothula omnivora	Pinus radiata	Insect	10	29-Apr-98
Liothula omnivora?	Pinus radiata	Insect	1	15-May-83
Liothula sp	Pinus radiata	Insect	1	01-May-19
Lissonota sp	Pinus radiata	Insect	2	17-Oct-97
Lissotes sp	Pinus radiata	Insect	1	05-May-95
Listroderes difficilis	Pinus radiata	Insect	1	22-Jan-73
Listroderes sp	Pinus radiata	Insect	1	10-Feb-98
Lucanidae	Pinus radiata	Insect	4	24-Jul-80
Lyctus brunneus	Pinus radiata	Insect	1	10-Feb-83

Lygaeidae	Pinus radiata	Insect	1	27-Jan-98
Lygaeidae?	Pinus radiata	Insect	1	12-Mar-92
Margarodidae	Pinus radiata	Insect	2	27-May-99
Mecodema sp	Pinus radiata	Insect	1	14-Aug-95
Mecyclothorax sp	Pinus radiata	Insect	2	18-Jun-07
Megadromus capito	Pinus radiata	Insect	1	12-Nov-04
Megadromus sp	Pinus radiata	Insect	1	30-Sep-98
Megadromus vigil	Pinus radiata	Insect	1	12-Apr-96
Megarhyssa nortoni nortoni	Pinus radiata	Insect	12	21-Nov-86
Melolonthinae	Pinus radiata	Insect	6	04-Nov-99
Melyridae	Pinus radiata	Insect	3	11-Jun-11
Mesocoton	Pinus radiata	Insect	1	29-Mar-06
Metablax acutipennis	Pinus radiata	Insect	1	05-Nov-87
Micrambina sp	Pinus radiata	Insect	1	26-Oct-04
Microcryptorhynchus sp	Pinus radiata	Insect	1	29-Mar-06
Millipede	Pinus radiata	Insect	2	13-May-92
Mimopeus sp	Pinus radiata	Insect	1	08-Nov-76
Miridae	Pinus radiata	Insect	2	08-Dec-00
Mitophyllus irroratus	Pinus radiata	Insect	1	23-May-91
Mitophyllus sp	Pinus radiata	Insect	1	21-Mar-77
Mitrastethus baridioides	Pinus radiata	Insect	51	14-Feb-77
Mitrastethus sp	Pinus radiata	Insect	1	19-Feb-02
Monomorium antarcticum	Pinus radiata	Insect	3	19-Jun-84
Monomorium antipodum	Pinus radiata	Insect	1	20-Sep-94
Monomorium sp	Pinus radiata	Insect	1	21-Mar-94
Mordellidae	Pinus radiata	Insect	1	11-Mar-93
Mycetophilidae	Pinus radiata	Insect	2	05-May-92
Mythimna separata?	Pinus radiata	Insect	2	24-Sep-92
Mythimna sp	Pinus radiata	Insect	1	01-Oct-13
Myzus sp	Pinus radiata	Insect	1	18-May-99
Nabis kinbergii	Pinus radiata	Insect	1	16-Mar-06
Naupactus leucoloma	Pinus radiata	Insect	5	18-Mar-92
Navomorpha lineata	Pinus radiata	Insect	11	09-Dec-91
Navomorpha sulcata	Pinus radiata	Insect	7	23-Jul-63
Nematocera	Pinus radiata	Insect	3	15-Jan-92
Nematoda	Pinus radiata	Insect	3	27-Oct-93
Neocicindela ? tuberculata	Pinus radiata	Insect	1	31-Jan-96
Neomyzus circumflexus	Pinus radiata	Insect	1	07-Mar-19
Neuroptera	Pinus radiata	Insect	3	03-Mar-99
Neuropteron	Pinus radiata	Insect	1	12-May-99
Nezara viridula	Pinus radiata	Insect	2	31-Mar-06
Nitidula sp	Pinus radiata	Insect	2	12-Mar-96
Nitidulidae	Pinus radiata	Insect	7	27-Aug-98
Noctuidae	Pinus radiata	Insect	9	05-Apr-93
Nomia melanderi	Pinus radiata	Insect	1	04-Dec-01
Nosodendridae	Pinus radiata	Insect	1	19-May-14
Nyctemera amica	Pinus radiata	Insect	1	21-Jun-05
Nyctemera annulata	Pinus radiata	Insect	3	02-Oct-96
Nysius caledoniae	Pinus radiata	Insect	1	27-Apr-19
Nysius huttoni	Pinus radiata	Insect	1	27-Jan-10
Ochrocydus huttoni	Pinus radiata	Insect	1	16-Jun-99
Odontomyia chloris	Pinus radiata	Insect	1	22-Feb-96
Odontria ?sylvatica	Pinus radiata	Insect	1	18-Aug-93
Odontria sp	Pinus radiata	Insect	7	23-Feb-84
Odontria sylvatica	Pinus radiata	Insect	2	02-Mar-95
Oechalia schellenbergii	Pinus radiata	Insect	2	26-Nov-12
Oedemeridae	Pinus radiata	Insect	6	12-Jun-12
Oemona hirta	Pinus radiata	Insect	16	08-Apr-81
Oemona separata?	Pinus radiata	Insect	1	05-May-94
Onthophagus sp	Pinus radiata	Insect	1	02-May-93

Onychiuridae	Pinus radiata	Insect	1	29-Mar-06
Ophryops sp.	Pinus radiata	Insect	1	27-Jun-84
Opogona comptella	Pinus radiata	Insect	1	19-Jan-18
Oribatida	Pinus radiata	Insect	1	09-Oct-18
Oribatidae	Pinus radiata	Insect	3	07-Sep-67
Orocrambus flexuosellus	Pinus radiata	Insect	2	22-Feb-91
Orocrambus ramosellus	Pinus radiata	Insect	1	17-Nov-98
Orocrambus sp	Pinus radiata	Insect	1	03-Feb-98
Orthodera novaezealandiae	Pinus radiata	Insect	1	15-Mar-02
Otiorhynchus ovatus	Pinus radiata	Insect	2	03-Feb-87
Pachycondyla castanea	Pinus radiata	Insect	7	01-Dec-92
Pachycotes peregrinus	Pinus radiata	Insect	96	11-Dec-79
Pachyderris sp	Pinus radiata	Insect	1	19-Feb-79
Pachyurinus sp	Pinus radiata	Insect	1	05-Nov-98
Pactola variabilis	Pinus radiata	Insect	1	28-Nov-72
Parabrontes	Pinus radiata	Insect	1	18-Jun-07
Parabrontes silvanoides	Pinus radiata	Insect	1	15-May-90
Parisopalpus thoracicus	Pinus radiata	Insect	2	08-Jan-85
Parlatoria pittospori	Pinus radiata	Insect	9	20-Aug-74
Parlatoria sp	Pinus radiata	Insect	1	04-Oct-13
Parmius debilis	Pinus radiata	Insect	2	02-Nov-84
Paropsis charybdis	Pinus radiata	Insect	1	25-Jan-05
Pasiphila ? sp	Pinus radiata	Insect	1	03-May-93
Pasiphila? paralodes	Pinus radiata	Insect	1	31-May-94
Pedilophorus humeralis ?	Pinus radiata	Insect	2	30-Mar-88
Pentarthrum sp	Pinus radiata	Insect	4	21-Mar-77
Pentarthrum zealandicum	Pinus radiata	Insect	2	13-Mar-13
Pentatomidae	Pinus radiata	Insect	8	16-Aug-89
Pericoptus truncatus	Pinus radiata	Insect	1	28-Nov-03
Peristoreus sp	Pinus radiata	Insect	2	13-Dec-12
Persectania sp	Pinus radiata	Insect	1	08-Dec-93
Philaenus spumarius	Pinus radiata	Insect	2	22-Feb-17
Philothermus sp.	Pinus radiata	Insect	1	06-Jan-18
Phloeophagosoma dilutum	Pinus radiata	Insect	1	19-Sep-11
Phloeophagosoma sp	Pinus radiata	Insect	5	09-May-13
Phloeophagosoma thoracicum	Pinus radiata	Insect	9	17-Nov-80
Phlyctinus callosus	Pinus radiata	Insect	1	13-May-91
Phrynixus sp	Pinus radiata	Insect	1	05-Apr-72
Phrynixus terreus	Pinus radiata	Insect	7	23-Nov-79
Phymatus cucullatus	Pinus radiata	Insect	1	23-Oct-86
Phymatus hetaera	Pinus radiata	Insect	4	10-Dec-90
Phymatus phymatodes	Pinus radiata	Insect	2	14-May-93
Pieris rapae	Pinus radiata	Insect	1	12-Mar-70
Pineus pini	Pinus radiata	Insect	60	04-Mar-76
Pineus sp	Pinus radiata	Insect	26	05-Dec-73
Pison sp.	Pinus radiata	Insect	1	19-Nov-19
Planotortrix excessana	Pinus radiata	Insect	2	07-Mar-85
Planotortrix notophaea	Pinus radiata	Insect	26	16-Apr-85
Planotortrix sp	Pinus radiata	Insect	2	26-Mar-02
Platygastridae	Pinus radiata	Insect	1	23-Nov-18
Platynus macropterus	Pinus radiata	Insect	1	25-Jun-15
Platypus apicalis	Pinus radiata	Insect	51	01-Nov-84
Platypus gracilis	Pinus radiata	Insect	2	28-May-91
Platypus sp	Pinus radiata	Insect	2	25-Jun-80
Platyzosteria novaeseelandiae	Pinus radiata	Insect	1	04-Mar-80
Plecoptera	Pinus radiata	Insect	1	28-Jan-97
Plocamostethus sp	Pinus radiata	Insect	1	23-Oct-03
Podagrion sp	Pinus radiata	Insect	1	17-Nov-95
Poecilasthena pulchraria	Pinus radiata	Insect	1	30-Apr-92
Poecilasthena sp.	Pinus radiata	Insect	1	04-Apr-02

