Biosecurity New Zealand
Ministry for Primary Industries
Manatū Ahu Matua

Threat Specific Readiness Manual for *Fusarium circinatum,* the Cause of Pitch Canker

Pine affected by pitch canker.
Source: Joseph OBrien, USDA Forest Service, Bugwood.org

March 2022

Version 1.1

forestgrowers levy trust inc
FOREST OWNERS ASSOCIATION
GIA Biosecurity through Partnership

Contents

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Working in partnership with industry

Under the Government Industry Agreement (GIA), MPI and industry partners agree to work collectively to undertake readiness activities that will prepare to prevent or reduce the impact that an unwanted organism that is not present in New Zealand would have if it were to enter New Zealand.

As such, the development of readiness collateral (such as this document) is a collaborative and iterative process with industry GIA partners, Biosecurity New Zealand's GIA team and other branches within MPI. This collective approach ensures the best biosecurity outcomes and reduces the risk of working in silos.

While the GIA Deed recognises the benefits of industry's engagement across the biosecurity system[1] (e.g. pre-border, border and long-term pest management), this contribution is managed through alternative public consultation processes and industry fora. This work is supported but not led by the GIA team.

For the avoidance of doubt, joint decision-making only applies to the post-border aspects of the biosecurity system. That is, activities that would result in better tools for either eradicating, stopping or slowing the spread of an unwanted organism. For more information and background on the scope of GIA please refer to the guidance material on the GIA website.

The process for developing and approving a joint readiness activity is outlined below. The highlighted green circle indicates the current stage of the process.

Process for developing and approving a joint readiness activity

This is where we are in the process currently (highlighted green) …			
STEP 1	STEP 2	STEP 3	STEP 4
PLANNING	DRAFTING & REVIEW	FINAL REVIEW	APPROVAL
Industry and the GIA team work iteratively to agree the purpose of the document and plan the overall structure and headings, in accordance with an agreed project brief.	The GIA team, MPI SME's, and industry work together to develop the content. **Workshops and meetings are held as necessary.**	Agreement is sought from industry and MPI subject matter experts on the final draft. **Major issues should have been resolved by now. Outstanding issues should be escalated.**	Memo to Director of Readiness and Response Services (or suitable delegation) for **final approval and adoption**.
Who's involved?			
1. GIA Relationship Manager (facilitates)	1. GIA Relationship Manager (facilitates)	1. GIA Relationship Manager (facilitates)	1. Director of Readiness and Response Services (or

[1] Ref: GIA policy for 'engagement across the biosecurity system'

2. GIA technical support 3. Industry Biosecurity Manager	2. GIA technical support 3. Industry Biosecurity Manager 4. MPI subject matter experts 5. Proof-reader (grammar, style, etc)	2. Peer reviewer (from a separate directorate of MPI). 3. Senior BNZ and industry management	suitable delegation) 2. Industry partner CEO (for post-border content only).
Who's accountable?			
GIA Team and Industry Biosecurity Manager	GIA Team and Industry Biosecurity Manager	Senior leadership - BNZ and industry partner.	MPI (and industry partner if post-border content)

Introduction

Pitch canker disease, caused by the fungal pathogen *Fusarium circinatum*, is a serious disease of pines (*Pinus* spp.). It may also infect Douglas-fir (*Pseudotsuga menziesii*). New Zealand is free from *F. circinatum*. Biosecurity New Zealand and the Forest Owners Association recognise that the pathogen presents a significant threat to the exotic forest growing industry in New Zealand, which is based principally on *Pinus radiata*, a highly susceptible host.

This Threat Specific Readiness Manual for *F. circinatum,* has been developed under the Commercial Plantation Forestry Sector Operational Agreement under the Government Industry Agreement (GIA) for Biosecurity Readiness and Response. This plan provides detailed information and guidance for responding to this high-risk organism of national significance.

This plan is based on, and draws extensively from, the "*F. circinatum* Incursion Management Plan for New Zealand" by Ganley & Bulman (2016).

This plan provides information on:

- What we know about *F. circinatum and* pitch canker disease;
- How we would respond;
- Knowledge gaps to inform future readiness work.

In 2003, an incursion response management plan for pitch canker was developed by Dr. Peter Gadgil from the New Zealand Forest Research Institute, Rotorua (Gadgil et. al., 2003). That plan was written for both Australia and New Zealand and contained various procedures for managing an incursion of *F. circinatum* based on the knowledge of the disease at that time. The New Zealand section of the 2003 plan was updated in 2016 by Dr. Rebecca Ganley and Mr. Lindsay Bulman, Scion, Rotorua (Ganley & Bulman, 2016).

Document Purpose

Biosecurity responses are most efficient if they are based on detailed knowledge of the life history, biology, ecology and susceptibility of the risk organism to eradication and control measures.

The purpose of this Threat Specific Readiness Manual for *F. circinatum* (causal agent of pitch canker) is to collate as much of this information as possible, so that it can be readily available to inform decision-making when preparing for and responding to *F. circinatum* incursion.

This document is divided into three parts, each of which may be read and used independently to provide information to inform a response, and projects to improve our readiness to respond to a *F. circinatum* incursion*.* It provides:

- An overview of the current knowledge of the organism (Part I);
- A proposed high-level response action plan that broadly identifies the tools, methods and resources for containment, control and/or eradication of a detected, or established, infection of *F. circinatum* wherever it is found. However, it has a focus on nursery, forest plantation, or public amenity situations (Part II);
- Current knowledge gaps and research that could improve readiness (Part III).

This document is intended to be a ‘living document’ and shall be reviewed and updated if and when new information, science, and response tools become available.

PART I – Current Knowledge of *Fusarium circinatum*, the Causal Agent of Pitch Canker

Understanding the life history, ecology and biology of *F. circinatum* is fundamental to an effective response. This knowledge allows for better evaluation of the threat that it poses, the feasibility of response options and the design of effective surveillance, containment, eradication and control measures.

Pitch canker, a disease caused by *F. circinatum*, is considered to be a serious disease of pines worldwide. The pathogen is native to Mexico, and has invaded the United States, Brazil, Chile, Haiti, Japan, Portugal, South Korea, Spain, South Africa, and Uruguay (CABI, 2018; Drenkhan, Ganley et. al., 2020; EPPO, 2019; Pfenning et. al., 2014).

Despite its seriousness as a plant pathogen, pitch canker disease expression has been variable in some locations. While the exact factors that influence pitch canker disease expression are currently unknown, the plant disease triangle (Figure 1) demonstrates the importance of the interactions between susceptible host, pathogen and environment for disease development. This is included to aid understanding of the variability of disease expression.

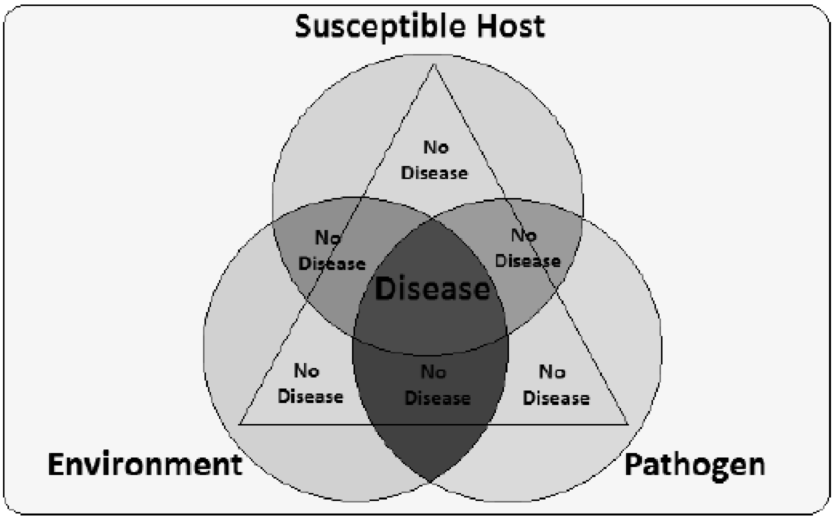

Fig. 1: Plant disease triangle (sourced from Islam et. al., 2017).

Part I provides known information on *F. circinatum*, including the risk pathways. This part is suitable for those that need to familiarise themselves with *F. circinatum* for readiness or response purposes, e.g., the Intelligence Workstream in a response.

1 Taxonomy

1.1 Scientific Name

Fusarium circinatum Nirenberg & O'Donnell, 1998

1.2 Classification

Kingdom	Fungi
Phylum	Ascomycota
Class	Sordariomycetes
Order	Hypocreales
Family	Nectriaceae
Genus	Fusarium

1.3 Synonyms

Gibberella circinata Nirenberg & O'Donnell ex Britz, T.A. Cout., M.J.Wingf. & Marasas, 2002

Gibberella circinata Nirenberg & O'Donnell, 1998

Fusarium lateritium f.sp. *pini* Snyder et. al.

Fusarium moniliforme var. *subglutinans* Wollenw. & Reinking

Fusarium subglutinans (Wollenw. & Reinking) P.E. Nelson et. al.

Fusarium subglutinans f.sp. *pini* J.C. Correll et. al.

Gibberella baccata f.sp. *pini*

Gibberella fujikuroi var. *subglutinans* E.T. Edwards

Gibberella subglutinans (E.T. Edwards) P.E. Nelson et. al.

(Sourced from GBIF, https://www.gbif.org/species/5252196, accessed 21 April 2020. Additional records from https://www.cabi.org/isc/datasheet/25153).

2 Legal Status of *Fusarium circinatum* in New Zealand

2.1 Notifiable Organism Status

***Fusarium circinatum* is a Notifiable organism under the Biosecurity Act 1993.**

Under section 45 of the Biosecurity Act "Notifiable Organisms" the Governor General has by Order in Council declared *F. circinatum* a notifiable organism (Biosecurity (Notifiable Organisms) Order 2016, Schedule Notifiable Organisms).

The Notifiable Organism status places a legal duty to report the suspected presence of this organism within New Zealand. Refer section 46, Biosecurity Act 1993 (Info Box 1).

46 Duty to report notifiable organisms

(1) Every person who—

(a) at any time suspects the presence of an organism in any place in New Zealand; and

(b) suspects that it is for the time being declared to be a notifiable organism under subsection (2) of section 45; and

(c) believes that it is not at the time established in that place; and

(d) has no reasonable grounds for believing that the chief technical officer is aware of its presence or possible presence in that place at that time,—

shall without unreasonable delay report to the chief technical officer its presence or possible presence in that place at that time.

(2) Every person who—

(a) at any time suspects the presence of an organism in a place in the region, or in any part of the region, of a regional council; and

(b) suspects that it is for the time being declared to be an organism notifiable within the region or part under subsection (3) of section 45; and

(c) believes that it is not at that time established in that place; and

(d) has no reasonable grounds for believing that the chief technical officer is aware of its presence or possible presence in that place at that time,—

shall without unreasonable delay report to the chief technical officer its presence or possible presence in that place at that time.

Section 46(1)(b): amended, on 26 November 1997, by section 35(2)(c) of the Biosecurity Amendment Act 1997 (1997 No 89).

Info Box 1. The Notifiable Organism status, Biosecurity Act 1993.

2.2 Unwanted Organism Status

***Fusarium circinatum*, is an Unwanted Organism under the Biosecurity Act 1993.**

The Biosecurity Act 1993 defines what constitutes an "Unwanted Organism" (Info Box 2).

unwanted organism means any organism that a chief technical officer believes is capable or potentially capable of causing unwanted harm to any natural and physical resources or human health; and

(a) includes—

(i) any new organism, if the Authority has declined approval to import that organism; and

(ii) any organism specified in Schedule 2 of the Hazardous Substances and New Organisms Act 1996; but

(b) does not include any organism approved for importation under the Hazardous Substances and New Organisms Act 1996, unless—

(i) the organism is an organism which has escaped from a containment facility; or

(ii) a chief technical officer, after consulting the Authority and taking into account any comments made by the Authority concerning the organism, believes that the organism is capable or potentially capable of causing unwanted harm to any natural and physical resources or human health

Info Box 2. The Unwanted Organism status, Biosecurity Act 1993.

Fusarium circinatum is an unwanted organism. It was determined as an unwanted organism on 16 November 2006, by the then Chief Technical Officer, Ruth Frampton (MPI Unwanted Organism Database, accessed 6 April 2019: https://www1.maf.govt.nz/uor/searchframe.htm).

Fusarium circinatum is not present in New Zealand and was not present in New Zealand immediately prior to 29 July 1998. Under the Hazardous Substances and New Organisms Act 1996 (Info Box 3), this means that it would also be considered a new organism and as such is also an unwanted organism by default.

2A Meaning of term new organism

(1) A **new organism** is—

(a) an organism belonging to a species that was not present in New Zealand immediately before 29 July 1998:

(b) an organism belonging to a species, subspecies, infrasubspecies, variety, strain, or cultivar prescribed as a risk species, where that organism was not present in New Zealand at the time of promulgation of the relevant regulation:

(c) an organism for which a containment approval has been given under this Act:

(ca) an organism for which a conditional release approval has been given:

(cb) a qualifying organism approved for release with controls:

(d) a genetically modified organism:

(e) an organism that belongs to a species, subspecies, infrasubspecies, variety, strain, or cultivar that has been eradicated from New Zealand.

Info Box 3. New Organisms status, Hazardous Substances and New Organisms Act 1996.

3 Biology and Epidemiology

Fusarium circinatum is a wind-borne fungal pathogen which causes branch dieback and resinous cankers in a number of pine species by compromising the vascular system. *Fusarium circinatum* has a wide host range within the *Pinus* genus, although the degree of susceptibility is variable. *Pinus radiata* and other members of the Attenuata Group, sub-section *Oocarpa* are considered the most susceptible species to *F. circinatum* (Gordon et. al., 2001).

In addition to pines, *F. circinatum* has also been identified on Douglas-fir, (*Pseudotsuga menziesii*). *Pseudotsuga menziesii* is the only tree species outside the *Pinus* genus that has been shown to be susceptible to *F. circinatum* infection in both greenhouse experiments and in the field. In general, most Douglas-fir trees in the field are asymptomatic. Additionally, those that do have active *F. circinatum* infections do not usually display the characteristic pitch canker symptoms, such as resinous cankers, which can make detection difficult (Storer et. al., 1997). Low susceptibility to *F. circinatum* has been observed with pre- and post-emergence of *Cupressus macrocarpa* and *Eucalyptus regnans* seed and seedlings in greenhouse experiments (Dick & Simpson, 2004), but these trees species are not considered susceptible to *F. circinatum* in the field.