Poecilasthena subpurpureata	Pinus radiata	Insect	2	21-May-96
Pogonorhinus opacus	Pinus radiata	Insect	1	09-Sep-08
Pogonorhinus sp	Pinus radiata	Insect	1	01-Sep-05
Polistes chinensis	Pinus radiata	Insect	3	10-Mar-96
Polistes humilis	Pinus radiata	Insect	2	22-Jul-81
Porrostoma rufipennis	Pinus radiata	Insect	2	11-Dec-06
Priateles optandus	Pinus radiata	Insect	1	11-May-12
Priocnemis monachus	Pinus radiata	Insect	3	02-Sep-93
Prionoplus reticularis	Pinus radiata	Insect	122	10-Nov-76
Pristoderus antarcticus	Pinus radiata	Insect	9	25-Jan-72
Pristoderus sp	Pinus radiata	Insect	2	28-Jun-96
Pristoderus viridipictus	Pinus radiata	Insect	2	18-Aug-89
Procyliosoma sp	Pinus radiata	Insect	1	28-Feb-03
Protelater elongatus	Pinus radiata	Insect	1	27-Nov-19
Protelater guttatus	Pinus radiata	Insect	2	28-Nov-72
Protelater sp	Pinus radiata	Insect	1	28-Nov-72
Protelater vitticollis	Pinus radiata	Insect	2	28-Nov-72
Protosynaema quaestuosa	Pinus radiata	Insect	1	21-Jun-00
Protosynaema steropucha	Pinus radiata	Insect	1	04-May-98
Psepholax macleayi	Pinus radiata	Insect	2	04-Dec-84
Psepholax sp	Pinus radiata	Insect	10	01-Nov-84
Psepholax sulcatus	Pinus radiata	Insect	4	10-Nov-76
Pseudococcidae	Pinus radiata	Insect	2	21-Apr-98
Pseudococcus longispinus	Pinus radiata	Insect	2	03-Nov-10
Pseudocoremia fenerata	Pinus radiata	Insect	14	17-Feb-92
Pseudocoremia leucelaea	Pinus radiata	Insect	6	18-Oct-95
Pseudocoremia productata	Pinus radiata	Insect	1	17-Mar-94
Pseudocoremia sp	Pinus radiata	Insect	4	30-Apr-97
Pseudocoremia suavis	Pinus radiata	Insect	61	04-Oct-93
Psilocnaeia bullata	Pinus radiata	Insect	1	16-Jan-98
Psocidae	Pinus radiata	Insect	9	14-Jun-96
Psocoptera	Pinus radiata	Insect	12	16-Nov-82
Psychidae	Pinus radiata	Insect	2	13-Oct-03
Psyllidae	Pinus radiata	Insect	5	11-Jun-97
Pteromalidae	Pinus radiata	Insect	1	11-May-04
Ptinosoma ptinoides	Pinus radiata	Insect	1	02-Feb-08
Ptinus tectus	Pinus radiata	Insect	1	07-Sep-76
Pycnomerodes peregrinus	Pinus radiata	Insect	1	29-May-18
Pycnomerus sophorae	Pinus radiata	Insect	18	18-Jan-94
Pycnomerus sp	Pinus radiata	Insect	16	09-Nov-76
Pyronota sp	Pinus radiata	Insect	1	25-Nov-97
Recyntus sp	Pinus radiata	Insect	1	23-Feb-72
Reduviidae	Pinus radiata	Insect	2	04-Feb-00
Rentonium sp.	Pinus radiata	Insect	1	04-Mar-18
Rhinocyllus conicus	Pinus radiata	Insect	2	10-Apr-01
Rhipistena sp	Pinus radiata	Insect	1	11-Nov-13
Rhopalimorpha sp	Pinus radiata	Insect	1	26-Oct-98
Rhopalomerus sp	Pinus radiata	Insect	2	10-Dec-08
Rhopalomerus tenuirostris	Pinus radiata	Insect	9	14-Jan-92
Rhopalum sp	Pinus radiata	Insect	3	23-Nov-94
Rhypodes clavicornis	Pinus radiata	Insect	2	27-Feb-79
Rhypodes sp	Pinus radiata	Insect	2	15-Jun-14
Rhysodiastes orbitosus	Pinus radiata	Insect	1	10-Nov-90
Rhysodidae	Pinus radiata	Insect	2	09-Nov-05
Rhyssa persuasoria	Pinus radiata	Insect	3	24-Oct-86
Rhyssa persuasoria persuasoria	Pinus radiata	Insect	2	10-Jan-83
Rhyssa sp	Pinus radiata	Insect	3	19-Mar-65
Rhyssinae	Pinus radiata	Insect	6	09-Apr-92
Rhyzobius forestieri	Pinus radiata	Insect	2	06-Mar-18
Rhyzobius sp.	Pinus radiata	Insect	1	18-Jan-07

Rhyzobius ventralis	Pinus radiata	Insect	1	17-Oct-03
Rhyzodiastes proprius	Pinus radiata	Insect	1	17-May-06
Rogas sp	Pinus radiata	Insect	2	26-Jun-91
Salpingus bilunatus	Pinus radiata	Insect	1	04-Aug-06
Salpingus sp	Pinus radiata	Insect	1	19-Mar-19
Saprosites communis	Pinus radiata	Insect	2	23-Feb-72
Saprosites exsculptus	Pinus radiata	Insect	2	15-Mar-93
Saprosites sp	Pinus radiata	Insect	2	18-Feb-15
Scarabaeidae	Pinus radiata	Insect	4	22-Mar-12
Sciaridae	Pinus radiata	Insect	1	02-May-17
Sclerodermus sp	Pinus radiata	Insect	1	18-Feb-93
Scolopterus aequus	Pinus radiata	Insect	1	18-Feb-10
Scolytidae	Pinus radiata	Insect	5	09-Jul-82
Scoparia diphtheralis	Pinus radiata	Insect	1	24-Jan-79
Scymnus sp	Pinus radiata	Insect	1	26-Apr-00
Selenopalpus ?cyaneus	Pinus radiata	Insect	1	29-Jan-92
Selenopalpus cyaneus	Pinus radiata	Insect	3	15-Jan-92
Sepedophilus sp	Pinus radiata	Insect	1	05-Oct-14
Sericotrogus subaenescens	Pinus radiata	Insect	1	05-Nov-19
Silvanidae	Pinus radiata	Insect	1	28-Oct-15
Siphonophora zelandica	Pinus radiata	Insect	1	25-Sep-17
Sirex noctilio	Pinus radiata	Insect	73	20-Mar-91
Siricidae	Pinus radiata	Insect	2	01-Dec-08
Sitona discoideus	Pinus radiata	Insect	3	18-Mar-87
Somatidia antarctica	Pinus radiata	Insect	2	16-Mar-88
Somatidia grandis	Pinus radiata	Insect	2	26-Jan-84
Somatidia longipes	Pinus radiata	Insect	2	30-Nov-95
Somatidia sp	Pinus radiata	Insect	14	16-Jan-89
Soronia sp.	Pinus radiata	Insect	1	06-Jan-18
Sphictostethus nitidus	Pinus radiata	Insect	2	28-Jan-97
Staphylinidae	Pinus radiata	Insect	9	09-Mar-93
Stenellipsis grata	Pinus radiata	Insect	1	11-Oct-91
Stenopotes pallidus	Pinus radiata	Insect	46	11-Oct-77
Stenoscelis hylastoides	Pinus radiata	Insect	1	20-May-10
Stenoscelis sp	Pinus radiata	Insect	1	19-Jan-03
Steriphus diversipes lineata	Pinus radiata	Insect	1	09-Feb-76
Stethaspis lineata	Pinus radiata	Insect	1	06-Dec-95
Stethaspis prasinus	Pinus radiata	Insect	1	18-Jan-96
Stethaspis sp	Pinus radiata	Insect	2	09-Jan-03
Stolotermes inopinus	Pinus radiata	Insect	10	04-Feb-88
Stolotermes ruficeps	Pinus radiata	Insect	106	18-May-84
Stolotermes sp	Pinus radiata	Insect	6	06-Dec-11
Stratiomyidae	Pinus radiata	Insect	2	23-Jan-02
Syrphetodes marginatus	Pinus radiata	Insect	1	09-May-13
Syrphetodes sp	Pinus radiata	Insect	1	28-Apr-14
Syrphidae	Pinus radiata	Insect	5	27-Nov-84
Tabanidae	Pinus radiata	Insect	1	27-Jan-98
Tanychilus metallicus	Pinus radiata	Insect	1	25-Jan-02
Tanychilus sophorae	Pinus radiata	Insect	1	28-Nov-72
Tarphiomimus indentatus	Pinus radiata	Insect	1	23-Feb-72
Technomyrmex albipes	Pinus radiata	Insect	1	23-Jul-19
Tenebrionidae	Pinus radiata	Insect	16	11-Mar-82
Tetrorea cilipes	Pinus radiata	Insect	1	21-Mar-00
Tetrorea longipennis	Pinus radiata	Insect	1	25-Jan-96
Tetrorea sp	Pinus radiata	Insect	4	03-Mar-80
Thelyphassa lineata	Pinus radiata	Insect	1	21-Dec-06
Thelyphassa nemoralis	Pinus radiata	Insect	1	18-Jan-95
Thelyphassa sp	Pinus radiata	Insect	3	07-Aug-63
Thoramus sp	Pinus radiata	Insect	7	10-Apr-91
Thoramus wakefieldi	Pinus radiata	Insect	6	25-Mar-77

Thripidae	Pinus radiata	Insect	2	14-Apr-98
Thrips tabaci	Pinus radiata	Insect	13	18-Jan-83
Thrips?	Pinus radiata	Insect	1	04-Nov-94
Thysanoplusia orichalcea	Pinus radiata	Insect	1	07-Mar-00
Thysanoptera:phlaeothripidae	Pinus radiata	Insect	4	09-Jun-09
Tineidae	Pinus radiata	Insect	5	03-Feb-92
Tineidae ?	Pinus radiata	Insect	1	18-Apr-89
Tingena armigerella	Pinus radiata	Insect	1	28-Oct-94
Tingena sp	Pinus radiata	Insect	1	03-Dec-99
Tipulidae	Pinus radiata	Insect	5	10-Oct-85
Tomoceridae	Pinus radiata	Insect	1	21-Nov-03
Tomogenious sp.	Pinus radiata	Insect	1	22-Oct-14
Torostoma apicale	Pinus radiata	Insect	16	05-Apr-72
Torostoma sp	Pinus radiata	Insect	1	13-Nov-84
Tortricidae	Pinus radiata	Insect	41	18-Apr-91
Tortricidae damage	Pinus radiata	Insect	5	02-May-88
Toura sp	Pinus radiata	Insect	1	13-Sep-13
Trachypepla sp	Pinus radiata	Insect	1	03-Dec-99
Trichogramma sp	Pinus radiata	Insect	1	19-Apr-00
Trigonospila brevifacies	Pinus radiata	Insect	1	17-Dec-18
Trogossitidae	Pinus radiata	Insect	1	20-Oct-17
Tubuliferous thrips	Pinus radiata	Insect	2	23-Sep-86
Tychanus sp	Pinus radiata	Insect	1	14-Mar-01
Tyria jacobaeae	Pinus radiata	Insect	2	10-Jan-01
Uloma tenebrionoides	Pinus radiata	Insect	17	17-Jan-89
Uresiphita polygonalis maorialis	Pinus radiata	Insect	2	13-Jan-95
Wiseana sp	Pinus radiata	Insect	1	07-May-15
Xanthopimpla rhopaloceros	Pinus radiata	Insect	5	05-Apr-93
Xanthorhoe sp	Pinus radiata	Insect	1	08-Dec-16
Xenocnema sp	Pinus radiata	Insect	2	19-Jan-03
Xenocnema spinipes	Pinus radiata	Insect	24	30-Jul-90
Xenogonus sp	Pinus radiata	Insect	3	08-Mar-78
Xyleborinus saxesenii	Pinus radiata	Insect	7	11-Jan-83
Xyletobius watti	Pinus radiata	Insect	2	29-Jan-88
Xylotoles ?griseus	Pinus radiata	Insect	2	14-Nov-84
Xylotoles griseus	Pinus radiata	Insect	7	01-Dec-88
Xylotoles humeratus	Pinus radiata	Insect	2	02-Jul-62
Xylotoles laetus	Pinus radiata	Insect	7	11-Nov-76
Xylotoles lynceus	Pinus radiata	Insect	1	02-Mar-92
Xylotoles sp.	Pinus radiata	Insect	16	18-Apr-78
Xylotoloides huttoni	Pinus radiata	Insect	1	10-Jul-84
Zermizinga indocilisaria	Pinus radiata	Insect	1	05-May-83
Zizina labradus	Pinus radiata	Insect	1	03-Mar-97
Zopheridae	Pinus radiata	Insect	15	15-Mar-93
Zorion minutum	Pinus radiata	Insect	3	08-Mar-78
Zorion sp.	Pinus radiata	Insect	1	30-Nov-17
Allantophomopsiella pseudotsugae	Pseudotsuga menziesii	Fungus	27	16-Oct-74
Alternaria alternata	Pseudotsuga menziesii	Fungus	2	10-Nov-08
Alternaria sp	Pseudotsuga menziesii	Fungus	5	20-Feb-74
Amanita muscaria	Pseudotsuga menziesii	Fungus	1	07-Jun-84
Armillaria limonea	Pseudotsuga menziesii	Fungus	1	13-Jul-88
Armillaria novae-zelandiae	Pseudotsuga menziesii	Fungus	3	10-Sep-86
Armillaria sp	Pseudotsuga menziesii	Fungus	31	22-Feb-99
Arthothelium sp	Pseudotsuga menziesii	Fungus	1	25-Mar-04
Ascomycete	Pseudotsuga menziesii	Fungus	2	04-Nov-94
Ascomycete - hemisphaeriales	Pseudotsuga menziesii	Fungus	1	10-Apr-78
Aureobasidium sp	Pseudotsuga menziesii	Fungus	2	12-Mar-96
Basidiomycete	Pseudotsuga menziesii	Fungus	5	19-Apr-83
Botryosphaeria sp	Pseudotsuga menziesii	Fungus	9	26-May-92
Botryotrichum sp	Pseudotsuga menziesii	Fungus	1	20-Feb-74