Recently, corn (*Zea mays*) and species from several plant families, i.e., *Agrostis capillaris, Pseudarrhenatherum longifolium, Briza maxima, Bromus carinatus,* *Ehrharta erecta var. erecta*, and *Pentameris pallida* (members of Poaceae), *Centaurea debeauxii, Hypochaeris radicata,* and *Sonchus oleraceus* (members of Asteraceae), *Teucrium scorodonia* (member of Lamiaceae), and *Rubus ulmifolius* (member of Rosaceae) have been shown to be asymptomatic hosts of *F. circinatum* (Swett et. al., 2014; Swett & Gordon, 2015; Hernandez-Escribano et. al., 2018; Carter & Gordon, 2020; Herron, et. al., 2020). The role these asymptomatic hosts may play in the disease epidemiology is unknown, however pine seedlings can be infected from senescent tissue of non-symptomatic plants colonized by the fungus (Hernandez-Escribano et. al., 2018). Non-symptomatic hosts may therefore act as reservoirs of inoculum or also as reservoirs of genetic diversity of the fungus (Hernandez-Escribano et. al., 2018). Diseases of pines caused by *Fusarium species* in forest nurseries have been reported in all habitable continents and in a wide range of climatic regions. Two species, *F. oxysporum* and *F. solani*, are by far the most commonly recorded from around the world causing seedling disease, and this is also true for New Zealand (Edmonds & Heather, 1973; Vaartaja & Bumbieris, 1967). The host plants and other plant species affected by *F. circinatum* are listed in Table 1.

Table 1. Host plants and other plant species affected by *F. circinatum* (CABI, 2021).

Plant name	Family	Context	Reference
Pinus elliottii	Pinaceae	Main	
Pinus palustris	Pinaceae	Main	
Pinus patula	Pinaceae	Main	Britz et al. (2001);
Pinus radiata	Pinaceae	Main	Coutinho et al. (2007);
Pinus taeda	Pinaceae	Main	Pfenning et al. (2014)
Pinus virginiana	Pinaceae	Main	
Cymbidium	Orchidaceae	Other	
Musa acuminata	Musaceae	Other	
Pinus arizonica	Pinaceae	Other	
Pinus attenuate	Pinaceae	Other	Gordon et al. (2001)
Pinus ayacahuite	Pinaceae	Other	
Pinus canariensis	Pinaceae	Other	
Pinus cembroides	Pinaceae	Other	
Pinus clausa	Pinaceae	Other	
Pinus contorta	Pinaceae	Other	Gordon et al. (2001)
Pinus coulteri	Pinaceae	Other	Gordon et al. (2001)
Pinus densiflora	Pinaceae	Other	
Pinus discolor	Pinaceae	Other	
Pinus douglasiana	Pinaceae	Other	
Pinus durangensis	Pinaceae	Other	
Pinus echinate	Pinaceae	Other	
Pinus estevezii	Pinaceae	Other	
Pinus glabra	Pinaceae	Other	Enebak and Carey (2003)
Pinus greggii	Pinaceae	Other	Britz et al. (2001)
Pinus halepensis	Pinaceae	Other	Carlucci et al. (2007);
Pinus hartwegii	Pinaceae	Other	
Pinus leiophylla	Pinaceae	Other	Britz et al. (2001)
Pinus luchuensis	Pinaceae	Other	
Pinus maximinoi	Pinaceae	Other	

Pinus michoacana	Pinaceae	Other	
Pinus montezumae	Pinaceae	Other	
Pinus muricata	Pinaceae	Other	Gordon et al. (2001)
Pinus oaxacana	Pinaceae	Other	
Pinus occidentalis	Pinaceae	Other	
Pinus oocarpa	Pinaceae	Other	
Pinus pinaster	Pinaceae	Other	Landeras et al. (2005)
Pinus pinea	Pinaceae	Other	Carlucci et al. (2007)
Pinus ponderosa	Pinaceae	Other	Gordon et al. (2001)
Pinus pringlei	Pinaceae	Other	
Pinus pseudostrobus	Pinaceae	Other	
Pinus pungens	Pinaceae	Other	
Pinus rigida	Pinaceae	Other	
Pinus sabiniana	Pinaceae	Other	Gordon et al. (2001)
Pinus serotina	Pinaceae	Other	
Pinus strobus	Pinaceae	Other	
Pinus sylvestris	Pinaceae	Other	
Pinus thunbergia	Pinaceae	Other	
Pinus torreyana	Pinaceae	Other	Gordon et al. (2001)
Pseudotsuga menziesii	Pinaceae	Other	Vogler et al. (2004)
Pinus	Pinaceae	Unknown	Pérez-Sierra et al. (2007)
Pinus jeffreyi	Pinaceae	Unknown	Gordon et al. (2001)
Pinus lambertiana	Pinaceae	Unknown	Gordon et al. (2001)
Pinus teocote	Pinaceae	Unknown	Britz et al. (2001)
Festuca arundinacea	Poaceae	Wild host	Swett and Gordon (2012)
Holcus lanatus	Poaceae	Wild host	Swett and Gordon (2012)

3.1 Natural Spread Mechanisms

The key biological and human mediated spread mechanisms important from a biosecurity risk management perspective are covered in Section 9. The following is an overview of natural spread mechanisms from a biological perspective taken from Gadgil et. al. (2003).

Fusarium circinatum can be disseminated vertically through infected seed, or horizontally by spores that can be vectored by a variety of different agents such as wind, rain, animals, insects or soil.

With vertical transmission, the pathogen can be carried externally, either on or within the seed coat, or internally within the seed, and can result in deterioration of the seed itself or mortality of the germinated seedling.

For horizontal transmission of *F. circinatum*, spores can be disseminated by a range of factors. However, successful infection occurs when vectoring of the spores is coupled with wounds or natural openings on the tree as intact tissue is not vulnerable to invasion by the fungus (Gordon et. al., 1998; Kuhlman, 1987). In general, pitch canker has been associated with wounds created by insects, weather or mechanical damage. Infections on wounds caused by cattle hooves or the bending of branches by ravens have also been observed (G. M. Blakeslee, personal communication, 2005).

Spores are produced in sporodochia, usually on the branches of their pine host near the needle fascicle and are released after rain softens the sporodochia. The spores can be dispersed either by wind or in water splash. Maximum dispersal has been found to occur during rain accompanied by turbulent air (Blakeslee et. al., 1979).

The exact distance air-borne spores can travel is unknown. A study conducted by Dvorák et. al. (2017) suggests spore dispersal up to at least 1 km from a detected inoculum source. At this point the levels of spores were 85% of those at the centre (even with very mild breezes).

In addition to airborne and water splash dispersal, *F. circinatum* spores are capable of surviving in soil, needle litter and wood debris (Gordon et. al., 2001; Viljoen et. al., 1994; Serrano et. al., 2016). *Fusarium circinatum* does not form specialised structures for surviving in soil (Nirenberg & O'Donnell, 1998), however, it has been reported that isolates of *F. circinatum* are still viable after three years in soil under refrigeration (Barrows-Broaddus & Kerr, 1981). Conidia of *F. circinatum* are not capable of surviving in soil after 224 days at 30°C (Serrano et. al., 2016). Branch segments and needles naturally colonized by *F. circinatum* are not considered to be a potential source of inoculum, and the fungus in soil is not likely to contribute to reinfection of new plantations after 2 years (Serrano et. al., 2016).

Fusarium circinatum spores have been isolated from the wood of infected trees that have been harvested, as well as from slash piles near infected sites. In addition, they have been found to be extremely tolerant of drying (T. R. Gordon, personal communication, 2004). Studies of the survival of *F. circinatum* in wood chips and branches in California found that the pathogen was still viable after one year and was even successfully recovered from three-year old branches (McNee et. al., 2002). Hernandez-Escribano et. al. (2018) reported no infection at branch segments after 858 days, and only 1 needle in 120. They reported no pathogen development after 2 years. Composting has been found to be effective at eliminating the pathogen from wood debris, as is exposure to high temperatures, 50°C or greater, for at least ten days (T. R. Gordon, personal communication, 2004).

Insects that predominantly feed in the crown of *P. radiata* can initiate branch canker infections in healthy stands. Repeated infections from these insects leads to intensification of the disease and can severely weaken the tree. Table 2 lists the insects present in New Zealand that may act as associates with *F. circinatum* (Brockerhoff et. al., 2016). Several *Ips* spp. (bark beetles) are known to facilitate infections on large branches or the main bole, as this is where they establish galleries (Fox, Wood, Koehler & O'Keefe, 1991). *Ips* spp. are attracted to stressed trees, thus they are more likely to be involved in killing already weakened trees and spreading the disease to adjacent trees, rather than initiating infections in uninfected, healthy stands (Fox et. al., 1990; Fox et. al., 1991; Furniss & Carolyn, 1977; Storer et. al., 2002a). Wingfield et. al. reported *F. circinatum* associates with *Hylastes ater* attack in Chile (Wingfield et. al., 2008) and *H. ater* is widespread in NZ plantation forests. Species in the same genus are known carriers of *F. circinatum* in Spain (Romon et. al., 2008). This has important implications for delimiting surveillance because *H. ater* can travel distances much greater than *F. circinatum* spores can travel. Spores of *F. circinatum* have been isolated from a variety of insects that are not known to feed on pines such as flies, wasps and beetles (Correll, et. al., 1991). However, the length of time that *F. circinatum* spores can survive on insects is currently unknown.

Table 2. Insects present in New Zealand that may act as associates with *Fusarium circinatum* (Brockerhoff et. al., 2016).

Species (* non-indigenous sp.)	Family (subfamily)	Origin (native region)	Attacks live (L) or dead plants (D)[a]	Potential pitch canker association[b]
Bark beetles and wood borers				
*Hylastes ater**	Curculionidae, Scolytinae	Europe	(L)[a] D	W, C
*Hylurgus ligniperda**	Curculionidae, Scolytinae	Europe	D	C
Pachycotes peregrinus	Curculionidae, Scolytinae	NZ	D	C
Platypus apicalis	Curculionidae, Platypodinae	NZ	D	C
*Arhopalus ferus**	Cerambycidae	Europe	(L)[a] D	(W), C
Calliprason pallidus	Cerambycidae	NZ	D	C
Hexatricha pulverulenta	Cerambycidae	NZ	(L)[a] D	C
Oemona hirta	Cerambycidae	NZ	(L)[a] D	(W), (C)
Prionoplus reticularis	Cerambycidae	NZ	D	C
*Ernobius mollis**	Anobiidae	Cosmopolitan	D	C
*Sirex noctilio**	Siricidae	Europe	L	C
Mitrastethus baridioides	Curculionidae, Cryptorhynchinae	NZ	D	(C)
Pycnomerus sophorae	Colydiidae	NZ	D	(C)
Xylosandrus crassiusculus	Curculionidae	Cosmopolitan	D	C
Shoot and foliage-feeders				
Pseudocoremia suavis	Geometridae	NZ	L	W, (C)
Hierodoris atychioides	Oecophoridae	NZ	L	W, (C)
Ctenopseustis obliquana	Tortricidae	NZ	L	W, (C)
*Epiphyas postvittana**	Tortricidae	Australia	L	W, (C)
Planotortrix notophaea	Tortricidae	NZ	L	W, (C)
Sapsuckers				
*Pineus boerneri**	Adelgidae	USA	L	(W), (C)
*P. pini**	Adelgidae	Europe	L	(W), (C)
*Essigella californica**	Aphididae	USA	L	(W), (C)
*Eulachnus brevipilosus**	Aphididae	Europe	L	(W), (C)

*Heliothrips haemorrhoidalis**	Thripidae	Cosmopolitan?	L	(W), (C)
Cone insects				
Erechthias fulguritella	Tineidae	NZ	(?)	(?)

[a] *Hylates ater* sometimes attacks pine seedlings for maturation feeding; *Arhopalus ferus* has been recorded as attacking live trees but this is rare and probably limited to fire-damaged trees; *Hexatricha pulverulenta* sometimes breeds in pines, always dead trees, but occasionally it feeds on green twigs of pine (Bain and Hosking 1988); *Oemona hirta* is normally associated with hardwood trees and attacks of softwoods are very rare (Hosking 1978).
[b]Possible association in case of establishment of *F. circinatum* in New Zealand: *W* wounding agent of live trees, *C* carrier, *V* vector; values in brackets indicate uncertainty of association.

4 Summary of Risk

Fusarium circinatum poses a significant threat to plantations and natural stands of *Pinus radiata* due to radiata pine's high susceptibility to this fungal pathogen. It is also known to affect Douglas-fir. In infected countries, the presence of this pathogen in *P. radiata* plantations and nurseries has resulted in severe economic losses due to reduced yields, tree mortality, planting restrictions in infected areas, the costs involved in monitoring and control, and trade restrictions; for example, it has resulted in some primary *Pinus* species becoming uneconomic as forest production species in some countries, i.e. South Africa.

5 Surveillance

Should *F. circinatum* arrive, early detection would contribute to increasing the likelihood of achieving eradication or containment objectives.

With current knowledge, surveillance for this pathogen may consist of combining visual inspections of nursery seedlings and planted trees together with on-site investigation and recognition of symptoms. This work may best fit with general forest plantation inspections for other diseases.

5.1 Current Active Surveillance

While there is no surveillance programme specifically targeting *F. circinatum*, there are several national surveillance programmes and approaches aimed at detecting pests and diseases of concern to native, exotic and commercial plantation tree species, including this fungal pathogen. These are described in Table 3.

These programmes combined provide for both early detection of pests and pathogens nationally, but also provide evidence that New Zealand and its production forests are free from pests and disease of trade significance.

Fusarium circinatum is both a Notifiable Organism (refer Section 2.1 Notifiable Organism Status) and an Unwanted organism (refer Section 2.2 Unwanted

Organism Status) under the Biosecurity Act 1993, placing strict responsibilities on every person who suspects its presence within New Zealand.

Table 3. Overview of the various national surveillance programmes undertaken in New Zealand relevant to *F. circinatum* detection.

Surveillance Programme	Funder	Description
High Risk Site Surveillance Programme (**HRSS**)	Biosecurity New Zealand	This programme is designed to monitor trees, shrubs and wood in areas (predominantly urban) that are endpoints for significant pathways and/or high-risk establishment sites for exotic organisms. These largely comprise active sea and airports, vegetation-rich urban areas, transitional facilities and tourist sites, but also some industrial and military sites that receive large volumes of imported goods. Surveillance effort is largely allocated using a specifically designed Bayesian risk allocation and resource optimisation model. The main objective of the HRSS programme is to detect new plant pests and diseases that may pose a biosecurity risk, negatively impacting on native forests, urban trees, plantation forests and other trees.
Forest Biosecurity Surveillance programme – model allocated surveillance effort (**FBS**)	Biosecurity New Zealand / Forest Owners Association on behalf of the Forest Growers Levy Trust	This programme is similar to the HRSS programme, however, it specifically targets commercial plantation forest species in areas (predominantly urban) that are endpoints for significant pathways and/or high-risk establishment sites for exotic organisms that are considered a risk to plantation forests. Surveillance effort is also allocated using a specifically designed Bayesian risk allocation and resource optimisation model. The main objective of the FBS programme is to detect new forest pests and pathogens that may pose a biosecurity risk, negatively impacting on forest production species.
Forest Biosecurity Surveillance programme – non model allocated surveillance effort (**NMA**)	Forest Owners Association on behalf of the Forest Growers Levy Trust	This is a component of the FBS, which also targets commercial plantation species, but where the FBS focuses primarily on areas that are endpoints for significant pathways and/or high-risk establishment sites for exotic organisms (predominantly urban areas), the NMA focuses effort toward high risk areas and pathways within and around plantation forests. Effort is not allocated using the model used in the FBS but utilises various risk information, experience, invasion biology and knowledge of internal risk pathways as mechanisms for spread. This shares the same objectives as the FBS.
Forest Health Assessments (**FHA**)	Forest Companies	These surveys fulfil a wide range of outcomes for forest growers, a key one of which is to understand the health of their forests and to provide early detection of any biosecurity threat, or other issues that may affect the health of their

		forests. These also provide for early detection of biosecurity threats (new or established) as well as monitoring the spread of established pests and pathogens throughout New Zealand. These surveys are undertaken within commercial forest plantations.
New Zealand's general surveillance system	Biosecurity New Zealand	Biosecurity New Zealand maintains a general (passive) surveillance system that comprises a free 24/7 Pest and Disease hotline (0800 80 99 66), specialist incursion investigators, diagnostics laboratories, a notifiable organisms list, an Unwanted Organisms register, legislative requirements to report suspect new to New Zealand organisms (Notifiable Organisms) or unwanted organisms, and an engaged and aware community (comprising industry staff, scientists, government staff, tangata whenua, and members of the public. This system encompasses all sectors and provides for broad geographic coverage and enables anyone in New Zealand to actively participate in the biosecurity surveillance system. All notifications made into this system are triaged by a call centre and allocated to specialist incursion investigators, or laboratory scientists, who follow these up with the aim of rapidly ascertaining or ruling out a potential biosecurity threat. The forest growing sector actively raises awareness of production forest pests and pathogens and promotes the pest and disease hotline with all growers and biosecurity surveillance providers through its electronic newsletters, and its biosecurity network – PineNet. It is also actively contributing to the development of the Find-A-Pest platform/app to improve the quality and timeliness of suspect notifications into this surveillance system.

5.2 Surveillance Gaps

5.2.1 Forest Nursery Surveys

There is no specific forest nursery surveillance programme in place. Forest nurseries are not specifically included in either MPI's HRSS programme or either of the FBS activities and are generally only inspected at the request of the nursery manager. Suspect samples can be sent by nursery managers to SCION for identification under the FBS diagnostics service and are therefore covered by the general surveillance system.

5.2.2 Asymptomatic Host Surveillance/Monitoring

Asymptomatic host species such as corn and several grass species are not surveyed, or tested, for *F. circinatum*. The risk asymptomatic host species pose in the transmission of this pathogen to susceptible host species is unclear. The potential host plants in New Zealand that can be infected by *F. circinatum* are unknown and there are several asymptomatic host plants that are present in New Zealand and there may be others which are unknown yet.

5.2.3 Monitoring and Surveillance of Other Plant Production Nurseries

There is currently no active or targeted monitoring or surveillance of plant production nurseries (urban or rural) which may propagate or trade in *F. circinatum* host species, beyond Biosecurity New Zealand's general surveillance system. These potentially represent a risk pathway for the introduction and subsequent spread of biosecurity risks as they propagate newly imported plants species and can distribute these locally and nationally.

However, Plant Pass, a national plant production biosecurity scheme, has recently been developed and implemented which when fully operational is anticipated to make a significant contribution to reducing the risk of spreading pests and pathogens via this pathway through improved hygiene practices and biosecurity monitoring. A specific forest nursery module is being planned.

6 Symptoms and Diagnostic Identification Methods

6.1 Symptoms

Fusarium circinatum can be difficult to detect, because:

- the disease symptoms are similar to other diseases,
- some infected plants are asymptomatic, and
- plants can be infected by *F. circinatum* and other pine pathogens (Elvira-Recuenco et. al., 2019).

In addition to pines, *F. circinatum* has also been identified on Douglas-fir, *Pseudotsuga menziesii*. In general, most trees in the field are asymptomatic. Even those that do have active *F. circinatum* infections do not usually display the characteristic pitch canker symptoms, such as resinous cankers, which can make detection difficult (Storer et. al., 1997).

Although they may exhibit different levels of susceptibility to *F. circinatum*, all *Pinus spp.* along with *P. menziesii*, may be affected by the fungus, and the symptoms can be observed at any time of year. In addition, *F. circinatum* can affect plants of different ages, ranging from seedlings to mature trees, and it can be detected on all plant parts (roots, trunk, branches, shoots, cones and seeds).

The symptoms of *F. circinatum* infection in pines is characterised by exudation of large amounts of resin in response to an infection. All tissue of susceptible hosts can be infected by this fungus, although resin soaking is not associated with seed infection.

The first symptom of *F. circinatum* infection is usually the wilting and discolouration of needles, which eventually turn red and fall off the tree, subsequently resulting in branch dieback. Dieback occurs from the tip of the branch to the lesion, due to obstruction of water flow caused by resinous cankers that form at the site of infection and completely girdle the branch (Gordon et. al., 2001).

However, as the fungus does not grow far proximally from the site of infection on branches it is unlikely to reach the bole of the tree and thus, damage proximal from the lesion is minimal. All branches can become infected and at any point along on a branch, although succulent, current-year growth tends to be more susceptible than woody tissue (Gordon, Storer et al. 2001). Individual branch infections are unlikely to kill a tree, but multiple infections can cause extensive dieback in the canopy and this may potentially lead to mortality. In addition to branch cankers, cankers can also develop on the main stem and exposed roots (Wikler et. al, 2003).

6.1.1 Trees

Aerial infection - Symptoms include yellowing of the needles, which turn red in time and finally drop, and dieback of the shoots. Multiple branch tip dieback, a result of repeated infections, may lead to a significant crown dieback. Cankers might appear on the shoots, on the main branches and even on the trunk, associated with conspicuous resin exudates (pitch) in response to the fungal infection (Figure 2A). The cankers can girdle branches and even trunks. The site of a bole or branch canker in pines is usually sunken and is associated with extensive resin flow (Correll et. al., 1991; Hepting et. al., 1946). The resin produced soaks the wood beneath the canker resulting in a honey-coloured wood, which is characteristic of *F. circinatum* infection in pine.

In contrast to pines, pitch canker infection in *P. menziesii* does not appear to be associated with resin production and the fungus has not been isolated from resin streaming on the bole (Storer, Gordon et al. 1994, Storer, Gordon et al. 1997). Instead, infection sites tend to be covered with callous tissue. Branch dieback has also been observed. Symptoms in older trees can be mistaken for those caused by *Diplodia pinea* (synonym *Sphaeropsis sapinea*) or feeding damage caused by wood-boring insects. The resin bleeding sometimes coats the trunk and lower branches for several metres below the level of the infection. Stem cankers are flat or slightly sunken and sometimes affect large areas of cortical and subcortical tissue of the trunk. Removal of the bark reveals subcortical lesions with brown and resin-impregnated tissues (Figure 2B).

Root infection - Symptoms include brown discoloration and disintegration of the cortex and are similar to symptoms caused by other root rot pathogens. Root symptoms may lead to above-ground symptoms, which are generally not apparent until the pathogen reaches the crown after it girdles the stem, causing yellowing of the foliage. Resin-soaked tissue may then be observed after removal of the bark on the lower part of the stem.

Female cones - On infected branches female cones may also become affected and abort before reaching full size. However, depending on the timing and severity of infection, an infected cone may remain symptomless.

Fig. 2. Characteristic symptoms of *Fusarium circinatum* infection on *Pinus radiata*: (A) cankers on the trunk and associated resinous exudates; and (B) subcortical lesions with brown and resin-soaked tissues following removal of the bark. Photo sourced from Food and Agriculture Organization of the United Nations, courtesy A. Pérez-Sierra, Forest Research, United Kingdom.

6.1.2 Seedlings and Seeds

Fusarium circinatum infection affects seed and seedlings.

Seeds

Fusarium circinatum is a seedborne pathogen and infection can result in the visible deterioration of the seed, however, infected seed frequently display no symptoms until the seed germinates. In some cases, infected seed can germinate and produce symptomless seedlings from which the fungus can be isolated. It is unknown whether such seedlings would eventually show pitch canker disease symptoms (Storer et. al., 1998). The fungus can be present externally in the seed coat or internally within the seed (Gordon et. al., 2001; Storer et. al., 1998). Carefully dissected radiata pine embryos have been proven to be free of the pathogen. Aitken and Itturitxa reported that no infection was detected in embryos of *P. radiata*, *P. pinaster*, and *P. nigra* (J Aitken & E Itturitxa, Spain (2004), confidential unpublished report to MPI).

It is reported in the literature that *F. circinatum* may sometimes be present in a quiescent form that cannot be detected in seeds by isolation (Storer et. al., 1998). Therefore, the absence of *F. circinatum* cannot be ascertained by isolation from seeds. In contrast, non-viable propagules of *F. circinatum* may generate positive results using the molecular tests.

Seedlings

Identification and diagnoses can be problematic, as the symptoms (rot root, wilting, damping-off), either separately or together, in young plants are similar to those caused by other fungal diseases (Gordon et. al., 2001; Viljoen et. al., 1994).

Infected seedlings usually show damping off symptoms, i.e., the needles turn red, brown or chlorotic and die from the base up, or the seedling dies (Figure 3). Damping off is characterised by collapsing, withered stems or rotting of the germinating seedling. In some cases, affected seedlings may show brown discoloration on roots and the lower part of stems.

Root rot is characterised by necrotic and undeveloped roots. Both pre- and post-emergence mortality is common. In older seedlings, stem cankers can develop from airborne spores or, at the soil level, from infested soil (Gordon et. al., 2001). Like the cankers that develop in larger trees, these lesions are associated with resin flow

(Gordon et. al., 2001). A single basal infection can completely girdle the stem causing severe wilting and can eventually kill the seedling.

Fig. 3. Typical symptoms of *Fusarium circinatum* infection on seedlings. Photo sourced from Food and Agriculture Organization of the United Nations, courtesy E. Landeras, Laboratorio de Sanidad Vegetal, Oviedo, Spain.

6.1.3 Soil

Fusarium circinatum can also survive in the soil, thus, infected seeds that germinate or seedlings growing in infested soil can develop *F. circinatum* infection associated root rot or damping-off (Barnard & Blakeslee, 1980; Gordon et. al., 2001; Viljoen et. al., 1994). There are no published methods for the isolation of *F. circinatum* from soil (IPPC 2017).

6.2 Sampling and sample preparation

Sample collection in the field, preparation, storage and transport to the laboratory is a critical component of any surveillance or monitoring effort to ensure that *F. circinatum* can be accurately diagnosed or ruled out from submitted samples.

Appendix 3 details the collection procedures for suspected *F. circinatum* samples. These procedures represent the minimum of what should be adhered to.

7 Diagnostics

Appendix 4 details the isolation and diagnostics methods for screening and validating the presence of *F. circinatum.*

Diagnostic methods for *F. circinatum* include:

- Examination of symptoms on plants or plant parts.
- Isolation from affected plant tissues, followed by identification of pure cultures by morphological examination/species-specific PCR/DNA sequence analysis.
- And/or direct testing of affected plant tissues using species-specific PCR tests.

Various PCR tests have been developed that claim to have high specificity to *F. circinatum*. However, cross reactions have been reported on some of these tests (Ioos et. al., 2013). Recently PHEL collaborated with 23 laboratories from European countries, South Africa, and Chile, and found cross reactions and/or false negative results in all nine *F. circinatum* PCR tests. Results are published in Ioos et. al. (2019). Biosecurity New Zealand's Plant Health and Environment Laboratory (PHEL) is comparing some of these PCR tests further in order to determine the best approach on addressing the non-specificity issues.

Other diagnostic methods (e.g., LAMP, Elisa) has been developed and can be considered when these tests are shown to be robust and provide consistent results.

7.1 Diagnostic service providers

Under the Biosecurity Act 1993, Biosecurity New Zealand's Plant Health and Environment Laboratory (PHEL) undertakes the initial validation testing where the organism is suspected and coordinates diagnostic testing during a response situation. Other service providers, including Scion, may be utilised once the organism has been found to be present in New Zealand, providing protocols can be agreed upon and the laboratories received biosecurity containment approval from MPI.

Scion is the primary forest diagnostics service provider for the forest growing sector and delivers the diagnostics services for all the forest related biosecurity surveillance programs identified in Table 3, except for Biosecurity New Zealand's general surveillance programme. However, Scion does provide identification services to the forest growing sector and as such is a key intermediary for the general surveillance system.

The likelihood is that Scion would receive and identify suspect *F. circinatum* samples as part of routine surveillance activities. They would then notify Biosecurity New Zealand's pest and disease hotline (0800 80 99 66) to report a suspect detection and validate or rule out *F. circinatum* by the PHEL. In addition, first notification of *F. circinatum* can come from arborists, nurseries and other members of the public.

8 Entry Pathways into New Zealand

8.1 Biosecurity New Zealand's Approved Pest Free Areas for *Fusarium circinatum* (Causal Agent of Pitch Canker)

Biosecurity New Zealand maintains a register of "Approved Pest Free Areas for *F. circinatum* (causal agent of pitch canker disease)". No other countries/states/provinces are approved pest free areas for *F. circinatum.* Table 4 lists the approved pest free areas.

Table 4. New Zealand Ministry for Primary Industries Approved Pest Free Areas for *Fusarium circinatum* (Pine Pitch Canker). Last updated: 6 June 2019.