Botrytis cinerea	Pseudotsuga menziesii	Fungus	14	20-Feb-79
Botrytis sp	Pseudotsuga menziesii	Fungus	12	11-Apr-80
Byssoloma sp	Pseudotsuga menziesii	Fungus	1	20-Mar-02
Ceuthospora sp	Pseudotsuga menziesii	Fungus	3	24-Sep-82
Chaetomella? sp	Pseudotsuga menziesii	Fungus	1	25-May-95
Chlorella	Pseudotsuga menziesii	Fungus	5	18-May-78
Cladosporium sp	Pseudotsuga menziesii	Fungus	3	09-Sep-94
Clitocybe nebularis	Pseudotsuga menziesii	Fungus	1	14-Mar-96
Clypeolinopsis sp	Pseudotsuga menziesii	Fungus	15	21-Jan-81
Clypeolinopsis? sp	Pseudotsuga menziesii	Fungus	1	22-Aug-79
Clypeolum sp	Pseudotsuga menziesii	Fungus	17	11-Sep-84
Coelomycete	Pseudotsuga menziesii	Fungus	1	08-Jan-99
Coleophoma cylindrospora	Pseudotsuga menziesii	Fungus	1	10-Dec-98
Colletotrichum acutatum f.sp. pineum	Pseudotsuga menziesii	Fungus	1	03-May-95
Cordyceps sinclairii	Pseudotsuga menziesii	Fungus	1	08-May-96
Cortinarius sp	Pseudotsuga menziesii	Fungus	1	16-Jun-00
Cryptosporiopsis sp	Pseudotsuga menziesii	Fungus	4	14-Dec-89
Cryptosporiopsis? Sp	Pseudotsuga menziesii	Fungus	1	14-Oct-86
Cylindrocarpon sp	Pseudotsuga menziesii	Fungus	10	26-May-92
Cylindrocladium scoparium	Pseudotsuga menziesii	Fungus	4	14-Jan-97
Cytospora sp	Pseudotsuga menziesii	Fungus	2	23-Mar-87
Diaporthe sp	Pseudotsuga menziesii	Fungus	1	17-Nov-16
Diatrype sp	Pseudotsuga menziesii	Fungus	1	25-Jan-00
Didymella sp	Pseudotsuga menziesii	Fungus	2	05-Mar-70
Didymellaceae	Pseudotsuga menziesii	Fungus	1	12-Sep-18
Diplodia sapinea	Pseudotsuga menziesii	Fungus	62	28-Oct-92
Elongisporangium undulatum	Pseudotsuga menziesii	Fungus	1	18-Nov-17
Entomogenous fungus	Pseudotsuga menziesii	Fungus	1	17-Apr-02
Epicoccum purpurascens	Pseudotsuga menziesii	Fungus	4	30-May-83
Epicoccum sp	Pseudotsuga menziesii	Fungus	1	31-May-19
Fomes pini	Pseudotsuga menziesii	Fungus	1	15-Feb-61
Fusarium acuminatum	Pseudotsuga menziesii	Fungus	1	12-May-18
Fusarium oxysporum	Pseudotsuga menziesii	Fungus	9	29-Apr-96
Fusarium solani	Pseudotsuga menziesii	Fungus	1	29-May-03
Fusarium sp	Pseudotsuga menziesii	Fungus	32	17-Apr-86
Fusicoccum sp	Pseudotsuga menziesii	Fungus	3	07-Oct-80
Fusicoccum? Sp	Pseudotsuga menziesii	Fungus	1	17-Jun-71
Ganoderma sp	Pseudotsuga menziesii	Fungus	1	13-Nov-95
Geastrum velutinum	Pseudotsuga menziesii	Fungus	1	13-May-99
Gloeocystidiellum sacratum	Pseudotsuga menziesii	Fungus	2	20-Jan-87
Grosmannia radiaticola	Pseudotsuga menziesii	Fungus	1	26-Jun-11
Gymnopilus junonius	Pseudotsuga menziesii	Fungus	1	21-May-96
Gyrodontium sacchari	Pseudotsuga menziesii	Fungus	1	08-Mar-18
Gyromitra infula	Pseudotsuga menziesii	Fungus	1	06-Jun-05
Hymenochaete mougeotii	Pseudotsuga menziesii	Fungus	1	23-Sep-60
Hyphomycete	Pseudotsuga menziesii	Fungus	2	08-Sep-06
Inocybe sp	Pseudotsuga menziesii	Fungus	1	09-Dec-98
Junghuhnia vincta	Pseudotsuga menziesii	Fungus	1	06-Jun-95
Laccaria sp	Pseudotsuga menziesii	Fungus	1	19-May-93
Lachnellula calyciformis	Pseudotsuga menziesii	Fungus	1	22-Sep-93
Lachnellula sp	Pseudotsuga menziesii	Fungus	2	08-Aug-95
Leptographium lundbergii	Pseudotsuga menziesii	Fungus	1	31-Oct-85
Leptographium procerum	Pseudotsuga menziesii	Fungus	1	02-Feb-90
Leptographium sp	Pseudotsuga menziesii	Fungus	1	26-Jun-15
Lycoperdon perlatum	Pseudotsuga menziesii	Fungus	1	04-Apr-00
Marasmius sp	Pseudotsuga menziesii	Fungus	1	22-Sep-17
Mikronegeria fuchsiae	Pseudotsuga menziesii	Fungus	1	21-Oct-76
Mycorrhiza	Pseudotsuga menziesii	Fungus	2	09-Jan-01
Nectriaceae	Pseudotsuga menziesii	Fungus	4	27-Nov-19
Neofusicoccum parvum	Pseudotsuga menziesii	Fungus	1	01-Sep-15

Nothophaeocryptopus gaeumannii	Pseudotsuga menziesii	Fungus	321	18-Apr-88
Oomycete - pythiaceous	Pseudotsuga menziesii	Fungus	2	21-Apr-81
Ophiostoma sp	Pseudotsuga menziesii	Fungus	1	28-Sep-94
Paecilomyces sp	Pseudotsuga menziesii	Fungus	3	09-Mar-93
Penicillium sp	Pseudotsuga menziesii	Fungus	3	08-Dec-80
Pestalotia sp	Pseudotsuga menziesii	Fungus	9	24-May-93
Pestalotiopsis sp	Pseudotsuga menziesii	Fungus	8	17-Nov-99
Pezicula cinnamomea	Pseudotsuga menziesii	Fungus	1	15-Apr-19
Pezicula livida	Pseudotsuga menziesii	Fungus	1	27-Jan-75
Pezicula sp.	Pseudotsuga menziesii	Fungus	2	18-Sep-18
Phacidiopycnis sp	Pseudotsuga menziesii	Fungus	5	09-Jan-04
Phanerochaete sp	Pseudotsuga menziesii	Fungus	1	28-Nov-19
Phoma leveillei	Pseudotsuga menziesii	Fungus	1	24-May-95
Phoma sp	Pseudotsuga menziesii	Fungus	5	11-Apr-80
Phoma spp	Pseudotsuga menziesii	Fungus	1	31-Jul-02
Phoma? Sp	Pseudotsuga menziesii	Fungus	3	12-Apr-72
Phomopsis sp	Pseudotsuga menziesii	Fungus	41	12-Dec-89
Phytophthora cinnamomi	Pseudotsuga menziesii	Fungus	21	08-Mar-90
Phytophthora citricola	Pseudotsuga menziesii	Fungus	2	11-Dec-00
Phytophthora cryptogea	Pseudotsuga menziesii	Fungus	2	22-May-95
Phytophthora megasperma	Pseudotsuga menziesii	Fungus	1	04-Jun-02
Phytophthora pluvialis	Pseudotsuga menziesii	Fungus	34	24-May-12
Phytophthora sp	Pseudotsuga menziesii	Fungus	28	16-May-69
Phytopythium vexans	Pseudotsuga menziesii	Fungus	1	31-May-19
Pseudohydnum gelatinosum	Pseudotsuga menziesii	Fungus	2	09-Dec-98
Pythium echinulatum	Pseudotsuga menziesii	Fungus	1	13-Oct-10
Pythium sp	Pseudotsuga menziesii	Fungus	5	29-Nov-66
Rhizosphaera kalkhoffii	Pseudotsuga menziesii	Fungus	30	12-May-70
Rhizosphaera pini	Pseudotsuga menziesii	Fungus	4	23-Apr-09
Rhizosphaera sp	Pseudotsuga menziesii	Fungus	31	24-Aug-87
Rhynchosphaeria sp	Pseudotsuga menziesii	Fungus	2	16-May-86
Rosellinia radiciperda	Pseudotsuga menziesii	Fungus	1	05-May-65
Sarea resinae	Pseudotsuga menziesii	Fungus	5	10-Oct-91
Sclerophoma sp	Pseudotsuga menziesii	Fungus	24	17-Jan-75
Stemphylium sp	Pseudotsuga menziesii	Fungus	3	30-May-83
Stereum sanguinolentum	Pseudotsuga menziesii	Fungus	2	06-Jul-76
Stereum sp	Pseudotsuga menziesii	Fungus	1	20-Feb-79
Stereum vellereum	Pseudotsuga menziesii	Fungus	1	28-Sep-88
Stomiopeltis sp	Pseudotsuga menziesii	Fungus	9	11-Mar-76
Strasseria geniculata	Pseudotsuga menziesii	Fungus	5	24-Sep-82
Strasseria sp	Pseudotsuga menziesii	Fungus	3	27-Aug-87
Sydowia polyspora	Pseudotsuga menziesii	Fungus	14	27-Sep-74
Thelephora sp	Pseudotsuga menziesii	Fungus	1	28-May-69
Thelephora terrestris	Pseudotsuga menziesii	Fungus	5	30-Jun-93
Thielaviopsis basicola	Pseudotsuga menziesii	Fungus	1	19-May-05
Thysanophora penicilloides	Pseudotsuga menziesii	Fungus	1	02-May-09
Thysanophora sp	Pseudotsuga menziesii	Fungus	1	21-Apr-80
Trametes versicolor	Pseudotsuga menziesii	Fungus	1	02-Dec-07
Trichoderma sp	Pseudotsuga menziesii	Fungus	9	23-May-80
Tricholomopsis rutilans	Pseudotsuga menziesii	Fungus	1	30-Jan-18
Truncatella sp	Pseudotsuga menziesii	Fungus	1	19-Nov-86
Tyromyces atrostrigosus	Pseudotsuga menziesii	Fungus	1	12-Jun-86
Valsaria rubricosa	Pseudotsuga menziesii	Fungus	3	26-Jun-11
Wojnowiciella dactylidis	Pseudotsuga menziesii	Fungus	1	13-Aug-19
Xenomeris abietis	Pseudotsuga menziesii	Fungus	1	27-Oct-92
?Catoptes sp	Pseudotsuga menziesii	Insect	1	15-Jan-92
?Coptomma sp	Pseudotsuga menziesii	Insect	1	01-Feb-96
?Parlatoria pittospori	Pseudotsuga menziesii	Insect	1	26-Nov-91
Adoxellus flavihirtus	Pseudotsuga menziesii	Insect	1	27-Jan-15
Amphipsalta sp	Pseudotsuga menziesii	Insect	1	20-Oct-03