Name of Country	States/Provinces with approved pest free status within each Country
Argentina	All
Australia	All
Austria	All
Belgium	All
Canada	All
Czech Republic	All
Denmark	All
Estonia	All
Finland	All
Germany	All
Greece	All
Hungary	All
Ireland	All
Latvia	All
Luxembourg	All
Netherlands	All
Norway	All
Poland	All
Slovakia	All
Switzerland	All
Sweden	All
Turkey	All
United Kingdom	All

8.2 Pathways that could carry infective propagules

For some of the pathways described below, regulatory phytosanitary changes have reduced the risk in comparison to other pathways that have limited regulation.

8.2.1 Germplasm via Mail

Seed for sowing - *Pinus* spp. and *Pseudotsuga menzieii* - Seed of *Pinus* spp. and Douglas-fir (*P. menziesii*) can contain asymptomatic infections of *F. circinatum* and are considered a high-risk pathway. New Zealand's current Import Health Standard (IHS) for 'Seed for Sowing' of *Pinus* spp. and of *Pseudotsuga* spp. from all countries list the requirements and any restrictions for importation. However, there is a risk imposed from seeds ordered online and their mail pathway, which is unquantified and the current IHS does not manage this risk pathway. This risk pathway may have a bearing on any response decisions, i.e., likelihood of reintroduction.

Seed for sowing - species other than *Pinus* spp. and *P. menziesii* - Seed from some plant species known to be asymptomatic hosts of *F. circinatum* can be imported into New Zealand (e.g., *Zea mays* and some grass species). There are restrictions on importation of some of these species, although this is not related to the risk of introducing *F. circinatum*. No seed imported to New Zealand, even from areas known to have *F. circinatum*, are specifically tested for this pathogen. Further risk assessments of this pathway are needed. The risk imposed from seeds ordered online and mail pathway is not quantified and managed by the current IHS

Live plant material - *Pinus spp*. and *P. menziesii*, including pollen - *Pinus* spp. and *P. menziesii* are high risk pathways for the introduction of *F. circinatum*. Due to the high-risk, *Pinus* spp. and *P. menziesii* plants or tissues cannot be imported into New Zealand. They are not currently covered by a valid IHS.

Note that there was a *Pinus* schedule in the nursery stock IHS, however, this was revoked, and removed in 1999. This appears to be primarily due to concerns around *F. circinatum* and the impacts that this was having in infected areas, and the risk of introduction through the nursery stock pathway. There was also little interest at the time to import *Pinus* nursery stock. In 2013 some interest was expressed to develop a new schedule; however it was considered a substantial piece of work that could not be justified against the lack of interest to import nursery stock at that time (Richard Lardner, MPI, pers. comm. 10 Feb 2020).

Live plant material - species other than *Pinus* spp. and *P. menziesii* - Live plant material can be imported into New Zealand for many plant species, see https://www1.maf.govt.nz/cgi-bin/bioindex/bioindex.pl for the list of plant species that can be imported and any requirements or restrictions on importation. Plant material imported to New Zealand, even from areas known to have *F. circinatum*, are not specifically tested for this pathogen. Plant species known to be asymptomatic hosts of *F. circinatum* have restrictions on importation. There are likely to be new discoveries of asymptomatic host species.

8.2.2 Germplasm via MPI's Passenger Processing System (PAX)

Mailed items, baggage, goods - No specific measures aimed at *F. circinatum* are in place for mailed items, baggage and goods. However, mail from overseas and accompanied baggage are inspected using x-ray equipment and dogs able to detect seeds and foliage.

8.2.3 Soil/Plant Debris Contaminating Equipment

Sporting and recreational equipment - Soil, plant debris or insects present on items such as footwear, hunting gear, clothing, and sporting or camping equipment could contain infective material. These items are required to be declared at the border and may be inspected and cleaned if necessary.

Used logging machinery - Soil, plant debris or insects present on used logging machinery could contain infective material. All forestry machinery imported into New Zealand is required to be free of bark, insects, fungal infection and soil. They are meant to be inspected at the border and if infected, are treated, reshipped or destroyed.

Cargo containers - Sea containers with soil on the bottom could contain infective material, this could include infected soil, plant debris or insects. No specific measures aimed at *F. circinatum* detection are in place.

8.2.4 Wood and Forest Products

All wood and forest products imported into New Zealand are required to be free of bark, insects, fungal infection and soil. They are inspected at the border and if found to be infected, are treated, reshipped or destroyed.

Specific requirements for *Pinus* species are in place for sawn timber (under 300 mm thick) originating from areas considered by MPI not to be free of *F. circinatum.* Currently there are no restrictions on importation of sawn timber of *P. menziesii*. It is recommended that sawn timber restrictions for *P. menziesii* should be the same as those required for *Pinus* species.

8.2.5 Dried and Preserved Plant Products

Pine and other conifer cones must be heat-treated; or contain no seed and have been completely covered in lacquer or a thick paint or varnish layer (Approved Biosecurity Treatments, MPI, 2020).

8.2.6 Soil, Peat, Compost, Potting Mix

Spores of *F. circinatum* can survive in soil. Imported soil must meet the requirements of the import health standard ‘Soil, rock, gravel, sand, clay, and water from any country’.

9 Key Biological and Human Mediated Spread Mechanisms from a Biosecurity Risk Management Perspective

9.1 Modes of Dispersal

(See also Section 3.1 Natural Spread Mechanisms)

9.1.1 Sporulation

As a wind-borne pathogen, the spores of *F. circinatum* can be dispersed locally either by wind or in water splash.

9.1.2 Plant Propagative Material

Nurseries have been associated with movement of *F. circinatum* around the world. Particularly, the out-planting of symptomless seedlings dispersing the pathogen over long distances is of concern.

9.1.3 Vector Transmission (Insects)

Insects such as wood boring granulate ambrosia beetles (*Xylosandrus crassiusculus* (present in New Zealand)) may carry *F. circinatum* on their bodies. However, these insects generally do not attack healthy trees and are not expected to be a common vector. There are some potential insect vectors present in New Zealand in association with transmission of *F. circinatum*, e.g., bark beetles and wood borers, shoot and foliage-feeders, sapsuckers, and cone insects (see Table 2).

9.1.4 Transmission in Contaminated Soil

Soil from an infected plant or nursery can disperse the spores which are able to survive in wet soil for several months and up to a year in dry soil.

9.2 Various Mechanisms of Spreading *F. circinatum*

9.2.1 Pathways that Could Carry Infective Propagules

- Seed for sowing: *Pinus* spp. and *Pseudotsuga menzieii*.
- Seed for sowing (other): species other than *Pinus* spp. and *Pseudotsuga menziesii*
- Insects: Bark beetles, cone and twig borers.
- Live plant material: *Pinus* spp. and *Pseudotsuga menziesii*, includes pollen
- Live plant material (other): species other than *Pinus* spp. and *Pseudotsuga menziesii*
- Soil, peat, compost, potting mix
- Wood, lumber, packaging, dunnage
- Seed of *Pinus* spp. for human consumption

9.2.2 Pathways that Could Contain Material Carrying Infective Propagules

- Cargo containers
- Used logging machinery
- Sporting and recreational equipment (tramping/hiking equipment and golf shoes)
- Mailed items, baggage, goods

9.3 Current Systems to Manage Domestic Pathway Spread

9.3.1 Nursery Hygiene

Nurseries are a key risk pathway for the potential spread of *F. circinatum*. Currently there are no pathway risk management programmes in place that would reduce this risk.

However, Plant Pass, a national nursery biosecurity scheme has been developed and is currently being implemented.

Plant Pass is intended to be a systematic approach to nursery production and biosecurity risk management which will assist producers to identify, control, manage or avoid biosecurity risks within their nurseries and production processes.

While this is voluntary, an accompanying Plant Buyers Accord will seek to incentivise plant producers to achieve certification and in turn provide plant buyers with the confidence and assurance that the products that they are purchasing have been grown to best practice standards to prevent or reduce their own risk exposure to biosecurity risks, and in turn reduce the likelihood of spreading pests and pathogens via this pathway.

The forest growing sector is currently exploring how it can adapt this scheme to be suitable for the forest nursery sector.

9.3.2 Forest Sector Operational Hygiene

The forest growing sector is also exploring how, and if, it can improve operational biosecurity to reduce the risk that certain high-risk industry activities pose to spreading pests and pathogens.

10 Overview of Market Access Readiness

Fusarium circinatum is listed as a quarantine pest in the following countries: Argentina, Brazil, China, Malaysia, Turkey, Uruguay and European Union[2].

Of these countries, New Zealand only exports logs to China which received 78% of log exports and 50% of all forestry products overall, in the year ended March 2019 (Ministry for Primary Industries, 2019).

The risk to trade of wood and wood products (especially logs) is assessed to be medium, although potentially high should other key log export markets such as India, Hong Kong and Taiwan also regulate it. China is currently the only log market that has *F. circinatum* in its quarantine organisms list. *F. circinatum* spores are able to remain viable in wood for at least one year (McNee et. al., 2002) and current treatments for log exports may not be very effective against this pathogen.

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[2] This is only current to the date of publication of this plan. An incursion in New Zealand could also result in further countries including *Fusarium circinatum* as a quarantine pest for timber products from New Zealand

Timber exports are not expected to be affected significantly because heat treatment can be applied prior to export (which effectively kills this pathogen). Any impact on timber export would be related to treatment cost because currently export to key markets such as China, Thailand, Indonesia, Korea and Taiwan require no treatment. Timber export to these 5 countries accounted for nearly half (49%) of exports in 2020 March quarter.

Debarking and surface washing of logs will mitigate some of the trade risk associated with this product. Fumigation to treat potential insect infestation could also provide assurances to trading partners but the likelihood of this being the case, particularly with current treatment rates, is probably low.

It is unknown how markets that list *F. circinatum* as a quarantine pest accept logs from markets where the disease is known to exist and if any specific risk mitigation is expected to take place. In addition, further assessment and potentially further research is needed as to the fate of the spores in wood. While they may remain viable at least one year (as per McNee et. al., 2002), which includes any infection potentially for a longer period, their viability in a commercial setting may be diminished and potentially lost.

Seed trade is the primary pathway which has facilitated the spread of this pathogen. Currently, there are no measures to mitigate the risk of spreading this disease through potentially infected *P. radiata* seed. Further assessment and potentially research on the efficacy of seed treatment fungicides is required. The effectiveness of fumigants is not proven to mitigate this pathogen risk pathway through seeds, however, Ethanedinitrile (EDN) could be more effective compared to Phosphine or Methyl Bromide. EDN approval request is already under consideration by the EPA.

Additionally, New Zealand adheres to the International Standards for Phytosanitary Measures no. 15 (ISPM 15 (2009); international standard for wood packaging), thereby minimising the risk of spreading *F. circinatum* through this pathway. Its main purpose is to prevent the international transport and spread of disease and insects that could negatively affect plants or ecosystems. ISPM 15 affects all wood packaging material (pallets, crates, dunnage, etc.) with a thickness greater than 6 mm, or made wholly of non-processed wood material requiring that they be debarked and then heat treated

PART II – Investigating and Responding to a Detection of *Fusarium circinatum*

Part II identifies the actions that may be undertaken in a response to a confirmed or suspected detection of *F. circinatum*. It will be used to guide and inform a response to the detection of an incursion/infection of *F. circinatum*. It will be used by a fairly wide range of audiences, e.g., members of the Incident Management Team (IMT), particularly the Controller/Response Manager, and the Planning and Operations workstreams: however, it will also be used by others involved in the various response phases, e.g., Communication, Liaison and industries, or those undertaking readiness work.

The plan will also be owned by the Forest Biosecurity Committee[3] and will be communicated to forest owners, farm foresters, and forest nursery owners and managers.

11 Biosecurity Responses

11.1 Lead Agency

Biosecurity responses are undertaken to manage unwanted pests and pathogens and their impacts on New Zealand's economy, environment, health, society and culture.

Biosecurity New Zealand, a business unit within the Ministry for Primary Industries, is the lead agency for biosecurity responses. It leads responses and coordinates response operations to biosecurity hazards and their impacts (MPI, 2018).

[3] The Forest Biosecurity Committee's (FBC) purpose is to "*provide industry with strategic leadership and oversight for all aspects of forest biosecurity, and foster cohesion across industry, government and the science community to improve forest biosecurity outcomes*". Its membership includes senior representatives from the Forest Owners Association, the Farm Forestry Association, the Forest Nursery association, Biosecurity New Zealand, Te Uru Rākau (Forestry New Zealand), and Scion (Crown Research Institute).

11.2 Coordinated Incident Management System

Biosecurity New Zealand uses the Coordinated Incident Management System (CIMS vs 3, 2019), a standardised, trusted and tested way of responding that is used by all government response agencies.

11.3 Government Industry Agreement

On 20 May 2014, the Government Industry Agreement for Biosecurity Readiness and Response (the GIA) was implemented. The GIA is a partnership agreement between primary industry and government to manage pests and pathogens that could badly damage New Zealand's primary industries, economy, and environment.

Under the GIA, signatories share the decision-making, responsibilities and costs of preparing for – and responding to – biosecurity incursions. By working in partnership, industry and government can achieve better biosecurity outcomes.

Given that, the known main hosts of *F. circinatum* belong to *Pinus spp*. (Table 1) the GIA signatories expected to be most affected by this pathogen will be the BNZ and the NZFOA. The NZFOA as representative of New Zealand's forest growers (including NZFOA, NZFFA, and NZFNGA) need to be engaged in rapid notification and response decision processes.

The New Zealand Forest Owners Association, representing New Zealand's forest growers became a signatory to the Deed http://www.gia.org.nz/Resource-Library#1157542-the-deed (http://www.gia.org.nz/Portals/79/Content/Documents/Resource-Library/GIA%20Deed.pdf?ver=2017-03-20-141003-987) on 5 November 2015.

11.4 Biosecurity Response Phases

There are 5 key phases to a response (GIA, 2016):

1. **Investigation** – Biosecurity New Zealand receives a notification of a possible unwanted organism through the 0800 Pest and Disease Hotline, assesses the potential risk, undertakes any immediate urgent risk management action and may notify potentially affected Signatories (in the case of suspected *F. circinatum* detection, the BNZ will notify affected signatories.

   MPI minimum commitments under the GIA Deed include rapidly notifying affected signatories when a suspected unwanted organism is detected in New Zealand. The BNZ Incursion Investigator is responsible for providing a Rapid Assessment Report (RAR) to the BNZ Response Group and, if appropriate, the investigator may apply provisions of the Biosecurity Act (1993) to manage and contain the situation.

2. **Initiate Response** – Once the RAR has been received, the response commences when the decision-makers (affected signatories) for the response activity agree that a response should commence. If affected GIA signatories agree that a joint response should be activated, MPI establishes a response structure and convenes Response Governance that sets response outcomes, objectives and resourcing levels.

   A response objective to eradicate may be the preferred option. However, if evidence indicates that this is not feasible, containment or area-freedom may become better options in return for response investment. These options do not exclude a response from being initiated to delimit the outbreak.

   The activation process needs to be completed within an agreed time (the BNZ Controller and Operations Manager to agree) of being notified of a potential biosecurity threat i.e., *F. circinatum*. Timeframes for response activities can be vary depending on the response scenario.

3. **Planning and Operations** – Includes the response action plan, reporting and implementation, and performing operations. Response operation options will be provided by the Controller to Response Governance. The options will be led, managed and reviewed by the Controller in accordance with the response objectives outlined and agreed by the Response Governance.

4. **Transition from response** – Long-term management options may need to be considered if the biosecurity threat (i.e., *F. circinatum*) is found to be widely established, or when all eradication options have been explored during a response and proven to be ineffective. The decision to stand down during the response phase may also occur when the cost of a continued response outweighs the benefit of doing so or if there are no viable response options. In such cases long term management options may be considered.

   The decision to stand down during the response phase will be made by the Response Governance and led and managed by the Controller in partnership with industry and other relevant parties in accordance with the approved transition plan. Transition to long-term management is a complicated process and the decision on quality and timeframe of this transition would vary in different response cases.

5. **Learn and close** – The decision to close out a response will be made by Response Governance and will be led and managed by the Controller.

   Under GIA, the signatories will agree to end the response when:

- The unwanted organism is confirmed to be eradicated;
- Long-term arrangements for controlling the unwanted organism have been developed for implementation;
- The decision-makers for the response activity decide that it is appropriate to take no action, or no further action, on the unwanted organism.

12 Incursion Investigation (Biosecurity New Zealand Accountability)

12.1 Accountability

Biosecurity New Zealand is responsible for all activities, decisions and costs in this phase of the response as this is an MPI minimum commitment under the GIA.

The investigation phase is outside of the joint decision making and cost sharing of GIA, however, the BNZ will provide affected signatories with an early notification when an unwanted organism is suspected (and likely to be confirmed) as per section 3.2.2 of the GIA Deed (2016).

12.2 Notification Phase

The notification phase is triggered by a report or "notification" (i.e., phone call) to Biosecurity New Zealand's Pest and Diseases Hotline 0800 80 99 66. These notifications can come from any number of sources, i.e., public, industry, diagnostics laboratory, science community, the BNZ, etc. Increasingly alternative reporting channels are being explored (i.e., Biosecurity New Zealand's reporting webform, ONIT, which is still under development, Scion's Find-A-Pest reporting app). However, these will all refer the notifier to the hotline if the call is about an urgent biosecurity threat that requires immediate attention.

Notifications are received and triaged by a call centre 24/7, every day of the year, and if they relate to a potential biosecurity notification, they are assigned to a duty incursion investigator to follow up. For production forest biosecurity issues these will primarily be directed to the Plant Health Surveillance and Incursion Investigation Team to follow up. However, if the notification relates to a species identification these may be directed to Biosecurity New Zealand's PHEL and, if a biosecurity risk is suspected following their assessment/identification, this would then be immediately notified to the duty incursion investigator via the hotline. Alternatively, some risk goods (i.e., recently imported goods) may be directed to the Aquatic and Environment Surveillance and Incursion Investigation Team, however, if a pest of disease of plant health significance was suspected these would be redirected to the Plant Health Surveillance and Incursion Investigation team.

If the incursion investigator believes that the notification represents a credible biosecurity threat that warrants any follow up action (i.e., they can't rule out a biosecurity threat based on the initial information obtained from the notifier, need to collect additional information to inform an assessment, need to obtain or facilitate samples for identification, a site visit to observe the situation, etc.), then an incursion investigation will be initiated.

If the incursion investigator can rule out a biosecurity threat or is able to immediately eliminate the threat (i.e., instructs the notifier to effectively treat the issue), then the notification can be stood down at this stage.

12.3 Incursion Investigation

The purpose of the Incursion Investigation phase is ultimately to establish and confirm the presence of a biosecurity threat, and where best able, and it is appropriate, to undertake urgent measures (immediate actions) to manage or mitigate the immediate and known, or suspected, threat (i.e., eliminate, eradicate, or contain).

A priority action undertaken during the incursion investigation phase is to confirm, or rule out, a biosecurity issue. Incursion investigators work closely with specialists from Biosecurity New Zealand's PHEL, or other laboratories where required, to obtain accurate diagnostics results to confirm, or rule out a biosecurity issue.

Field activities may also be undertaken to obtain samples and to gain an understanding of the scale of the issue to inform further action.

The length of an investigation is highly variable and depends on the complexity of the situation, the availability of diagnostics tools, the availability of information on the biosecurity risk an organism poses, the situation and unique circumstances within which the report was made.

The biosecurity status of the organism will determine if, and what, powers Biosecurity New Zealand can utilise. *Fusarium circinatum* is both a notifiable organism (Refer 2.1 Notifiable Organism Status) and an unwanted organism (Refer 2.2 Unwanted Organism Status). However, the industry is also able to undertake significant actions and would work closely with Biosecurity New Zealand to do so.

A presumptive diagnosis of *F. circinatum* on a typically infected plant can be achieved within 24 hours by using molecular methods only. Definitive diagnosis where the culture has been isolated and characterised will take up to two weeks. Given that the symptoms of this pathogen are similar to those caused by environmental stress or *Sphaeropsis sapinea*, more time will be required if the plant is asymptomatic or the samples are suboptimal for diagnosis. It is anticipated that immediate urgent measures would be initiated upon suspicion of *F. circinatum.*

12.4 Urgent Measures

Incursion investigators may undertake urgent measures to manage any immediate risks where they are best placed to do so. Urgent measures are, essentially, immediate actions that can be implemented practically and cost effectively (i.e., less than $5k) to contain, mitigate or eliminate known or suspected biosecurity threats or to inform or preserve response options.

Urgent measures can/and should involve the affected signatories where they are best placed to manage the potential biosecurity risk or the potential risk to their businesses (Refer to section 12.6 Rapid Notification and Communications During Investigation Phase).

Urgent measure intent to contain or limit organism movement prior to a formal decision to stand up a response (i.e., following the identification of a suspect case).

Examples of potential urgent measures during an investigation include:

- If the incursion investigator determines that further investigation is required, they will organise to visit the suspected location and initiate tracing to understand any possible linkages to the suspected infected place (i.e., backward tracing to understand any historic linkages to the location(s), forward tracing to understand movements from the suspect location).

- If the incursion investigator determines that a visit is required, they will notify the property owner that no plant material and soil which might be contaminated with *F. circinatum,* should be moved off the suspected location until further notice. This is to minimise the risk of further disease spread during the investigation phase.

- The incursion investigator will undertake a thorough investigation, including taking samples and submitting them for analysis at the appropriate labs (PHEL, Scion, etc.).

- In anticipation that *F. circinatum* is highly suspected, the incursion investigator will notify the Director of Diagnostic and Surveillance Services who will, in turn notify the Director of Readiness and Response Services. The incursion investigator will start to prepare a RAR detailing the findings of the initial investigation.

- The incursion investigator may continue epidemiological investigations to determine:
    - How long the fungus may have been present in the suspected location (the risk period).

- The extent of the infection or exposed area.
- The likely source or cause of infection or whether infection originated at this suspected location.
- Whether plant material and soil particles or other risk items have left the suspected location, where and when they moved.

- The owner of the suspected property must provide any information required by the II to determine the presence or absence of infection pursuant to section 43 of the Biosecurity Act 1993. The owner of the property must provide access to any risk materials required for the II to complete the investigation pursuant to section 121 of the Biosecurity Act 1993.

- Heat or fumigation treatment (i.e., Ethanedinitrile; EDN if approved) of risk goods, such as woodware, dunnage, inanimate objects (for example, car), or removal and destruction of infected trees.

- Issue directions under the Biosecurity Act 1993, for example, movement controls, implementation strict hygiene measures for any operations etc.

12.5 Investigation Outcomes

12.5.1 Stand Down an Investigation

Once the results of the epidemiological investigation and diagnostic testing are finalised, there are two possible scenarios:

- If the investigation rules out a biosecurity threat or the threat is eliminated during the investigation (i.e., urgent measures effectively eliminate the threat) then the notification can be stood down.

- Alternatively, if the investigation finds that the infestation is present, a recommendation will likely be made for the BNZ and NZFOA to stand up a biosecurity response (refer 12.5.2).

- If the infestation is determined to be so widespread that any containment or management actions are unlikely to be feasible, it may be recommended to stand down further action. This outcome is unlikely to occur for *F. circinatum*, given its significance and the likely requirement to manage its spread within New Zealand. Should this situation arise any decision to stand down would be undertaken in partnership with the affected signatories.

12.5.2 Recommend a Response

If the presence of *F. circinatum* is confirmed, or suspected, MPI's Incursion Investigation team will make a recommendation to transition to response as soon as possible. This recommendation will be to the BNZ's Response and GIA teams, alongside internal risk escalation procedures.

At this point GIA joint decision making will take effect and the issue will transition to the "Initiate Response" phase (Refer 13.1 Decision to Initiate a Response). The response will be initiated according to the cost-sharing agreements in an operational agreement for response under the GIA. Given that a response operational agreement (OA) is not in place yet, an OA, beneficiaries and associated cost-shares would have to be agreed at the time of an incursion.

Note that given the fact that this is a high impact biosecurity issue for the forest sector depending on the situation, this recommendation may be made prior to confirmation of the ID to ensure that any associated risks (i.e., trade, media, stakeholder management, harvest, operations, political etc.) can be managed through the Coordinated Incident Management System (CIMS).

12.6 Rapid Notification and Communications During Investigation Phase

12.6.1 Rapid Notification During Investigation Phase

Biosecurity New Zealand will rapidly notify the affected signatories Biosecurity Manager if *F. circinatum* detection is suspected or confirmed, as being present within New Zealand.

The key principles around biosecurity notifications and communications are "**no surprises**" and "**trust**" to ensure that parties can work effectively in partnership.

Other notification triggers include:

- Where the investigation location is within or is near a production forest plantation or forest nursery and the owner or manager is, or may be, a member of the NZFOA, New Zealand Farm Forestry Association (NZFFA), or the New Zealand Forest Nursery Growers Association.
- Where there is potential for media interest surrounding the situation.
- Where the BNZ has identified a potential biosecurity risk that may impact on forestry interests, but further investigation is required to determine if this is an actual risk and this may take some time, this would allow the situation to be managed and would avoid surprises at a later date.
- Note: the plantation forestry sector is of the position that it will act with urgency in the face of uncertainty (i.e., lack of confirmation is not a reason not

to act if a potential biosecurity threat may be present) and will in some circumstances do so at its own cost and risk to protect its extensive forest investments and assets.

The purpose of rapid notification is for the BNZ to provide the affected signatories with a situation report, including (GIA Response Guide 2016):

- Information on the suspected unwanted organism;
- Known geographic information;
- Critical detail of the investigation and anticipated timeframes;
- Potential risks;
- Urgent measures to manage these risks (if any);
- Recommendations on next steps.

Based on this information and associated conversations, affected signatories can start to understand and prepare to manage their respective risks, and/or provide operational support for urgent measures. This will also enable consideration to be given to the best timing to stand up a response to manage the associated risks and operational activities.

The forest growing sector has extensive experience in emergency response management and has extensive resources to draw on to support a response and depending on the situation may be well placed to undertake urgent measures to preserve response options, while also managing their own organisational risk.

The forest growing sector has a high expectation that it will be notified as early as is practicable to ensure that it can participate in urgent measures work, where it is best placed to do so and to be able to undertake its own internal response preparation and risk management. To enable this without generating additional work, or risks, to have to manage during the investigation phase it will work in close collaboration with Biosecurity New Zealand's incursion investigators until a decision is made to stand up a response.

12.6.2 Communications During Investigation Phase

In undertaking investigations, Biosecurity New Zealand may communicate directly with stakeholders, including the NZFOA, NZFFA and NZFNGA or its members. Table 5 below from the GIA Response Guide (2016) outlines some examples of circumstances where this may occur.

Table 5. Examples of stakeholder communications that may occur during an investigation (GIA Response Guide, 2016).

Category	**Possible circumstances**
To get information	Where stakeholders may hold information that could help determine the nature and level of biosecurity risk/issue and inform management options
To seek support	Where stakeholders may have resources such as subject matter experts, personnel, equipment, records or databases to help carry out the investigation or urgent measures
To direct action	Where MPI investigators need someone to stop movement of risk goods as part of urgent measures during an investigation
To inform	Where MPI investigators need to inform owners or occupiers of investigation progress or outcomes
To manage communication risks	Where investigation activity may attract public attention and queries, or an industry organisation may need early notification to enable it to manage its own risks [*Note: this could trigger an early heads up to industry representatives to advise them that an investigation is underway and that more information will be available soon and/or in some circumstances could trigger rapid notification requirements*]

13 Response Decision Making (Joint Accountability)

13.1 Decision to Initiate a Response

Initiating a response should be decided in the event of an incursion of *F. circinatum* by affected GIA signatories, including the BNZ and NZFOA. A response is an effective action to an incursion of this organism through appropriate coordination. If a detection of *F. circinatum* is confirmed (or suspected) within New Zealand's post-border environment during the incursion investigation phase, actions to initiate and establish a response under the GIA will commence as per the commitments entered into under GIA (GIA Deed, 2016; GIA Response Guide, 2016). The decision-making process for initiating a response to an incursion of *F. circinatum* in accordance with the GIA is summarised in Appendix 5.

The BNZ and NZFOA (as the representative of the NZFOA, NZFFA and NZFNGA) will be affected GIA signatories by *F. circinatum* incursion. The BNZ will notify affected GIA signatories (i.e., NZFOA) if the presence of *F. circinatum* is confirmed (or suspected and likely to be confirmed) within New Zealand (section 3.2.2, GIA Deed, 2016). The BNZ will provide the affected GIA signatories with relevant background information, a situation report, and will make a recommendation on whether a response should be activated. A heads-up may be provided earlier if it would add value to the investigation or assist the affected GIA signatories with their preparedness. The NZFOA and the BNZ, as affected GIA signatories, will jointly decide whether to initiate a response. Contractual obligations of the GIA partners involved in a response need to be negotiated at the time of a response and will be set out in an operational agreement. The OA will also confirm the affected GIA industry partners that will share response decisions and costs, and any non-signatory beneficiaries.