Anacharis sp	Pseudotsuga menziesii	Insect	1	11-May-99
Anagotus helmsi	Pseudotsuga menziesii	Insect	2	17-Dec-93
Androporus discedens	Pseudotsuga menziesii	Insect	1	08-Feb-72
Aneurus (Aneurodellus) brouni	Pseudotsuga menziesii	Insect	1	08-Oct-19
Anobium punctatum	Pseudotsuga menziesii	Insect	1	07-Mar-78
Anthocoridae	Pseudotsuga menziesii	Insect	1	27-Oct-92
Anthribidae?	Pseudotsuga menziesii	Insect	1	15-Apr-86
Aphididae	Pseudotsuga menziesii	Insect	6	28-Sep-95
Arachnida	Pseudotsuga menziesii	Insect	1	16-Nov-16
Arhopalus ferus	Pseudotsuga menziesii	Insect	8	31-Jan-86
Artystona rugiceps	Pseudotsuga menziesii	Insect	1	12-Oct-95
Ataenius brouni	Pseudotsuga menziesii	Insect	1	03-Feb-86
Atrichatus aeneicollis	Pseudotsuga menziesii	Insect	1	03-Oct-17
Baculipalpus strigipennis	Pseudotsuga menziesii	Insect	1	08-Jan-98
Balcus niger	Pseudotsuga menziesii	Insect	1	26-Jan-01
Betarmonoides sp	Pseudotsuga menziesii	Insect	1	05-Nov-93
Bitoma insularis	Pseudotsuga menziesii	Insect	1	01-Dec-05
Cacephatus incertus	Pseudotsuga menziesii	Insect	1	13-Jan-94
Cacephatus sp	Pseudotsuga menziesii	Insect	1	08-Feb-72
Caedicia simplex	Pseudotsuga menziesii	Insect	1	10-Mar-72
Carabidae	Pseudotsuga menziesii	Insect	2	03-Apr-97
Carystoterpa aurata	Pseudotsuga menziesii	Insect	1	17-Feb-03
Casinaria sp	Pseudotsuga menziesii	Insect	1	10-Mar-72
Catoptes ?planus	Pseudotsuga menziesii	Insect	1	25-Jan-94
Catoptes planus	Pseudotsuga menziesii	Insect	1	17-Jan-94
Catoptes sp	Pseudotsuga menziesii	Insect	1	21-Dec-17
Cerambycidae	Pseudotsuga menziesii	Insect	3	06-Nov-90
Cermatulus nasalis	Pseudotsuga menziesii	Insect	1	23-Apr-15
Cermatulus nasalis nasalis	Pseudotsuga menziesii	Insect	1	14-Dec-95
Chionaspis sp	Pseudotsuga menziesii	Insect	1	14-Sep-00
Cicindela tuberculata	Pseudotsuga menziesii	Insect	1	25-Jan-01
Cleora scriptaria	Pseudotsuga menziesii	Insect	1	24-Oct-00
Coccus hesperidum	Pseudotsuga menziesii	Insect	2	25-Nov-11
Coccus hesperidum ?	Pseudotsuga menziesii	Insect	1	28-Mar-91
Coleoptera	Pseudotsuga menziesii	Insect	2	27-Oct-93
Collembola	Pseudotsuga menziesii	Insect	1	06-Jun-05
Coptomma sp	Pseudotsuga menziesii	Insect	1	23-Jul-70
Corylophidae	Pseudotsuga menziesii	Insect	1	07-Apr-94
Corymbites sp	Pseudotsuga menziesii	Insect	2	26-Nov-87
Costelytra sp	Pseudotsuga menziesii	Insect	1	19-Apr-15
Costelytra zealandica	Pseudotsuga menziesii	Insect	1	09-May-89
Crisius binotatus	Pseudotsuga menziesii	Insect	1	19-Apr-77
Cryptophagidae	Pseudotsuga menziesii	Insect	1	07-Apr-94
Cryptophagus sp	Pseudotsuga menziesii	Insect	1	27-Oct-92
Ctenoplectron sp	Pseudotsuga menziesii	Insect	1	24-Nov-88
Ctenopseustis obliquana	Pseudotsuga menziesii	Insect	9	22-Jun-90
Curculionidae	Pseudotsuga menziesii	Insect	6	18-Dec-97
Curculionidae?	Pseudotsuga menziesii	Insect	1	14-May-90
Declana floccosa	Pseudotsuga menziesii	Insect	6	16-Dec-89
Degithina davidi	Pseudotsuga menziesii	Insect	2	29-May-14
Dendroblax earlii	Pseudotsuga menziesii	Insect	1	20-Dec-95
Desiantha? Sp	Pseudotsuga menziesii	Insect	1	06-Jun-85
Diaspididae	Pseudotsuga menziesii	Insect	1	23-Jan-86
Diaspidiotus perniciosus	Pseudotsuga menziesii	Insect	1	02-Dec-87
Diptera	Pseudotsuga menziesii	Insect	1	13-Nov-95
Diptera tipulidae?	Pseudotsuga menziesii	Insect	1	26-May-94
Eburilla sericea	Pseudotsuga menziesii	Insect	1	02-Apr-05
Echthromorpha intricatoria	Pseudotsuga menziesii	Insect	2	08-Mar-93
Elateridae	Pseudotsuga menziesii	Insect	2	10-Apr-97
Ephydridae	Pseudotsuga menziesii	Insect	1	11-May-99

Epiphyas postvittana	Pseudotsuga menziesii	Insect	3	18-Jun-93
Epuraea zealandica	Pseudotsuga menziesii	Insect	1	05-Nov-93
Ernobius mollis	Pseudotsuga menziesii	Insect	1	18-Dec-00
Erotylidae	Pseudotsuga menziesii	Insect	1	26-Nov-08
Essigella californica	Pseudotsuga menziesii	Insect	1	23-Feb-99
Etnalis spinicollis	Pseudotsuga menziesii	Insect	2	08-Feb-72
Eucolaspis brunnea	Pseudotsuga menziesii	Insect	4	02-Nov-93
Eucolaspis sp	Pseudotsuga menziesii	Insect	3	21-Nov-72
Eugnomus maurus	Pseudotsuga menziesii	Insect	4	14-Dec-88
Euophryum confine	Pseudotsuga menziesii	Insect	2	26-Nov-19
Euophryum rufum	Pseudotsuga menziesii	Insect	1	24-May-19
Graphania sp	Pseudotsuga menziesii	Insect	1	30-Mar-04
Grynoma sp	Pseudotsuga menziesii	Insect	1	11-Oct-72
Hadrobregmus magnus	Pseudotsuga menziesii	Insect	1	21-Nov-72
Helicoverpa armigera conferta	Pseudotsuga menziesii	Insect	1	19-May-99
Heliothrips haemorrhoidalis	Pseudotsuga menziesii	Insect	5	30-Mar-71
Hemiptera	Pseudotsuga menziesii	Insect	1	20-Dec-95
Hexatricha pulverulenta	Pseudotsuga menziesii	Insect	3	25-Nov-96
Hierodoris atychioides	Pseudotsuga menziesii	Insect	4	17-Oct-74
Holcaspis sp	Pseudotsuga menziesii	Insect	1	17-Jun-15
Hylastes ater	Pseudotsuga menziesii	Insect	13	06-Nov-90
Hylurgus ligniperda	Pseudotsuga menziesii	Insect	11	06-Nov-90
Hymenoptera	Pseudotsuga menziesii	Insect	1	26-Feb-00
Icerya purchasi	Pseudotsuga menziesii	Insect	1	08-Sep-81
Isanthribus proximus	Pseudotsuga menziesii	Insect	3	08-Feb-72
Izatha sp	Pseudotsuga menziesii	Insect	2	15-Sep-87
Kalotermes brouni	Pseudotsuga menziesii	Insect	4	07-Mar-90
Lepidoptera	Pseudotsuga menziesii	Insect	3	04-Jan-84
Lindingaspis rossi	Pseudotsuga menziesii	Insect	6	16-Nov-82
Liothula omnivora	Pseudotsuga menziesii	Insect	2	28-Sep-00
Liothula sp	Pseudotsuga menziesii	Insect	2	24-May-19
Lycaena ?salustius	Pseudotsuga menziesii	Insect	1	06-Jan-98
Megastigmus spermotrophus	Pseudotsuga menziesii	Insect	1	30-Mar-88
Melolonthinae	Pseudotsuga menziesii	Insect	3	15-Sep-87
Metablax cinctiger	Pseudotsuga menziesii	Insect	1	13-Mar-98
Microcryptorhynchus sp	Pseudotsuga menziesii	Insect	1	17-Nov-72
Mimopeus sp	Pseudotsuga menziesii	Insect	1	15-Nov-17
Mitophyllus parrianus	Pseudotsuga menziesii	Insect	1	10-Apr-06
Mitrastethus baridioides	Pseudotsuga menziesii	Insect	4	14-Feb-06
Mycetophilidae	Pseudotsuga menziesii	Insect	1	20-Dec-95
Navomorpha lineata	Pseudotsuga menziesii	Insect	28	05-Nov-87
Navomorpha sulcata	Pseudotsuga menziesii	Insect	7	09-Nov-90
Nezara viridula	Pseudotsuga menziesii	Insect	1	17-Nov-93
Nitidula sp	Pseudotsuga menziesii	Insect	1	12-Mar-96
Odontria sp	Pseudotsuga menziesii	Insect	1	19-Apr-15
Oecophoridae	Pseudotsuga menziesii	Insect	1	30-Nov-19
Oemona hirta	Pseudotsuga menziesii	Insect	1	06-Sep-18
Oncacontias vittatus	Pseudotsuga menziesii	Insect	1	09-Mar-94
Oribatidae	Pseudotsuga menziesii	Insect	3	13-Nov-84
Pachycotes peregrinus	Pseudotsuga menziesii	Insect	13	22-Feb-79
Parlatoria pittospori	Pseudotsuga menziesii	Insect	3	12-Jun-80
Parlatoria sp	Pseudotsuga menziesii	Insect	2	05-Mar-80
Pentatomidae	Pseudotsuga menziesii	Insect	1	10-Mar-03
Phrynixus sp	Pseudotsuga menziesii	Insect	1	22-Apr-12
Phrynixus terreus	Pseudotsuga menziesii	Insect	1	21-Feb-97
Phynomerus sp	Pseudotsuga menziesii	Insect	1	10-Feb-93
Phytodietus zealandicus	Pseudotsuga menziesii	Insect	1	07-Apr-77
Pineus pini	Pseudotsuga menziesii	Insect	2	20-Mar-95
Pison spinolae	Pseudotsuga menziesii	Insect	1	27-Nov-01
Planotortrix excessana	Pseudotsuga menziesii	Insect	3	29-Apr-96

Planotortrix notophaea	Pseudotsuga menziesii	Insect	8	25-Jan-94
Planotortrix notophaea ?	Pseudotsuga menziesii	Insect	1	23-Jan-92
Platypus apicalis	Pseudotsuga menziesii	Insect	9	22-Feb-79
Praolepra fultoni	Pseudotsuga menziesii	Insect	1	19-May-72
Praolepra sp	Pseudotsuga menziesii	Insect	1	16-Dec-88
Prionoplus reticularis	Pseudotsuga menziesii	Insect	13	26-Oct-93
Psepholax macleayi	Pseudotsuga menziesii	Insect	1	30-Sep-17
Pseudocoremia fenerata	Pseudotsuga menziesii	Insect	5	03-Nov-87
Pseudocoremia suavis	Pseudotsuga menziesii	Insect	14	10-Feb-93
Psocidae	Pseudotsuga menziesii	Insect	3	27-Oct-92
Psocoptera	Pseudotsuga menziesii	Insect	7	12-Feb-92
Pycnomerus sophorae	Pseudotsuga menziesii	Insect	1	25-Jan-72
Pycnomerus sp	Pseudotsuga menziesii	Insect	1	24-May-19
Pyrgotis plagiatana	Pseudotsuga menziesii	Insect	2	11-Oct-94
Pyronota festiva	Pseudotsuga menziesii	Insect	2	17-Nov-93
Reduviidae	Pseudotsuga menziesii	Insect	1	23-Feb-99
Rhopalomerus tenuirostris	Pseudotsuga menziesii	Insect	4	14-Dec-88
Rhyzobius sp.	Pseudotsuga menziesii	Insect	1	06-Mar-98
Scolopterus penicillatus	Pseudotsuga menziesii	Insect	1	08-Feb-72
Scolypopa australis	Pseudotsuga menziesii	Insect	1	08-Feb-72
Sephena cinerea	Pseudotsuga menziesii	Insect	1	23-Feb-99
Sharpius brouni	Pseudotsuga menziesii	Insect	1	19-May-72
Sharpius venustus	Pseudotsuga menziesii	Insect	1	22-Apr-16
Silphidae	Pseudotsuga menziesii	Insect	1	08-Aug-96
Somatidia longipes	Pseudotsuga menziesii	Insect	1	22-Mar-85
Somatidia sp	Pseudotsuga menziesii	Insect	3	25-Mar-94
Stenopotes pallidus	Pseudotsuga menziesii	Insect	10	13-Apr-76
Stenotus binotatus	Pseudotsuga menziesii	Insect	1	23-Jan-92
Stephanorhynchus curvipes	Pseudotsuga menziesii	Insect	1	10-Mar-72
Stethaspis sp	Pseudotsuga menziesii	Insect	1	02-Aug-73
Stethaspis suturalis	Pseudotsuga menziesii	Insect	1	13-Apr-89
Stolotermes ruficeps	Pseudotsuga menziesii	Insect	7	02-Oct-91
Stolotermes sp	Pseudotsuga menziesii	Insect	1	31-Oct-18
Targarema sp	Pseudotsuga menziesii	Insect	1	25-Jan-72
Tarphiomimus indentatus	Pseudotsuga menziesii	Insect	2	08-Feb-72
Tarphiomimus sp	Pseudotsuga menziesii	Insect	1	10-Feb-93
Tessaromma undatum	Pseudotsuga menziesii	Insect	1	16-Jan-97
Thelyphassa nemoralis	Pseudotsuga menziesii	Insect	1	27-Jan-85
Thrips	Pseudotsuga menziesii	Insect	2	03-Jun-87
Thysanoptera	Pseudotsuga menziesii	Insect	2	10-Sep-85
Tineidae	Pseudotsuga menziesii	Insect	2	04-Jan-84
Torostoma apicale	Pseudotsuga menziesii	Insect	1	21-Apr-94
Tortricidae	Pseudotsuga menziesii	Insect	8	17-Nov-82
Trathala agnina	Pseudotsuga menziesii	Insect	1	05-May-04
Trogossitidae	Pseudotsuga menziesii	Insect	1	06-Sep-18
Wiseana sp	Pseudotsuga menziesii	Insect	1	15-Nov-18
Xylotoles sp.	Pseudotsuga menziesii	Insect	2	11-Sep-18
Zorion australe	Pseudotsuga menziesii	Insect	2	25-Nov-19
Zorion minutum	Pseudotsuga menziesii	Insect	2	03-Nov-84
Zorion sp.	Pseudotsuga menziesii	Insect	1	10-Nov-18

Appendix II – Pest and Pathogen Details

Pathogens

Armillaria species

Transmission Factors:

- **Transmission substrates(s):** Although new disease foci become established by means of spores, *Armillaria* species spread predominantly by means of vegetative growth through contact between roots and inoculum sources such as colonised stumps or wood debris. Means of transmission may include bark, timber, wood packaging or dunnage. Mycelial fans of *Armillaria* have been observed beneath the bark of stacked logs awaiting export.
- **Current Distribution:** Widespread – Worldwide.
- **Evidence that pest has already been successfully transmitted to new areas:** *A. mellea* and *A. gallica* have been found in Cape Town, South Africa. It is believed that these Northern Hemisphere species were introduced on potted plants from Europe during early European settlement (Coetzee et al. 2003).

Damage and Economic Impact: *Armillaria* species may cause root disease in pines and firs. Armillaria is one of several root diseases that cause significant losses in a wide range of hosts in forest plantations, horticultural crops, orchards and amenity plantings. *A*. *ostoyae* is one of the most pathogenic species in the Northern Hemisphere, being found more often on conifer hosts. Minor losses from "*A*. *mellea*" (possibly *A*. *ostoyae*) have occurred in *Pinus radiata* stands in California in which oak stumps were also present (Offord 1964). *Armillaria* is generally not a serious root disease in plantations of *P*. *radiata* in Australia. The disease also occurs at only a low incidence in *P*. *radiata* plantations in Chile, at least some, however, due to *A*. *luteobubalina* (Pidain et al. 2009). Four indigenous species are present in New Zealand, two of which occur in plantations of *P. radiata* (*A. novae-zelandiae* and *A*. *limonea*).

References:

Coetzee, MPA; Wingfield, BD; Roux, J; Crous. PW; Denman, S; Wingfield, MJ 2003: Discovery of two northern hemisphere *Armillaria* species on Proteaceae in South Africa. Plant Pathology 52: 604-612.

Offord, HR 1964: Diseases of Monterey pine in native stands of California and in plantations of western North America. US Forest Service Research paper PSW-14 (37 pp.). Pacific Southwest Forest and Range Experiment Station, Berkely, California. United States Department of Agriculture Forest Service.

Pidain, MB; Coetzee, MPA; Rajchenberg, M; Petersen, RH; Wingfield, MJ; Wingfield, BD 2009: Molecular phylogeny of *Armillaria* from the Patagonian Andes. Mycological Progress 8: 181-194.

Cronartium quercuum f. sp. *fusiforme*

Transmission Factors:

- **Transmission substrates(s):** Pine branches/stems with sporulating galls. Leaves of alternate host, oak, with uredinial or telial pustules.
- **Survivability over time:** Galls are perennial and the fungus will survive in this tissue for years as galls enlarge. Basidiospores are more delicate than the other spore types and effective dispersal is usually limited to less than 500m indicating that they do not last long (Hansen and Lewis 1997). Length of time the other spore forms will survive is not known.
- **Current Distribution:** South eastern United States (Gibson 1979; Hansen and Lewis 1997).
- **Evidence that pest has already been successfully transmitted to new areas:** No evidence found. Development of serious disease problems in the south eastern United States followed the widespread planting of susceptible pine species in plantations where there was close proximity to the alternate hosts (Gibson 1979). The fungus is presumed to be native to those areas.

Damage and Economic Impact:

- **Production loss**: Fusiforme rust is one of the most economically important tree diseases in North America. It is most severe on *P. elliotii* and *P. taeda*, killing seedlings and young trees, and causing galls and cankers that destroy tree form and value of surviving trees. Sometimes branches and stems are killed beyond the point of the galls. Stem breakage at galls is common. Infections on nursery seedlings at usually at soil level and lead to early mortality, infected plants often dying within 2-to-3 years following out-planting. If they survive, they are generally deformed, grow poorly, and frequently break off at the point of infection several years later. Infected plants are therefore culled and losses in individual nurseries can exceed 80 percent (Hansen and Lewis 1997). Severe outbreaks of fusiform rust in commercial forest nurseries in Florida in 1979 and 1980 resulted in losses of millions of seedlings valued at nearly $US 150,000. In 1981 the annual loss due to devaluation of living trees, exclusive of mortality was estimated at $US 75 million (Sinclair et al. 1987). Rust-resistant stock is produced through an intensive selection and testing programme.

References:

Gibson, I.A.S. 1979: ‘Diseases of Forest Trees Widely Planted as Exotics in the Tropics and Southern Hemisphere. Part II. The Genus Pinus.’ Commonwealth Mycological Institute, Kew, and Commonwealth Forestry Institute, Oxford.

Hansen, E.M.; Lewis, K.J. 1997: ‘Compendium of Conifer Diseases.’ APS Press, St Paul, Minnesota.

Sinclair, W.A.; Lyon, H.H.; Johnson, W.T. 1987: ‘Diseases of Trees and Shrubs.’ Cornell University Press, Ithaca and London.

Endocronartium harknessii (J.P. Moore) Hiratsuka

Transmission Factors:

- **Transmission substrates(s):** Rusts are obligate parasites so any host material infected by a rust has to be living, that is, if the host dies then the fungus dies. If the host material died after the rust had begun to produce spores the rust would die but its spores would remain viable. Therefore the transportation of infected, but now dead, branches with sporulating galls could act as a means of transmission but only from existing spores; no new spores will be produced. Spore survival is favoured by low RH and low temperatures (Chang and Blenis 1989). At 98% humidity approximately 90% of aeciospores are dead within 2 days. At the lower humidities tested aeciospore mortality was more linear. Chang and Blenis (1989) also found that 67% of aeciospores exposed to full sunlight on a clear day between 8.30 am and 8.30 pm were dead after the 12 hours of exposure.
- **Current Distribution:** Much of North America.
- **Evidence that pest has already been successfully transmitted to new areas:** There is no evidence that it has been transmitted, or has established, in new areas.

Damage and Economic Impact

- **Production loss:** Western gall rust can intensify in highly managed, young pine forests due to its pine-to-pine life cycle, the high susceptibility of young host tissue, and the long life of sporulating galls. Working with *Pinus contorta* Bella and Navratil (1988) found that in stands up to 12 years old infection incidence averaged 5% but rapidly increased to 20% at age 20. In stands 20 years or older incidence of new infection was low. Mortality associated with the disease was low, however a 30% mortality in an unthinned 22 year old stand occurred. Bella and Navratil (1988) analysised the stems of 75 *Pinus contorta* trees and showed that 11-15 years after infection the volume loss was 21-32%.

References:

Bella, I.E.; Navratil, S. 1988: Western gall rust dynamics and impact in young lodgepole pine stands in west-central Alberta. Canadian Journal Forest Research 18: 1437-1142.

Chang, K.F.; Blenis, P.V. 1988: Survival of *Endocronartium harknessii* telioaeciospores in a simulated airborne state. Canadian Journal of Botany 67: 928-932.

Hansen, E.M.; Lewis, K.J. (eds) 1997: 'Compendium of conifer diseases.' The American Phytopathological Society, St Paul, Minnesota.

Old, K.M. 1981: Western gall rust, a serious disease of *Pinus radiata* in California. Australian Forestry 44: 178-184.

Ramsfield, T D; Kriticos, D J; Vogler, D R; Geils, B W; 2007. Western gall rust – a threat to *Pinus radiata* in New Zealand. New Zealand Journal of Forestry Science 37(2): 143-152.

Fusarium circinatum Nirenberg & O'Donnell

Transmission Factors:

- **Transmission substrates(s):** Natural infection occurs from insect-vectored spores and by airborne spores. The fungus can be distributed in seed, nursery stock, bark, timber, wood packaging and dunnage.
- **Current Distribution:** Brazil, Chile, Colombia, Haiti, Japan, Mexico, Portugal, South Africa, Spain, South Korea, southern USA and Uruguay.
- **Evidence that pest has already been successfully transmitted to new areas:** The fungus was recorded and described in south east USA in 1946. It was subsequently found in Haiti (1959), south west USA (1986), Japan (1989) and South Africa (1994). More recently it has been reported in Brazil, Chile and in Spain.

Damage and Economic Impact: The effect of this disease varies considerably between countries, depending on the climate, wound agents, host resistance and silvicultural practices. There have been numerous reports of the seriousness of outbreaks in several countries. Young trees may be killed by a single stem infection. Older individual trees may sustain crown infection for many years resulting in loss of height growth.

References:

Dick, MA 1998. Pine pitch canker -- the threat to New Zealand. New Zealand Forestry 42: 30-34.

Ganley, R. J. 2007. Pitch canker - risk of establishment in New Zealand based on a global perspective. New Zealand Journal of Forestry 52(2): 26-30

Ganley, R J; Watt, M S; Iturritxa, E; Manning, L K; 2009. A global climatic risk assessment of pitch canker disease. Canadian Journal of Forest Research 39: 2246-2256.

Wingfield, M J; Hammerbacher, A; Ganley, R J; Coutinho, T A; Steenkamp, E T; Gordon, T R; Wingfield, B D; 2007. Pitch canker caused by *Fusarium circinatum*: A growing threat to pine plantations and forests worldwide. Australasian Plant Pathology 37(4): 319-334.