If the affected GIA signatories agree that response action is appropriate, the BNZ will convene Response Governance (made up of the BNZ and affected industry signatories) to make all strategic response decisions, and will appoint a Response Controller who will establish a response team following the CIMS structure based on the scale of the response. Cost sharing of any subsequent response activity will commence from this point on. Immediate "interim measures" may need to be initiated prior to the first Response Governance meeting to preserve response options, or to initiate critical work, while the response governance and response structure is activated and being stood-up.

In July 2020, the BNZ set up a panel of providers to lead operational services in a response or programme of work. There is a secondary procurement process in place to select an appropriate provider from the panel. A surveillance contract used to manage the investigation phase cannot be varied for response activities, as all response activities must be put through the panel.

The NZFOA Chief Executive, or their delegate, would represent the Commercial Forest Plantation Sector (i.e., NZFFA and NZFNGA) on Response Governance, and would be supported by the NZFOA's Biosecurity Manager.

13.2 Response Governance

The decision to respond and the response strategy is the responsibility of Response Governance. This group must make a joint decision to respond based on the information collected within the investigation phase. The strategic objectives of a response will be dependent on the context of the situation, e.g., distribution of *F. circinatum*. Response Governance will be required to determine the strategic approach depending on the situation at hand and the information available (this would likely include this Threat Specific Readiness Manual and any information collected during the investigation).

The first Response Governance meeting will be chaired by the Director Readiness & Response. The Response Controller will present a rapid assessment report and/or a response situation report. Review of the strategic direction is made regularly, and all decision-makers are aware of the appropriate courses of action and are made aware of any changes. The assessment and recommendation of the response options will be also presented and discussed.

Response Governance will confirm the decision to activate a response and will agree the desired response outcomes, and resourcing and will work with the Response Controller to establish the response objectives to be shared to ensure a unity of response effort (finalising the outcomes and objectives may take some time). Response Governance will then direct the Response Controller to develop and implement a response action plan to achieve the desired outcomes and objectives. Responding to eradicate may be the preferable option, however where evidence indicates that this is not feasible, containment or area freedom may become better options in return for response investment.

13.3 Decision to Stand Down

Biosecurity New Zealand and affected industry signatories may agree not to stand up a response under GIA. The reasons would be that response action is not appropriate due to the cost of responding outweighing the benefit of doing so or if no feasible or practical response options exist to act. Any decision to stand down will be made jointly. If the affected GIA signatories cannot reach consensus on whether a response should be activated, then Response Governance will be convened as soon as possible to determine the best course of action. The decision to stand down during the response phase may also occur when the cost of a continued response outweighs the benefit of doing so or if there are no viable response options. In such cases long-term management options may be considered.

The decision to stand down during the response phase will be made by the Response Governance in partnership with industry and in consultation with other relevant parties. The standing down of response is different to a response being closed out. A response is closed out when:

- The unwanted organism is confirmed to be eradicated.
- Long-term arrangements for controlling the unwanted organism have been developed for implementation.
- Response Governance decide that it is appropriate to take no action, or no further action, on the unwanted organism.

14 Planning and Operations

14.1 Standing Up a Response

Response management and work-streams will be structured using the BNZ's implementation of the Coordinated Incident Management System (CIMS 3; see Appendix 1). The first stage of the response is to collate and collect all the information possible on the issue to inform a decision on the most appropriate response strategy. The detection of *F. circinatum* may result in the following actions in the first instance:

- A delimiting survey and surveillance to determine the extent of *F. circinatum* incursion. The extent of trace properties from the suspected or index property may determine the extent of delimiting. Testing would include validated diagnostic testing that include visual symptoms, molecular methods, etc.
- Restricting the movement of risk plant materials, soil particles, etc. on or off a property through a written Restricted Place (RP) (refer 14.7 Movement

Control) Notice pursuant to section 130 or a Notice of Direction (NoD) pursuant to section 122 of the Biosecurity Act 1993. Risk goods are likely to include any plant material or equipment and vehicles that may have come in contact with infected plant materials. A RP and NoD would also necessitate the disinfection of clothes, equipment and vehicles leaving the premises. If at any point a risk good needs to leave the property a permit can be applied for and will be granted if the biosecurity risks are adequately mitigated as agreed by the response operational and technical standards.

- The declaration of a Controlled Area by a CTO to minimise the risk of spread. A Controlled Area Notice (CAN), pursuant to section 131 of the Biosecurity Act 1993, can specify particular risk items that cannot be moved in or out of an identified geographical area or treatments required before movement. A CAN must be publicly notified and will remain in force until revoked by a CTO.

Industry may also elect to have personnel embedded with the CIMS structure (typically in the Liaison, Planning or Intelligence work stream, or on the Technical/Strategic Advisory Group (T/S AG)).

14.2 Impact of Response on People Involved

Responses can have a significant impact on those involved and a welfare plan may be required. Appropriate levels of support should be provided to forest owners affected, their staff and response staff.

All interactions with affected individuals should be supportive, empathetic and seek to minimise disruption and delays.

Affected people should be empowered to regain control over their lives and self-efficacy, as much as possible.

14.3 Response Costs

Compensation is provided under section 162A of the Biosecurity Act 1993. The Biosecurity Act provides that in certain circumstances a person or business is entitled to compensation where MPI has exercised powers, and a verifiable loss has resulted. For example:

- If there was a property damaged or destroyed.
- If restrictions have been imposed on the movement or disposal of your goods, which have caused loss. The restrictions might be through a Restricted Place Notice, a Notice of Direction, or a Controlled Area Notice.

Losses must be verifiable, and reasonable steps must have been taken to mitigate any ongoing losses.

Response costs will be reported, monitored and tracked by Response Governance. Response costs will be shared with industry in accordance with the OA. If industry reaches its fiscal cap (as per the OA) it can either increase its fiscal cap or withdraw from the response.

14.4 Response Options

The following section provides potential response options. Note that these are not steadfast and will change depending on the situation at hand and the information available. The two broad response options for a *F. circinatum* incursion in New Zealand are:

14.4.1 Eradication

Eradication is the preferred default response option for *F. circinatum*.

The response outcome would be to eradicate this fungus as efficiently and quickly as the circumstances allows, if eradication is feasible. Eradication may be feasible if the infection is detected early, found to be localised, contained, managed and limited and the entry pathway has been identified.

Given the longevity of this organism in soil and plant material, eradication may only be achieved under a long-term programme or a long-term management plan with eradication as the objective or outcome being sought.

14.4.2 Containment or Area Freedom

Where eradication is not considered feasible, measures may be implemented to contain the pathogen and delay its spread and therefore mitigate its impact on biological assets, production and trade by applying a combination of strategies depending on the overall outcome that is being sought. Containment may need to be considered when infection extends to multiple plantations, particularly if these plantations are not within close proximity of each other.

Aiming for containment may require a transition to a long-term management programme, however, it may also provide for a second window of eradication with the development of new technology or tools should these be identified.

The objectives of a containment option may be to

- achieve zone, area, or compartment freedom
- contain the spread using a range of strategies, i.e. internal borders, movement controls etc.
- exclude the organism from high value areas
- reducing the prevalence of the organism

14.4.3 Risk Management Considerations

Within these overall options, the general principles for the risk management of *F. circinatum* include:

- Rapid detection and confirmation of infection;
- Rapid identification of the extent of the problem;
- Rapid selection and implementation of response control measures;
- Maintenance of appropriate plant health management practices and high standards of hygiene.

The most appropriate option will depend on:

- The outcome being sought;
- Geographical location of the issue;
- Effective treatment;
- Chances of successful *F. circinatum* eradication;
- Level of risk accepted for any future spread of infection;
- Short-term costs of response control measures and disruption to forestry production;
- Long-term costs to forestry production in the presence or absence of *F. circinatum*;
- Long-term management costs should *F. circinatum* become endemic.

14.5 Response Operational Activities

The detection of *F. circinatum* on a nursery or forest plantation may result in several operational activities that will need to be undertaken to achieve the response outcomes, these are outlined in the sections below with the aim of informing response action planning.

A high-level response action plan needs to be drafted when a response is initiated. The details will depend on the specific circumstances but the below provides guidance to what actions may be necessary. Each work stream may need to complete their own detailed response action plan that will cover specific items in more detail.

14.6 Delimiting Survey, Tracing, Surveillance, and Diagnostics

To determine the appropriate course of action, a thorough delimiting survey should be conducted, followed by tracing of risk goods and both active and passive surveillance. It is important for the Surveillance and Diagnostics work streams to work closely together to ensure the service is effectively delivered. The purpose of tracing is to determine all other plantation properties, which may be at risk of the infection (forward tracing), as well as determine the possible source of the infection onto the infected properties (backward tracing). Surveillance streams required would include:

- Delimiting surveillance, based on epidemiological links to the plantation property where the original detection was made, as well as those in geographical proximity to it.
- National surveillance to determine if outbreaks exist outside of the infected properties' network(s).
- Report cases, where suspected *F. circinatum* cases can be reported through the Exotic Pest and Disease hotline.
- Retrospective surveillance – reviewing recent plantations health data and samples, including previous hotline notifications, and laboratory submissions.

Following delimiting of the outbreak, a plan for long-term, national disease freedom testing will then be considered, as this will be required to declare freedom from *F. circinatum* to the IPPC and trading partners.

14.6.1 Plantations and amenity plantings

- An initial inspection of host species within 100 m of the infected tree will be carried out as soon as possible.
- All stands of *Pinus* spp. and Douglas-fir within a 1.5 km radius of the point of detection will be inspected using an agreed sampling framework for signs of *F. circinatum* infection (dieback, resin bleeding and so on; see Section 6 for details).
    - The search area will be extended if more infected trees are found so that all areas within a 1.5 km radius of every infected tree are inspected.
    - If the stands are too dense or the trees too tall for their tops to be plainly visible from the ground, helicopter or UAV surveys will be carried out in addition to the ground surveys. Any trees within 1.5 km of the infected tree with relevant crown die-back or dead trees will be inspected on the ground for symptoms.
- Quarantine of infected property (declared as a restricted place)
- Tracing of suspected plants and plant materials, and people arriving on and leaving the infected property.
- Defining a Controlled Area Notice (CAN).
- Defining a Restricted Place (RP) Notice
- Defining a Notice of Direction (NoD)
- During an investigation or response, the following controls can be used to manage or contain any biosecurity risk:

Response Controls	**Description**
Controlled Area Notice (CAN)	This area will be subject to quarantine, surveillance and movement control of plants and plant material, equipment, and vehicles.

Restricted Place (RP) Notice	This will require all exposed plant material, equipment, clothes, and vehicles to remain on site and restricting the movement of these out of the property.
Notice of Direction (NoD)	This will require specific biosecurity controls to be put in place. A NoD is a direction that can be given by an inspector or authorised person to an occupier, owner, or person in charge of an organism or risk good to take specific actions to eliminate or mitigate the risk posed, or to prevent further spread.

- All suspect samples will be packed securely and sent to the PHEL (or other approved laboratory) for diagnosis.
- Locations of all potential hosts should be captured in GPS for follow-up surveys.
- Any new infections found should initiate another 1.5 km zone search.
- Cleaning and disinfecting clothing, footwear, vehicles and equipment by all of personnel before entering or leaving the site.
- Active national surveillance programme to monitor the disease status.
- Continued surveillance post-response to confirm that the disease has been eradicated.

14.6.2 Nurseries

- The points identified above in Plantations and Amenity Plantings will also apply
- If any seedlings from the nursery have been planted out in the season in which the infection was detected, these will be traced and destroyed in the field.
- If *F. circinatum* is detected in a seed orchard, then all seedlings raised from seed from that orchard should be considered infected and destroyed.
- All suspect samples will be packed securely and sent to the PHEL (or other approved laboratory) for diagnosis.
- All personnel will clean and disinfect clothing, footwear and equipment before entering or leaving the site.

14.7 Movement control

Movement controls will be put in place for any positive detections, and for properties with suspicious infection of *F. circinatum* or epidemiological links to a property where the pathogen has been confirmed. The following movement control restrictions may be imposed in order to contain potential *F. circinatum* spread. Recommended movement control restrictions, based on possible detection locations, are outlined here and discussed in the following subsections:

- A CAN in the case of a geographical area;

- An RP Notice restricting movement of any inoculated material out of the restricted area;
- A NoD requiring specific biosecurity controls to be put in place.

14.7.1 Declare a Restricted Place (RP) (s130 of the Biosecurity Act 1993)

The declaration of a Restricted Place (RP) as a control, can be implemented to contain a biosecurity risk through the control of activities and movements on and off a specific property, or a defined place. The specific RP restrictions established will be determined by the inspector or authorised person following a chief technical officer, a principal officer, or a management agency approval, taking account of the response objectives, the situation and any associated risk activities. For *F. circinatum* the RP will be defined by a 100m radius circular area around the initial detection point. If at least one infected sample was detected in the controlled area, an extra 100m-radius RP needs to be defined in addition to the initial detection point (Figure 4).

These are generally issued directly to the owner/occupier/manager by an inspector or authorised person (under the Biosecurity Act 1993).

Infected properties and suspected properties may be declared restricted places if "an inspector or authorised person believes or suspects on reasonable grounds that a pest or unwanted organism is or has been in a place”. The inspector or authorised person may declare that place and any other place in the neighbourhood to be considered as restricted place. To aid the consistent interpretation and application of restricted place declarations, the case definitions below describe the types of restricted place status to be applied and the rationale for these:

- Case definition of an Infected Place (IP): Any property with an MPI validated or confirmed diagnosis of *F. circinatum.*
- Case definition of a Suspected Place (SP): Any property immediately adjacent to an IP, or currently under investigation of having received a high-risk trace item, or under investigation as having a *F. circinatum* infection (but not yet confirmed).

A RP means that any organism, organic material, or risk goods; or any other goods that may have been in contact with any organism, organic material, or risk goods cannot be removed from the restricted place without the permission of an inspector or authorised person. Any goods of any kind can also not be introduced to the place without the permission of an inspector or authorised person.

14.7.2 Establish a Controlled Area Notice (CAN) (s131 of the Biosecurity Act 1993)

A Controlled Area Notice (CAN) is a broader control compared to RP that can be implemented across any specified area (which may be the whole or any specified part or parts of New Zealand) to:

- enable the limitation of the spread of any pest or unwanted organism; or
- minimise the damage caused by any pest or unwanted organism; or
- protect any area from the incursion of pests or unwanted organisms; or
- facilitate the access of New Zealand products to overseas markets; or
- monitor risks associated with the movement of organisms from parts of New Zealand the pest status of which is unknown.