Heterobasidion annosum sensu lato

Transmission Factors:

- **Transmission substrates(s):** The most likely transmission substrate is decayed wood. Spores have been shown to survive on foliage (Rishbeth and Merideth 1957) and on bark (Korhonen 1981). Spores could survive in dry soil for more than a year and with a few surviving for up to 5 years (Rishbeth 1963) but viability was quickly lost in wet soil.
- **Current Distribution:** Europe and North America
- **Evidence that pest has already been successfully transmitted to new areas**: There is no evidence that these fungi have been successfully transmitted to, and established in new areas.

Damage and Economic Impact:

- **Production loss:** The economic impact of root and butt rot caused by *Heterobasidion annosum* in Denmark is estimated to be 50 million Dkr. (6.7 million ECU) or the equivalent of 125,000 m^3 of *Picea abies* timber (Bendz-Hellgren et al. 1998). Dimitri and Tomiczek (1998) estimated that the ecological and economic impact in Germany exceeded DEM 130 million per year. Delatour (1998) estimated that at the time of clear-felling of a 60-yearold plantation of *Picea abies* in France could expect a financial loss higher than 10%.

Environmental Invasiveness: Because *Heterobasidion annosum* sensu lato has a broad host range including both conifers and angiosperm trees it is likely that this fungus would spread reasonably quickly in New Zealand. As these species can be both saprophytic as well as parasitic it might go unnoticed for some time after establishment.

References:

Bendz-Hellgren, M.; Lipponen, K.; Solheim, H.; Thomsen, I.M. 1998: The Nordic countries. Pp.333-345. In Woodward, S.; Stenlid, J.; Karjalainen, R.; Hüttermann, A. '*Heterobasidion annosum*: Biology, Ecology, Impact and Control *Heterobasidion annosum*: Biology, Ecology, Impact and Control.' CAB International, Oxon and New York.

Delatour, C. 1998: France. Pp. 369-376. In Woodward, S.; Stenlid, J.; Karjalainen, R.; Hüttermann, A. '*Heterobasidion annosum*: Biology, Ecology, Impact and Control.' CAB International, Oxon and New York.

Dimitri, L.; Tomiczek, C. 1998: Germany and Austria. Pp. 355-368. In Woodward, S.; Stenlid, J.; Karjalainen, R.; Hüttermann, A. '*Heterobasidion annosum*: Biology, Ecology, Impact and Control.' CAB International, Oxon and New York.

Hansen, E.M.; Lewis, K.J. 1997: 'Compendium of conifer diseases.' APS Press, St Paul, Minnesota.

Korhonen, K.; Stenlid, J. 1998: Biology of *Heterobasidion annosum*. Pp. 43-70. In Woodward, S.; Stenlid, J.; Karjalainen, R.; Hüttermann, A. '*Heterobasidion annosum*: Biology, Ecology, Impact and Control' CAB International, Oxon and New York.

Morrison, D.J. 1989: Factors affecting infection of preconditioned thinning stumps by *Heterobasidion annosum* in British Columbia. Pp. 95-100. In Otrosina, W.J.; Scharf, R.F. (Eds) 'Proceedings of the Symposium on Research and Management of Annosum Root Disease (*Heterobasidion annosum*) in Western North America. United States Department of Agriculture, Forest Service, General Technical Report PSW-116.

Rishbeth, J. 1959: Dispersal of *Fomes annosus* Fr. and *Peniophora gigantea* (Fr.) Massee. Transactions of the British Mycological Society 42: 243-260.

Rishbeth, J. 1963: Stump protection against *Fomes annosus* III. Inoculation with *Peniophora gigantea*. Annals of Applied Biology 52: 63-77.

Rishbeth, J.; Merideth, D.S. 1957: Surface microflora on pine needles. Nature 179: 682-683.

Leptographium wageneri (Kendrick) M.J. Wingfield

Transmission Factors:

- **Transmission substrate(s):** Possible means of transmission may include bark, timber, wood packaging or dunnage. It is possible that the fungus may be introduced via invasive bark beetles.
- **Current Distribution:** North America
- **Evidence that pest has already been successfully transmitted to new areas:** The fungus has spread through BC since its first report there in 1976.

Damage and Economic Impact:

In interior BC up to 50% of trees in some 60-110 year old *P. contorta* stands have been killed. On the coast the disease has been frequently reported in younger 15-30 year old stands

References:

Hansen, E. 1997. Leptographium diseases. In: Compendium of conifer diseases. Hansen EM and Lewis KL (Eds.) APS Press, St. Paul, Minnesota. pp. 8-9.

Schweigkofler, W, Otrosina, WJ, Smith, SL, Cluck, DR, Maeda, K, Peay, KG, Garbelotto, M. 2005. Detection and quantification of *Leptographium wageneri*, the cause of black-stain root disease, from bark beetles (Coleoptera: Scolytidae) in Northern California using regular and real-time PCR. Canadian Journal of Forest Research, 35:1798-1808.

Wagner, RE. 1977. *Verticiladiella* species associated with *Hylurgops porosus* LeConte (Coleoptera: Scolytidae) in lodgepole pine. M.Sc. thesis. University of Idaho, Moscow, Idaho.

Wagener WW, and Mielke JL. 1961. A staining fungus root disease of ponderosa, Jeffrey and pinyon pines. Plant Disease Reports. 45:831-835.

Wood DL, Koerber TW, Scharpf RF, Storer AJ. 2003. Pests of the native California conifers. University of California Press, Berkeley, California.

Mycosphaerella dearnessii Barr

Transmission Factors:

- **Transmission substrate(s):** Both live and dead needles (Hansen and Lewis 1997, Myren 1994, Sinclair et al. 1987). Movement of infected nursery stock has been the main form of spread in the Southern United States (Gibson 1979).
- **Current Distribution:** North America, South Africa, various parts of Europe, and Japan.
- **Evidence that pest has already been successfully transmitted to new areas:** The fungus is believed to be of North American origin (Holdenrieder and Sieber 1995, Huang et al. 1995). Over the past 10 years there are numerous records of the fungus establishing in new areas. In Europe alone the disease has been found in Bulgaria, Spain, Austria, Yugoslavia, Georgia (ex USSR) and more recently in France, Southern Germany and Switzerland (Holdenrieder and Sieber 1995). It has also recently been found in Japan (Suto and Ougi 1998).

Damage and Economic Impact:

- Production loss of major hosts(s): In *P. palustris* the 'grass stage' (a growth period when diameter increases but height does not) which usually lasts 5 years can be delayed for 10-20 years. Severe blight, 3 years in succession can kill seedlings. In *Pinus sylvestris* Christmas tree plantations needle browning and defoliation can make the trees unmarketable (Gibson 1979, Hansen and Lewis 1997, Sinclair et al. 1987). *Mycosphaerella dearnessii* affects all ages of susceptible tree species but is most dangerous to young ones and it generally takes 2-3 years for the disease to reach epidemic status (Sinclair et al. 1987). Li et al. (1991) found that the disease incidence increased gradually within 3-4 years of planting *P. elliottii* in Jiangxi Province, China, and decreased after the fifth year. The disease spread rapidly from the infection focus. *Pinus palustris* seedlings were assessed for infection and at age 30 the survival of trees that were classed as lightly infected as seedlings exceeded those that were classed as moderately to severely infected. Pulp wood production from 30-year-old trees that were lightly infected as seedlings averaged 2-4 times that of moderately to heavily infected seedlings (Wakely 1970). Gibson (1979) notes that the ability of this pathogen to adapt to new hosts and physical environmental conditions enhances its threat to pine crops.

References:

Cech, T. L. 1997: Brown spot disease in Austria – the beginning of an epidemic? Forstschutz Aktuell 19-20: 17.

Derr, H. J.; Melder, T. W. 1970: Brown spot resistance in longleaf pine. Forestry Science 16: 201-209.

Evans, H. C. 1984: The genus Mycosphaerella and its anamorphs *Cercoseptoria*, *Dothistroma* and *Lecanosticta* on pines. Mycological Paper 153: 7-35.

Gibson, I.A.S. 1979: 'Diseases of Forest Trees Widely Planted as Exotics in the Tropics and Southern Hemisphere. Part II. The Genus *Pinus'*. Commonwealth Mycological Institute, Kew.

Hansen, E. M.; Lewis, K. J. 1997: 'Compendium of Conifer Diseases.' APS Press, St Paul, Minnesota.

Jewell, F. F. Sr.; 1993: Histopathology of loblolly pine needles infected by *Mycosphaerella dearnessii*, the brown-spot needle disease pathogen. European Plant Pathology 23: 110-119.

Li, C. D.; Ye, J. R.; Han, Z. M.; Zheng, P.; Xu, G. H.; Min, S. B.; Li, X. Y. 1991: Development of brown spot needle blight in young slash pine plantations in Fengxin, Jiangxi provinence. Journal of Nanjing Forestry University. 15: 1-6.

Sinclair, W. A.; Lyon H. H.; Johnson, W. T. 1987: Diseases of Trees and Shrubs. Cornell University Press, Ithaca and London.

Suto, Y.: Ougi, D. 1998: *Lecanosticta acicola*, casual fungus of brown spot needle blight in *Pinus thunbergii*, new to Japan. Mycoscience, 39: 319-325.

Wakely, P. C. 1968: Rust susceptibility in longleaf pine associated with brown spot resistance and early commencement of height growth. Forestry Science 14: 323-324.
Wakely, P. C. 1970: Thirty year effects of uncontrolled brown spot on planted longleaf pine. Forestry Science 16: 197-202.
Ye, J. R.; Qi, G. F. 1999: Studies on the biological specialization of the toxin producing by brown spot needle blight fungus. Journal of Nanjing Forestry University. 23: 1-4.
Ye, J. R.; Xe, C. X.; Wang, Y. Y.; Cheng, S. W.; 1998: Primary reasearch on the pathogenic mechanisms of *Lecanosticta acicola*, the causal organism of brown spot needle blight. Forest Research 11: 243-248.

Phytophthora pinifolia Alv. Durán, Gryzenh. & M.J. Wingf.

Transmission Factors:

- **Transmission substrates(s):** Natural infection is assumed to result from airborne sporangia (carried in rain or mist). As for other *Phytophthora* spp. it is likely that the organism can be transmitted by infected plant material, water and soil. Studies have shown that green sawn timber did not carry *P. pinifolia.*
- **Current Distribution:** Chile
- **Evidence that pest has already been successfully transmitted to new areas:** No evidence. However researchers suggest that as it has recently emerged as a new organism and new disease, it is likely that it was introduced to Chile. Results of DNA sequence analysis of 88 isolates show that all belong to a single genotype further supporting this conclusion. The country of origin is unknown.

Damage and Economic Impact: The disease is characterized by a relatively rapid death of needles and subsequent defoliation of trees. While some diseased trees can recover the following growing season, others may suffer reduced growth rate and be more susceptible to attack by other pathogens. Tree death has occurred. *Phytophthora pinifolia* is currently the most important problem affecting *P. radiata* populations in Chile and seriously threatens the local forestry industry. In addition trade bans on the importation of logs and sawn timber from Chile have been imposed by Australia and by Korea.

References:

Ahumada, R; Diaz, C; Peredo, M; Barría, C; González, P; Cuevas, G 2009: Detection of possible *Phytophthora pinifolia* infection in *Pinus radiata* green sawn timber produced in Chile. Fourth Sudden Oak Death Science Symposium, June 15-18, 2009, Santa Cruz, California.