These will be declared by a chief technical officer or a management agency taking account of the response objectives, the situation, and any associated risk activities. The controlled area will be defined by a 2km radius circular area around the initial detection point. The controlled rea will be extended by 2km from the second detection point (Figure 4).

A CAN is generally notified via public notice, i.e., newspaper, radio, TV announcement, or other public facing channels as the chief technical officer or management agency considers most effective or appropriate to suit the situation.

A CAN means that both or either of the following apply:

a) The movement into, within, or from the controlled area of such organisms, organic material, risk goods or other goods as are specified in the notice is restricted, regulated, or prohibited in the manner, to the extent and subject to the conditions specified in the notice.
b) The organisms, organic material, risk goods, or other goods within the controlled area that are specified in the notice, must be subject to such treatment and procedures as are specified in the notice.

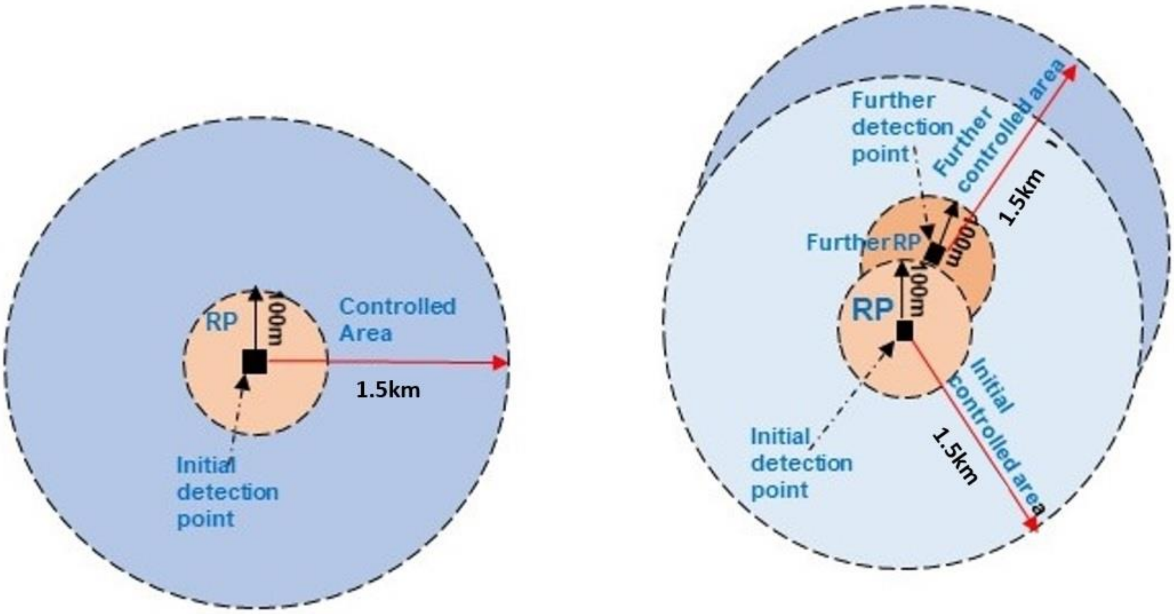

Fig. 4. Restricted Place and Controlled Area defined from the detection point of *F. circinatum*.

14.7.3 Forest Plantations

Once plant material in a forest plantation is identified as being infected by *F. circinatum,* MPI will declare the infested area to be a 'Restricted Place' (Section 130, Biosecurity Act 1993). A notice of the restricted place (RP) declaration will be given to the owner/occupier of each property included in the restricted place, or publicly if the inspector or authorised person cannot with reasonable diligence discover an occupier of that place who can be found quickly. Recommended movement control restrictions on and off a RP are as follows:

- No person shall, without the permission of an inspector or authorised person remove any organism, organic material, or risk goods; or any other goods that may have been in contact with any organism, organic material, or risk goods from the place to which the notice relates or introduce any goods of any kind to the place.
- All forestry operations that involve the removal of plant material grown within the RP will cease. Except for samples of diseased material collected by authorised people, no material grown in this area may be taken out.
- Specified organisms, risk goods, or other goods in the RP must be isolated, confined, or stored in such manner as the inspector or authorised person directs.
- Unauthorised access to the RP will be prohibited where possible and if there is a public road through the area, access away from the road will also be restricted.
- Where a restricted place includes businesses that cannot be closed long-term or residential areas, vehicle movement to the premises will be restricted to allow time to assess the site.

- Measures to contain the spread of infective propagules via vehicle movement will be implemented (e.g., removal of soil and plant material on vehicles, disinfection, or laying of plastic sheets).
- Once the appropriate measures have been implemented, vehicles are free to come and go from the area but need to stay within the designated parking and roadways.
- If the business or residence is close to the infection zone additional cleaning of the vehicles and wheels could be considered longer-term to further minimise spread.

A controlled area notice (CAN) will be determined by a chief technical officer or a management agency and declared through a public notice. Recommended movement control restrictions on and off a controlled area are as follows:

- Movement into, within, or from the controlled area of such organisms, organic material, risk goods or other goods as are specified in the notice is restricted, regulated, or prohibited in the manner, to the extent and subject to the conditions specified in the notice.
- The organisms, organic material, risk goods, or other goods within the controlled area that are specified in the notice, must be subject to such treatment and procedures as are specified in the notice.
- The transport of logs to and from ports and mills that may be within a controlled area is not considered high risk, as long as the trees were not grown within the RP. Movement permits will be required to move logs out of the restricted place. Surface washing of logs within the controlled area would minimise any contamination and could provide assurances for trading partners.
- The controlled area will extend 1.5 km in all directions of the location where suspected infected plants have been found, or as required to manage the issue while suiting the situation for practical application[4] and the outcome being sought.
- Forestry machinery, such as harvesting machinery, working within the controlled area will be cleaned of any plant material and soil contamination and steam-cleaned on site if possible, or taken by transporter to a place where a concrete pad and steam-cleaning facilities are available.
  - It is recommended the machinery is steam-cleaned and all debris collected and disposed of by burial to a minimum depth of 2 m.

[4] This recognises that there may need to be some flexibility in interpretation when applying a movement control conditions and boundaries to suit the situation while achieving the same outcome.

- If there is any suspicion that a fungus may be sporulating on the suspected diseased material, all such material should be sprayed to run-off with cuprous oxide (50g/10 litres of water, as a 75% wettable powder) and permethrin (12.5g a.i./10 litres of kerosene).

14.7.4 Nurseries

Once plant material in a nursery is identified as being infected by *F. circinatum,* MPI will declare the infested area to be a 'Restricted Place' (Section 130, Biosecurity Act 1993). A notice of the declaration will be given to the owner/occupier of each property included in the restricted place, or publicly if the inspector or authorised person cannot with reasonable diligence discover an occupier of that place who can be found quickly. and communicated to the owner/occupier of each property included in the restricted place. Suggested recommendations are as follows:

- The entire nursery in which suspected infected seedlings have been found will be declared a restricted place.
- All operations connected with working the nursery (cultivation, sowing, wrenching, lifting and so on) will cease.
- All machinery and vehicles will be steam cleaned within the confines of the nursery.
- There will be no unauthorised access and no material may be taken out of the restricted place without permission.
- This will be enforced until the nursery can be declared free of *F. circinatum* and there is no risk of spread through nursery plant movement or practices.

14.7.5 Urban Amenity Plantings

If an infected place is declared in an urban amenity planting, the Response Team will make recommendations to the MPI Chief Technical Officer (CTO) to begin preparations to declare a 'restricted place' and 'Controlled Area' (Section 131, Biosecurity Act 1993) if required. Suggested recommendations are as follows:

- An RP will be defined as 100m radius in all directions from the infection detection point.
- The Controlled Area will extend 1.5 km in all directions of the location where suspected infected plants have been found, or as required to manage the issue while suiting the situation for practical application[5].

[5] This recognises that there may need to be some flexibility in interpretation when applying a movement control conditions and boundaries to suit the situation while achieving the same outcome.

    - This may be extended when the results from the delimiting survey and trace forward/trace back procedures become available.
- All operations that involve the removal of host plant material grown within the restricted place will cease. Except for samples of diseased material collected by authorised people, no host material grown in this area may be taken out.
- Access restrictions on infected properties will be assessed on a case-by-case basis.
- Where a Controlled Area includes businesses that cannot be closed long-term or residential areas, vehicle movement to the premises will be restricted to allow time to assess the site.
    - Measures to contain the spread of infective propagules via vehicle movement will be implemented (e.g., removal of soil and plant material on vehicles, disinfection, or laying of plastic sheets).
    - If the business or residence is close to the infection zone additional cleaning of the vehicles and wheels could be considered longer-term to further minimise spread.

14.8 Organism management

The following subsections outline the recommended organism management actions based on *F. circinatum* detection location.

14.8.1 Seedlings in the nurseries

All seedlings of *Pinus* spp. and of Douglas-fir in an infected nursery and all seedlings raised from potentially infested seed in other nurseries will be sprayed with a concrete sealant and lifted, with as much of the root system intact as possible. Any grasses present in the nursery that are known to be hosts of *F. circinatum* will also be removed. They will be placed in a trailer or truck with closed bodywork, covered completely, taken to a site within the nursery and burnt. It may be necessary to start a fire with other fuel before placing the seedlings on it. A desiccant should not be used to make burning easier as any dropping of needles must be avoided. If burning within the nursery is not permitted, the seedlings must be securely covered and transported to a site where they can be burnt. All beds from which the seedlings or grasses have been removed will be fumigated with chloropicrin or another appropriate fumigant.

Chloropicrin is the preferred fumigant for treating *F. circinatum* (Gadgil et. al., 2003). The use of Chloropocrin in NZ is approved with controls by EPA. Recommended procedures for the fumigants Chloropicrin and Basamid are provided in Table 6. Fumigation must be carried out by a licensed operator.

Table 6. Fumigation procedures.

Fumigant	Chloropicrin	Basamid

Recommended procedure	○ The chemical should be applied with an injection rig. ○ Inject 3 ml chloropicrin per injection site at 30 cm centres to a depth of 20 cm. ○ The beds must be covered with polythene sheeting immediately after treatment. ○ Do not fumigate when soil temperatures are below 7°C. ○ Remove polythene sheets after 7 days and allow a further period of 14 days for aeration. ○ Soil should be moist at the time of treatment. ○ The tractor and fumigation rig must be steam cleaned before they leave the nursery. ○ In a containerised nursery, seedlings will be taken out of the containers and burnt. ○ The potting medium will be either steam sterilised or piled up on hard standing and fumigated with Basamid.	○ Use 60 g Basamid granular to a cubic metre of medium. ○ Make up the heap in batches making sure that the granules are thoroughly incorporated in each batch as it is added to the heap. ○ Cover the heap with polythene sheeting and leave for 3 weeks. ○ Allow an aeration period of 4-6 weeks.

Containers made of porous material such as polystyrene will be incinerated. Plastic containers may be disinfected by immersing them overnight in a solution of Alkyl Dimethyl Benzyl Ammonium Chloride (1.7 g/litre).

The treatments given in Table 6 may be substituted by others of equal effectiveness, e.g., Ethanedinitrile (EDN) (if permission to use is issued by EPA) and methyl bromide at the appropriate rate may be used instead of chloropicrin.

Effectiveness of fumigation will be checked immediately after the period of fumigation is over. Soil samples (about 125 ml) will be collected with a core sampler (4 cm diameter) to a depth 10 cm. Sampling frequency will be 1 sample per square metre from the beds in which infected plants were found and 1 sample per 10 square metres from other parts of the nursery. Potting medium samples will be collected at the rate of 10 samples per cubic metre. Each sample will be placed in a polythene bag, packed securely and sent to the PHEL for identification.

There are currently no published methods that are robust for isolation of *F. circinatum* from soil (IPPC 2017; ISPM 27 Diagnostic protocol 22: *Fusarium circinatum*). A diagnostic protocol for detection of viable propagules for *F. circinatum* in soil needs to be developed, because the current test method for viable spores in soil is a planting test. This method requires a lot of space in a laboratory and the process is laborious. This method is not scalable to meet the diagnostic need during a response.

Isolations for *Fusarium* will be made by the laboratory from each sample, using methods given in Appendix 4. If any species of *Fusarium* is isolated from a sample, the nursery beds or the potting medium will be re-fumigated and re-sampled. It must be noted that in analysing the soil samples, presence or absence of species of *Fusarium* is used as a proxy for *F. circinatum*, to measure failure or success of the fumigation. *F. circinatum* is not specifically looked for, but the absence of any species of *Fusarium* is taken to indicate that *F. circinatum* is likely to have been eliminated.

Fumigation may not be successful in eliminating *Fusarium* spp. from soils with a very high organic matter content. If *F. circinatum* is found in a nursery with such soils, the nursery will be closed, and the area put to another use. No soil may be exported from the site.

If no *Fusarium* spp. are isolated after fumigation, all fumigated beds will be sown with a plant species not known to be a host of *F. circinatum*. The alternative plant species will be maintained for two growing seasons. After this period, the beds may be used for growing seedlings of any species. If host species are grown, for two more years, the nursery will be inspected for *F. circinatum* presence three times during the growing season and random samples from asymptomatic plants will be sent for laboratory identification. Fumigated potting medium will not be used again for growing host species.

14.8.2 Seed

The seed source of all seedlings confirmed as infected by *F. circinatum* will be determined and the seed merchant from whom the putatively infected seed lot was bought identified. Unsown seed of the infected seed lot will be tested for *F. circinatum,* and if positive, the remaining seed will be recovered and destroyed by burning. A list of all nurseries which received seed belonging to the infected seed lot will be obtained from the seed merchant.

14.8.3 Seed Trees

If the infected seed was obtained from a seed source within Australia or New Zealand, the trees from which the seed was obtained will be examined very thoroughly and samples will be taken, packed securely and sent for laboratory identification. If infection by *F. circinatum* is confirmed, the stand or seed orchard in which the infected tree is located will be treated according to the methods in Section 14.8.6 Plantations.

14.8.4 Out-Planted Stock

Any seedlings (i) from the infected nursery which were planted out in the season in which the infection was detected and (ii) from other nurseries raised from the infected seed lot and planted out in the same season will be traced to the planting site. All such seedlings will be pulled out and examined for symptoms of *F. circinatum* infection. Symptomatic samples along with a selection of asymptomatic samples will be taken, securely packed and sent for laboratory identification. All seedlings will be burnt on the planting site, if possible or, if not, as close as possible to the planting site. If infection by *F. circinatum* is confirmed, the plantation will be treated according to the methods in Section 14.8.6 Plantations.