Duran, A; Gryzenhout, M; Slippers, B; Ahumada, R; Rotella, A; Flores, F; Wingfield, B; Wingfield, M 2008: *Phytophthora pinifolia* sp nov associated with a serious needle disease of *Pinus radiata* in Chile. Plant pathology 57: 715-727

EPPO 2009: European and Mediterranean Plant Protection Organization (EPPO), 2009. *Phytophthora pinifolia* is a new pathogen of *Pinus radiata* in Chile: addition to the EPPO Alert List. EPPO Reporting Service – Pests & Diseases

Pseudocercospora pini-densiflorae (Hori & Nambu) Deighton

Transmission Factors:

- **Transmission substrates(s):** Airborne spores, primarily in water droplets (Gibson 1979).The fungus is an obligate parasite and survival of inoculum during unfavourable weather is by mycelium in infected needle tissue (Gibson 1979).
- **Current Distribution:** Widespread in Asia, Africa and Central America, and in Brazil (Evans 1984; Gibson 1979; Ivory 1994).
- **Evidence that pest has already been successfully transmitted to new areas:** The fungus was described in Japan in 1917 and remained confined to Japan, Taiwan and Korea until 1960, when it was found in Tanganyika followed by records in Zimbabwe and Zambia. Records from other parts of Asia and Africa, and from Central and South America, followed (Ito 1972; Gibson 1979). The first known occurrence in India of *P. pini-densiflorae,* on 5- and 6-year-old trees of *Pinus radiata* at Amarkantak, Madhya Pradesh, and on *P. oocarpa* and *P. kesiya* in the nursery at the Forest Research Institute, Dehra Dun was reported in 1973 (Reddy and Pandey 1973).

Damage and Economic Impact:

- **Production loss:** There has been significant reduction in growth of seedling pines in Malaysia. In addition, the disease persisted on *P. caribaea* and *P. merkusii* after planting out and many died or became severely weakened (Ivory 1975). In Japan, Ito (1972) reported epidemics where 100% of seedlings of *Pinus* spp. were infected and 50-80% killed. Of those hosts recorded as highly susceptible (Gibson 1979; Ito 1972) the species grown in New Zealand plantations are *P. contorta*, *P. lambertiana*, *P*. *nigra*, *P. pinaster*, *P. ponderosa*, *P. radiata*, and *P. strobus*.

References:

Evans, H.C. 1984: The genus Mycosphaerella and its anamorphs *Cercoseptoria*, *Dothistroma* and *Lecanosticta* on pines. Mycological Paper 153: 1-102. Gibson, I.A.S. 1979: 'Diseases of Forest Trees Widely Planted as Exotics in the Tropics and Southern Hemisphere. Part II. The Genus Pinus'. Commonwealth Mycological Institute, Kew.

Gibson, I.A.S. 1979: 'Diseases of Forest Trees Widely Planted as Exotics in the Tropics and Southern Hemisphere. Part II. The Genus Pinus'. Commonwealth Mycological Institute, Kew.

Ito, K. 1972: Cercospora needle blight of pines in Japan. Bulletin of the Government Forest Experiment Station, Meguro 246. 21-33.

Ivory, M.H. 1975: The pathology of *Pinus* spp. in West Malaysia. Commonwealth Forestry-Review 54: 154-165

Ivory, M.H. 1994: Records of foliage pathogens of *Pinus* species in tropical countries. Plant Pathology 43: 511-518.

Reddy, M.A.R.; Pandey, P.C. 1973: Cercospora needle blight of radiata pine in India. Indian Forester 99: 308-309.

Sujan-Singh; Khan, S.N. 1988: Relative resistance of pines to Cercoseptoria needle blight in India. Indian Forester 114: 84-88.

Suto, Y. 1979: Pathogenicity of *Cercospora pini-densiflorae* Hori et Nambu to various coniferous seedlings Journal of the Japanese Forestry Society 61: 180-183.

Insects

Dendroctonus ponderosae Hopkins

Transmission Factors:

- **Transmission substrate(s):** Wood with bark attached.
- **Survivability over time:** Species of *Dendroctonus* (not *D. ponderosae*) have been intercepted alive at New Zealand ports and at least two species have become established outside their native ranges (Stephen and Grégoire 2001).
- **Current Distribution:** Canada, USA, and Mexico (Wood and Bright 1992).
- **Evidence that pest has already been successfully transmitted to new areas:** There is no evidence that *D. ponderosae* has moved into new areas.

Damage and Economic Impact: This is one of the most destructive insects in the pine forests of western North America. Severe economic damage is most common in *P. contorta, P. lambertiana* and *P. ponderosa* stands (Bright and Stark 1973). In *P. contorta* stands when outbreaks are extensive millions of trees may be killed each year (Amman et al 1989).

References:

Amman, G.D.; McGregor, M.D.; Dolph, R.E. 1989: Mountain pine beetle. United States Department of Agriculture, Forest Service, Forest Insect and Disease Leaflet 2. (http://www.fs.fed.us/r6/nr/fid/fidls/fidl2.htm).

Bright, D.E.; Stark, R.W., 1973: The bark and ambrosia beetles of California (Coleoptera:Scolytidae and Platypodidae). California Insect Survey Bulletin 16.

Browne, F.G. 1968: 'Pests and Diseases of Forest Plantation Trees. An Annotated List of the Principal Species Occurring in the British Commonwealth.' Clarendon Press, Oxford.

Furniss, R.L.; Carolin, V.M. 1977: Western forest insects. United States Department of Agriculture Forest Service Miscellaneous Publication 1339.

Graham, S.A. and Knight, F.B. 1965: 'Principles of Forest Entomology.' McGraw-Hill, New York.

Stephen, F.M.; Grégoire, J.C. 2001: Introduction and establishment of exotic bark beetles. Http://www.exoticpests.apsnet.org/Papers/stephen.htm.

United States Department of Agriculture 1992: Pest risk assessment of the importation of *Pinus radiata* and Douglas-fir logs from New Zealand. United States Department of Agriculture, Forest Service, Miscellaneous Publication 1508.

Wood, S.L.; Bright, D.E. 1992: A catalog of Scolytidae and Platypodidae, Part 2: Taxonomic Index, Volume B. Great Basin Naturalist Memoirs No. 13.

Dendroctonus valens Le Conte

Transmission Factors:

- **Transmission substrates(s):** Wood with bark attached.
- **Current Distribution:** Canada, USA, Mexico, and China (Shanxi, Shaanxi, Hebei and Henan).
- **Evidence that pest has already been successfully transmitted to new areas:** It is established in China (Stephen and Grégoire 2001).

Damage and Economic Impact: *Dendroctonus valens* normally attacks injured, weakened, or dying trees and freshly cut logs and stumps. It often attacks trees that are left after logging. Fire scorched trees in camp grounds and around homes are also frequently attacked. Usually it is not aggressive and does not have outbreaks (Furniss and Carolin 1977). However is does act aggressively in China (where it became established in the 1990s). More than 500 000 hectares of pine forests have been attacked in Shanxi, Shaanxi, Hebei and Henan and it is estimated that over 10 million *Pinus tabulaeformis* have been killed (issg.org/database/species/impact_info.asp?si=1405&fr=1&sts=&lang=EN)

References:

Cibrián Tovar, D.; Mendéz Montiel, J. T.; Campos Bolaños, R.; Yates, H. O.; Flores Lara, J., 1995. Forest insects of Mexico. Universidad Autónoma Chapingo, Mexico.

Furniss, R.L.; Carolin, V.M. 1977: Western forest insects. United States Department of Agriculture Forest Service Miscellaneous Publication 1339.

http://www.issg.org/database/species/impact_info.asp?si=1405&fr=1&sts=&lang=EN (accessed 7 September 2010).

Stephen, F.M.; Grégoire, J.C. 2001: Introduction and establishment of exotic bark beetles. Http://www.exoticpests.apsnet.org/Papers/stephen.htm.

Wood, S.L., 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Naturalist Memoirs 6.

Wood, S.L.; Bright, D.E. 1992: A catalog of Scolytidae and Platypodidae, Part 2: Taxonomic Index, Volume B. Great Basin Naturalist Memoirs No. 13.

Hylobius abietis L.

Transmission Factors:

- **Transmission substrate(s):** Wood with bark attached.
- **Current Distribution:** Eurasia.
- **Evidence that pest has already been successfully transmitted to new areas:** Intercepted six times at New Zealand ports, four times alive (Scion BUGS database 1948-1990).

Damage and Economic Impact: *Hylobius abietis* is the most important pest of replanted coniferous sites across Europe, where feeding by adult weevils can result in up to100% mortality of seedlings (eg. Dillon et al. 2008, Leather et al. 1999).

References:

Dillon, A.B.; Moore, C.P.; Downes, M.J.; Griffin, C.T. 2008. Evict or infect? Managing populations of the large pine weevil, *Hylobius abietis*, using a bottom–up and top–down approach. Forest Ecology and Management 255: 2634–2642.

Leather, S.R.; Day, K.R.; Salisbury, A.N. 1999. The biology and ecology of the large pine weevil, *Hylobius abietis* (Coleoptera: Curculionidae): a problem of dispersal? Bulletin of Entomological Research 89: 3-16.

Wainhouse, D.; Reay, S.; Kay, M. 2010.Predicting the vulnerability of New Zealand radiata pine plantations to the European pine weevil. Forestry 83(3): 277-283.

Ips grandicollis (Eichhoff)

Transmission Factors:

- **Transmission substrate(s):** Wood with bark attached.
- **Current Distribution:** Antilles Islands, Australia, Canada, El Salvador, Guatemala, Honduras, Mexico, USA (Wood and Bright 1992).
- **Evidence that pest has already been successfully transmitted to new areas:** Has been established in Australia.

Damage and Economic Impact: This species (along with *Ips avulsus* and *I. calligraphus*) is responsible for much annual mortality in the USA (Graham and Knight 1965), killing more pine timber in the southern USA than any other forest insect, with the exception of *Dendroctonus frontalis* (Douce 2000). However, in Mexico it apparently infests the branches of fallen trees and does not attack live trees (Cibrián Tovar et al 1995). In Australia, Neumann and Marks (1990) state that *Ips grandicollis* has not yet caused economically important damage but Neumann and Morey (1984) report hundreds of apparently healthy *P. radiata* trees killed after massed attacks.

References:

Baker, W.L. 1972: Eastern forest insects. United States department of Agriculture Forest Service Miscellaneous Publication No. 1175.

Cibrián Tovar, D.; Mendéz Montiel, J.T.; Campos Bolaños, R,; Yates, H.O.; Flores Lara, J. 1995. 'Forest insects of Mexico.' Universidad Autónoma Chapingo, Mexico.

Coulson, R.N.; Flamm, R.O.; Pulley, P.E.; Payne, T.L.; Rykiel, E.J.; Wagner, T.L. 1986: Response of the southern pine bark beetle guild to host disturbance. Environmental Entomology 15: 850-858. Dixon, W.N. 1983: Clonal specificity of Ips and Pityophthorus spp. (Coleoptera: Scolytidae) in a slash pine seed orchard. Florida Entomologist 66: 515-517.

Douce, K.G. 2000: Ips beetles. Http://www.barkbeetles.org/pbb/pbbips.html

Graham, S.A. and Knight, F.B. 1965: 'Principles of Forest Entomology.' McGraw-Hill, New York.

Morgan, F.D. 1967: *Ips grandicollis* in South Australia. Australian Forestry 31: 137-155.

Neumann, F.G.; Marks, G.C. 1990: Status and maagement of insect pests and diseases in Victorian softwood plantations. Australian Forestry 53: 131-144.

Neumann, F.G.; Morey, J. 1984: Studies on the introduced bark beetle *Ips grandicollis* (Eichhoff) in Victorian radiata pine plantations. Australian Forest Research 14: 283-300.

Wood, S.L.; Bright, D.E. 1992: A catalog of Scolytidae and Platypodidae, Part 2: Taxonomic Index, Volume B. Great Basin Naturalist Memoirs No. 13.

Ips paraconfusus Lanier

Transmission Factors:

- **Transmission substrate(s):** Wood with bark attached.
- **Current Distribution:** USA (Wood and Bright 1992).
- **Evidence that pest has already been successfully transmitted to new areas:** None found.

Damage and Economic Impact: *Ips paraconfusus* is the most common and most destructive species of *Ips* in California (Bright and Stark 1973). It attacks and can kill standing, apparently healthy trees from saplings up to about 650 mm in diameter (Bright and Stark 1973; Furniss and Carolin 1977). Populations of *Ips paraconfusus* build up in logging slash. The insects emerging from the slash attack standing trees (Bright and Stark 1977).

References:

Bright, D.E.; Stark, R.W. 1973: The bark and ambrosia beetles of California (Coleoptera:Scolytidae and Platypodidae). California Insect Survey Bulletin 16.

Furniss, R.L.; Carolin, V.M. 1977: Western forest insects. United States Department of Agriculture Forest Service Miscellaneous Publication 1339.

Wood, S.L.; Bright, D.E., 1992: A catalog of Scolytidae and Platypodidae, Part 2: Taxonomic Index, Volume B. Great Basin Naturalist Memoirs No. 13.

Ips sexdentatus (Boerner)

Transmission Factors:

- **Transmission substrate(s):** Wood with bark attached.
- **Current Distribution:** Eurasia.
- **Evidence that pest has already been successfully transmitted to new areas:** None found.

Damage and Economic Impact: Browne (1968) calls this species is an unaggressive, secondary borer and Bevan (1987) classifies it as 'Less important, causing some loss of increment or value'. On the other hand, Ferreira and Ferreira (1986) say that periodic outbreaks cause the death of many trees. Goix (1977) reports that *I. sexdentatus* is one of the principal insect pests associated with increasing mortality of pines in the central region of France since 1973.

References:

Bevan, D. 1987: 'Forest insects. A guide to insects feeding on trees in Britain. Forest Commission Handbook 1.' HMSO, London.

Browne, F.G. 1968: 'Pests and Diseases of Forest Plantation Trees. An Annotated List of the Principal Species Occurring in the British Commonwealth.' Clarendon Press, Oxford.

Cobos Suarez, J.M.; Ruiz Urrestararazu, M.M. 1990: Problemas fitosanitarios de la especie *Pinus radiata* D.Don en Espana, con especial referencia al Pais Vasco. Boletin de Sanidad Vegetal Plagas 16: 37-53.

Ferreira, M.C.; Ferreira, G.W.S. 1986: Pragas do pinheiro bravo em Portugal – escolitideos. Boletim Agricola No. 36.

Goix, J. 1977: Le deperissment des pins dans la region 'Centre'. Phytoma 29: 18-21.

Loyttyniemi, K.; Uusvaara, O. 1978: Insect attack on pine and spruce sawlogs felled during the growing season. Metsantutkimuslaitoksen Julkaisuja 89: 1-48.

Schimitschek, E. 1940: Beitrage zur Forstentomologie der Turkei III. Die Massenvermehrung des Ips sexdentatus Borner im Gebeite der orientalischen Fichte. II. Teil. Zeitschrift fur Angewandte Entomologie 27: 84-113.

Lymantria monacha (L.)

Transmission Factors:

- **Transmission substrate(s):** The eggs are normally laid in bark crevices on tree trunks but females may deposit eggs in crevices on containers, pallets, and ships (http://na.fs.fed.us/spfo/pubs/pest_al/nunmoth/nun_moth.shtm).
- **Current Distribution:** China, Japan, North & South Korea, Russia, Turkey, Europe (http://www.inspection.gc.ca/english/plaveg/pestrava/lymmon/tech/lymmone.shtml).
- **Evidence that pest has already been successfully transmitted to new areas:** There is no evidence of establishment outside its native range but larvae have intercepted on used vehicles at New Zealand ports (Armstrong et al 2003).

Damage and Economic Impact: *Lymantria monacha* is a serious defoliator of conifers, and to a lesser extent hardwoods. Most damage is to *Picea* and *Pinus*.

References:

Armstrong, K.F.; McHugh, P.; Chinn, W.; Frampton, E.R.; Walsh, P.J. 2003. Tussock moth species arriving on imported used vehicles determined by DNA analysis. New Zealand Plant Protection 56: 16-20.

http://www.inspection.gc.ca/english/plaveg/pestrava/lymmon/tech/lymmone.shtml (accessed 8 September 2010).

Lipa, J.J.; Glowacka, B., 1995. Nun moth (*Lymantria monacha* L. (sic)) in Europe and Poland. *In* Proceedings of the Annual Gypsy Moth Review, Traverse City, Michigan, U.S.A.

Withers, T.M.; Keena, M.A. 2001. *Lymantria monacha* (nun moth) and *L. dispar* (gypsy moth) survival and development on improved *Pinus radiata*. New Zealand Journal of Forestry Science 31 (1): 66-77.

Neodiprion sertifer Geoffroy

Transmission Factors:

- **Transmission substrate(s):** Eggs (overwintering stage) and larvae are present on foliage and pupae in soil (during summer).
- **Current Distribution:** Europe, Asia, and North America.
- **Evidence that pest has already been successfully transmitted to new areas:** Accidentally introduced from Europe to North America, where it may in fact have evolved (Anderbrant et al. 1991).

Damage and Economic Impact: This insect has caused serious damage to young plantations of *Pinus radiata* in Turkey (Kucuk et al. 2003). It is one of the most serious defoliators of *Pinus sylvestris* in northern Europe, where frequent outbreaks occur (Virtanen et al. 1996). Defoliation causes volume losses and can result in tree death (Lyytikäinen-Saarenmaa et al. 2002).

References:

Anderbrant, O.; Löfqvist, J.; Högberg, H.-E.; Hedenström, E.; Wassgren, A.-B.; Bergström, G.; Bengtsson, M.; Magnusson, G. 1991. Field response of the pine sawfly *Neodiprion sertifer* to the pheromone (2S,3S,7S)-diprionyl acetate and its stereoisomers. Entomologia Experimentalis et Applicata 62: 169-181.

Kucuk, M.; Ulu, F.; Cetiner, S.; Akyuz, M. 2003. Growth of Monterey Pine (*Pinus radiata* D. Don) Around Trabzon Province. Paper submitted to the XII World Forestry Congress, Québec City, Canada.

Lyytikäinen-Saarenmaa, P Tomppo, E. 2002. Impact of sawfly defoliation on growth of Scots pine *Pinus sylvestris* (Pinaceae) and associated economic losses. Bulletin of Entomological Research 92(2): 137-140.

Virtanen, T.; Neuvonen, S.; Nikula, A.; Varama, M.; Niemelä, P. 1996. Climate change and the risks of *Neodiprion sertifer* outbreaks on Scots pine. Silva Fennica 30(2–3): 169–177.

Rhyaciona buoliana (Denis & Schiffermüller)

Transmission Factors:

- **Transmission substrate(s):** Foliage, branches.
- **Current Distribution:** Eurasia, North Africa, North America, South America.
- **Evidence that pest has already been successfully transmitted to new areas:** This moth has been introduced into the USA and has since spread across the country and into Canada (Furniss and Carolin 1977). It was also introduced into Argentina and spread from there to Uruguay and Chile (Anon. 1998).

Damage and Economic Impact: This insect affects height growth of young pines and causes deformations, including multiple leaders and crooked stems (Furniss and Carolin 1977). It is considered the most destructive pest of *P. radiata* plantations in Chile (Alvarez de Araya and Ramírez 1989, Lanfranco et al. 1991) and it is considered to be an important pest on *P. radiata* plantations in Turkey (Seven et al. 2005).

References:

Abgral, J.F.; Soutrenon, A. 1991. La forêt et ses ennemis. Paris: Centre National du Machinisme Agricole du Genie Rural des Euax et des forêts, 399 pp.

Anon. 1998: *Rhyacionia buoliana*. http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=18&langdisplay=english.

Alvarez de Araya, G.; Ramírez, O. 1989. Assessment of damage caused by European pine shoot moth in radiata pine plantations in Chile. *In* Alfaro, R.I.; Glover, S. G., (Eds) Insects affecting reforestation: biology and damage. Proceedings, IUFRO Working Group (S2.07-03), XVIII International Congress of Entomology; Vancouver, BC; July 1988: 145-154.

Furniss, R.L.; Carolin, V.M. 1977. Western Forest Insects. United States Department of Agriculture, Forest Service Miscellaneous Publication 1339. 654 pp.

Lanfranco, D.; Aguilar, A.; Ide, S.; Vallejos, R. 1991. Evaluación del daño causado por infestación natural de *Rhyacionia buoliana* sobre plantaciones jóvenes de *Pinus radiata* en la provincia de Valdivia. Informe de Convenio 188. Valdivia: Facultad de Ciencias Forestales, Universidad Austral de Chile, 34 pp.

Seven, S.; Özdemir, M.; Özdemir, Y.; Bozkurt, V. 2005. On the species of *Rhyacionia* Hübner [1825] (Lepidoptera: Tortricidae) in Turkey. Phytoparasitica 33: 123-128.

Thaumetopoea pityocampa (Denis & Schiffermüller)

Transmission Factors:

- **Transmission substrate(s):** Eggs and larvae could be transported on foliage and pupae are present in soil. A gravid female could potentially be brought in accidentally.
- **Current Distribution:** Europe, North Africa and the Near East. In recent decades its range has been expanding, both northward and altitudinal and this has been attributed to warmer temperatures (eg. Battisti et al. 2005).
- **Evidence that pest has already been successfully transmitted to new areas:** Introduced from continental Italy to Sardinia, presumably through human-mediated transport (Luciano et al. 2007).

Economic Impact: This insect is considered a major forest defoliator in Mediterranean forests (Kerdelhué et al. 2009). This pest also has a socioeconomic impact because it possesses urticating setae that can cause contact dermatitis (Lamy, 1990).

References:

Aimi, A.; Zocca , A.; Minerbi, S.; Hellrigl, K.; Gatto, P.; Battisti, A. 2006. The outbreak of the pine processionary moth in Venosta/Vinschgau: ecological and economic aspects. *Forest Observer* **2/3:** 69 – 80.

Battisti, A.; Stastny, M.; Netherer, S.; Robinet, C.; Schopf, A.; Roques, A.; Larsson, S. 2005. Expansion of geographic range in the pine processionary moth caused by increased winter temperatures. *Ecological Applications* **15:** 2084 – 2096.

Brockerhoff, E.; Berndt, L.; 2005. Pine processionary moth and other European forest biosecurity threats. Forest Health News 151, May.

Kerdelhué, C.; Zane, L.; Simonato, M.; Salvato,P.; Rousselet, J.; Roques, A.; Battisti, A. 2009. Quaternary history and contemporary patterns in a currently expanding species; *BMC Evolutionary Biology* 9: 220.

Lamy, M. 1990. Contact dermatitis (erucism) produced by processionary caterpillars (genus *Thaumetopoea*). Journal of Applied Entomology **110:** 425 – 437.

Luciano P.; Lentini A.; Battisti A. 2007**.** First record of *Thaumetopoea pityocampa* in Sardinia**.** Proceedings of the Italian Congress of Entomology 273.

Tomicus piniperda (L.)

Transmission Factors:

- **Transmission substrate(s):** Wood and wood products.
- **Survivability over time:** Well-known to survive in dunnage and packing crates.
- **Current Distribution:** Eurasia, North Africa, USA, Canada.
- **Evidence that pest has already been successfully transmitted to new areas:** Often intercepted in New Zealand, intercepted at US ports several times and now established in the US and Canada.

Economic Impact: Considered the most serious scolytid pine pest in Europe causing losses in annual growth increment and volume (Thomas and Dixon 2004).

References:

Amezaga, I. 1996. Monterrey pine (*Pinus radiata* D. Don) suitability for the pine shoot beetle (*Tomicus piniperda* L.) (Coleoptera: Scolytidae). Forest ecology and management 86: 73-79.

Morgan, R.E., de Groot, P. and Smith, S.M. 2004. Susceptibility of pine plantations to attack by the pine shoot beetle (*Tomicus piniperda*) in southern Ontario, Canadian journal of forest research 34: 2528–2540.

Thomas, M.C. and Dixon, W.N. 2004. Featured creatures: pine shoot beetle, *DPI Entomology Circular 354*. University of Florida Institute of Food and Agricultural Sciences: Florida.

http://www.issg.org/database/species/ecology.asp?si=1200&fr=1&sts=sss&lang=EN