14.8.5 Amenity Plantings

Plants confirmed to be infected as well as all host plants within 1.5 km of plants confirmed as infected will be felled. If only a part of a group of host plants falls within 1.5 km of an infected plant, the whole group will be felled. Plants known to be infected will be felled last. In felling all trees, safe felling will be paramount. Where possible, care will be taken, to make sure the tree falls within of a zone extending 10 m from edge of the crown (or crowns if the trees are in a group). This may mean that large trees will have to be lowered section by section. If disposal by burning or deep burial in situ is not possible, all plant material less than 10 cm in diameter will be chipped on the spot. Larger material may be chipped or cut in sections no longer than 3 m. While chipping, care must be taken to ensure that all material falls into the receptacle intended for its reception. All material will be transported in a covered truck for disposal either by burning or burial to a depth of at least 1 m. All the remaining trunks, stumps and roots will be removed and destroyed.

After all plant material has either been removed or burnt, all vegetation in an area extending 10 m beyond the edge of the crown or crowns of the felled tree or trees (including stumps and roots) will be removed. The area will be fumigated with chloropicrin. After the aeration period is over, the area will be sown with grass. Trees or shrubs which are not hosts of *F. circinatum* may be planted in the area.

14.8.6 Plantations

A fire break will be cleared around all demarcated ‘infected’ areas (an area with a radius of 100 m from the host plant initially and extended outwards as required to suit the situation). The width of the fire break will depend on the height of the stand, the terrain and the environmental conditions prevailing at the time. All vegetation must be cleared from the fire break. If marketable it may be sold.

All the trees in the 100m demarcated area should be sprayed with a fungicide and an insecticide. If practicable, plants will be sprayed with a desiccant and all trees within the demarcated area will be felled. A diquat formulation e.g., Reglone is recommended. Reglone is approved for use in New Zealand and MPI uses it in the National Interest Pests Response (NIPR) Programmes. Reglone should be applied as a high-volume spray at a concentration of 4 litres per hectare with the addition of a wetting agent. Apply in at least 300 litres of water/hectare to ensure good coverage. All material will be cut in sections no longer than 3 m., windrowed and burnt as soon as suitable conditions for a burn prevail. The use of fire accelerants may be required to achieve a good burn.

The Response should work with Fire and Emergency New Zealand (FENZ) to help plan and conduct the burn, and possibly even providing resources in support of ensuring it is done safely and effectively. A permit to burn is required (Section 58, Fire and Emergency New Zealand Act, Section 190 Fire and Emergency New Zealand Regulations 2017). At times of high fire hazard, no burns are generally permitted, and no permits issued. For reasons of biosecurity, however, a Special Permit may be obtained from FENZ (Section 57, Fire and Emergency New Zealand Act 2017; Section 190, Fire and Emergency New Zealand Regulations 2017).

In situations where the material cannot be burnt because of unsuitable conditions, windrowing should be delayed. Felled trees will be sprayed with permethrin to limit borer infestation and to kill emerging insects. Spraying will continue at fortnightly intervals until conditions are suitable for a burn. The material will then be windrowed and burnt.

After a clean burn has been achieved, the demarcated area or areas will be kept free of regenerating crop seedlings and known hosts (to avoid providing a host for *F. circinatum*), by regular spraying with a non-selective herbicide, e.g., Roundup® or Paraquat, for a period of two years. The site or sites will be inspected once a month and the herbicide applied as necessary. After the two-year stand down period, the site may be replanted.

14.9 Post-Treatment Surveys

All areas within a 1.5 km radius of an infected area will be surveyed for *F. circinatum* infection. Three surveys will be carried out, in spring, summer and autumn of every year for two years. If infected sites are planted in a host species after the two-year stand down period, they will be surveyed from the ground for a period of a further two years.

The two-year period for which the growing of susceptible host species is prohibited in infected nurseries and forest areas is based on *F. circinatum* being unlikely to survive in soil in the absence of host plants for much longer than one year.

15 Communications Strategy

15.1 Stakeholders

- A liaison cascade will be developed to ensure appropriate engagement occurs across a range of key stakeholders and partners via the Response Operational Liaison function.
- A stakeholder matrix will be developed outlining the level of importance of each stakeholder in terms of maintaining engagement and mitigating outrage to any proposed response activity and to the incursion of a harmful strain of *F. circinatum*.

15.2 Wider Industry

- Further communication of major developments will occur as per the communication plan, to be developed in conjugation with the operations action plan. Public media release and direct notification of wider industry bodies are also coordinated by the Public Information Management (PIM) workstream lead.
- Provide all forest owners with best practice advice for high-risk activities, which includes hygiene recommendations and other measures to mitigate risk.
- Passive surveillance messages, reporting process and symptom and monitoring guides issued to the entire industry (including all forest owners, post-harvest organisations and nurseries).

PART III – Current Research and Key Knowledge Gaps

16 Knowledge Gaps

- Pre-agreed sampling framework to detect infected trees within a 1.5 km radius from a known infected tree with a 95% confidence interval.
- The distance of natural spread from an infected place needs to be clarified to inform the placement of area control zones or distances.
- Sampling methodology should be developed to streamline processing work in the laboratory. Samples should be prepared in the way that allow high throughput processing in the laboratory. Funding is required to develop and validate a sampling protocol.
- Reliable PCR protocols to be developed for rapid detection of this fungus. Work is underway at Biosecurity New Zealand's Plant Health and Environment Laboratory to determine the most specific molecular approach.
- There are currently no published methods that are robust for isolation of *F. circinatum* from soil (IPPC 2017; ISPM 27 Diagnostic protocol 22: *Fusarium circinatum*). A diagnostic protocol for detection of viable propagules for *F. circinatum* in soil needs to be developed.
- Climatic modelling of *F. circinatum* in New Zealand - risk map of establishment and sporulation in different seasons/months.
    - Initial climatic modelling has been done by MPI. According to this, the northern Island and western parts of Southern Island are potentially more suitable parts of New Zealand for this fungus establishment (Ministry for Primary Industries, 2018). In addition, a modelling has been done by Watt et. al. (2011) on the global suitability for *F. circinatum* in 2080s. For New Zealand expansion of suitable climate was projected in the 2080s.
- Epidemiological modelling of *F. circinatum* in New Zealand – risk map of spread from high-risk points of entry.
- Technologies to improve large scale aerial surveillance – e.g., spectral signatures of infected trees
- Cost-benefit analyses of response operations under different response scenarios (e.g., various scales, geographical locations, and forest plantation vs. urban amenities).
- *F. circinatum* impact assessment on the commercial forest sector, and on other sectors, environment etc.
- Compensation estimates and procedures in event of an incursion in nurseries and forest plantations.

- Establishing pre-agreements with suppliers/contractors to rapidly carry out response operations.
- Current Import Risk assessment. The existing risk assessment was undertaken in 2002. Risk pathways have changed significantly since then (online trade), and *F. circinatum* has been associated with several other species.
- Research/explore alternative more environmentally appropriate chemical treatment options as response tools
- Chemical treatment availability and legal status of its use for *F. circinatum* response.
- Further assessment and potentially research on the efficacy of seed treatment fungicide.
- Ethanedinitrile (EDN) approval by EPA is still in process. The effectiveness of EDN fumigant could be higher that Phosphine and Methyl Bromide to mitigate risk of seed pathway for this fungus.
- The necessary stock and equipment for a response to this fungal pathogen in the event of an incursion is procured by the BNZ's Response Capacity team, including addressing stores requirements and resources (i.e., for chemicals), disposal requirements, etc. the BNZ's Response Capacity team should be informed of the required stock/equipment for a *F. circinatum* response.
- Consider research into the potential to breed for resistance to *F. circinatum.*
- Development of a response surveillance plan in order to implement of recovery procedures and to meet the requirements of country freedom or free compartment.

References

Aitken, J. (2004). Safe importation of plant material using new technology. Confidential unpublished report to MPI.

Barnard, E. L., & Blakeslee, G. M. (1980). Pitch canker of slash pine seedlings: A new disease in forest tree nurseries. *Plant Disease, 64*, 695-696.

Barrows-Broaddus, J., & Kerr, T. J. (1981). Inhibition of *Fusarium moniliforme* var. *subglutinans*, the casual agent of pine pitch canker, by the soil bacterium *Arthrobacter* sp. *Canadian Journal of Microbiology, 27*, 20-27.

Blakeslee, G. M., Dorset, R. D., & Oak, S. W. (1979). Inoculum dispersal of the pine pitch canker fungus *Fusarium moniliforme* var. *subglutinans*. *Phytopathology, 69*, 1022.

Blakeslee, G.M. (2005). Personal communication with R. Ganley and L. Bulman.

Brockerhoff, E.G., Dick, M., Ganley, R. *et. al.* (2016). Role of insect vectors in epidemiology and invasion risk of *Fusarium circinatum*, and risk assessment of biological control of invasive *Pinus contorta*. *Biol Invasions* **18,** 1177–1190. https://doi.org/10.1007/s10530-016-1059-8

Centre for Agriculture and Bioscience International [CABI]. (2018). *Gibberella circinata (pitch canker)*. Retrieved July 2, 2019, from https://www.cabi.org/isc/datasheet/25153

Correll, J. C., Gordon, T. R., McCain, A. H., Fox, J. W., Koehler, C. S., Wood, D. L., & Schultz, M. E. (1991). Pitch canker disease in California: Pathogenicity, distribution, and canker development on Monterey pine (*Pinus radiata*). *Plant Disease, 75*(7), 676-682.

Dick, M. A., & Simpson, J. A. (2004). *Fusarium circinatum* as a cause of damping-off: Exploring the host range. *Unpublished data.*

Drenkhan, R., et al. (2020). "Global Geographic Distribution and Host Range of Fusarium circinatum, the Causal Agent of Pine Pitch Canker." Forests 11(7): 724.

Dvořák, M., Janoš, P., Botella, L., Rotková, G., & Zas, R. (2017). Spore dispersal patterns of Fusarium circinatum on an infested Monterey pine forest in North-Western Spain. *Forests*, *8*(11), 432.

Edmonds, R. L., & Heather, W. A. (1973). Root diseases in pine nurseries in the Australian Capital Territory. *Plant Disease Reporter*.

Elvira-Recuenco et. al. (2019). Potential Interactions between Invasive *Fusarium circinatum* and Other Pine Pathogens in Europe. Forest https://doi.org/10.3390/f11010007

European and Mediterranean Plant Protection Organization [EPPO]. (2019). *Fusarium circinatum*. Retrieved July 2, 2019, from https://gd.eppo.int/taxon/GIBBCI/distribution

Fox, J. W., Wood, D. L., & Koehler, C. S. (1990). Distribution and abundance of engraver beetles (Scolytidae: *Ips* species) on Monterey pines infected with pitch canker. *The Canadian Entomologist, 122*, 1157-1166.

Fox, J. W., Wood, D. L., Koehler, C. S., & O'Keefe, S. T. (1991). Engraver beetles (Scolytidae: *Ips* species) as vectors of the pitch canker fungus, *Fusarium subglutinans*. *The Canadian Entomologist, 123*, 1355-1367.

Furniss, R. L., & Carolin, V. M. (1977). *Western Forest Insects.* Washington, DC: USDA Forest Service.

Gadgil, P., Dick, M., Simpson, J., Bejakovick, D., Ross, M., Bain, J., Horgan, G., & Wylie, R. (2003). Management Plan Response to an Incursion of Pine Pitch Canker in Australia or New Zealand. *Australasian Standing Committee on Forestry*.

Ganely, B., and Bulman, L. (2016). *Fusarium circinatum* Incursion Management Plan for New Zealand. Unpublished Report. Scion, Rotorua, New Zealand.

Garbelotto, M., Smith, T., & Schweigkofler, W. (2008). Variation in rates of spore deposition of *Fusarium circinatum*, the causal agent of pine pitch canker, over a 12-month-period at two locations in Northern California. *Phytopathology, 98*(1), 137-143.

Gordon, T. R., Okamoto, D., Storer, A. J., & Wood, D. L. (1998). Susceptibility of five landscape pines to pitch canker disease, caused by *Fusarium subglutinans* f. sp. *pini*. *HortScience, 33*(5), 868-871.

Gordon, T. R., Storer, A. J., & Wood, D. L. (2001). The pitch canker epidemic in California. *Plant Disease, 85*(11), 1128-1139.

Government Industry Agreement (GIA), 2016. *GIA Response Guide A guide to managing biosecurity responses under the Government Industry Agreement for Biosecurity Readiness and Response.* Wellington. Retrieved from http://www.gia.org.nz/Portals/79/Content/Documents/Resource-Library/GIA%20Response%20Guide.pdf?ver=2016-06-27-140714-970

Hernandez-Escribano, L.; Iturritxa, E.; Aragonés, A.; Mesanza, N.; Berbegal, M.; Raposo, R.; Elvira-Recuenco, M. Root Infection of Canker Pathogens, *Fusarium circinatum* and *Diplodia sapinea*, in Asymptomatic Trees in *Pinus radiata* and *Pinus pinaster* Plantations. *Forests* **2018**, *9*, 128.

Hepting, G. H., & Roth, E. R. (1946). Pitch Canker, a new disease of some southern pines. *Journal of Forestry, 44*, 724-744.

Herron, D. A., et al. (2020). Grasses as a refuge for *Fusarium circinatum* L. - evidence from South Africa. Southern Forests: a Journal of Forest Science 82(3): 253-262.

Ioos R, Fourrier C, Iancu G, Gordon TR (2009). Sensitive detection of *Fusarium circinatum* in pine seed by combining an enrichment procedure with a real-time polymerase chain reaction using dual-labeled probe chemistry. Phytopathology 99: 582–590.

Ioos R, et. al. (2019). Transferability of PCR-based diagnostic protocols: An international collaborative case study assessing protocols targeting the quarantine pine pathogen *Fusarium circinatum*. Scientific reports 9, 8195. https://doi.org/10.1038/s41598-019-44672-8

IPPC (2018). ISPM 15 Regulation of Wood Packaging Material in International Trade. Retrieved from https://pflanzengesundheit.julius-kuehn.de/dokumente/upload/ISPM_15_2018_En_2018-05-16.pdf

IPPC (2017). Explanatory Document for ISPM 15 (Regulation of Wood Packaging Material in International Trade). Retrieved from https://www.ippc.int/static/media/files/publication/en/2017/02/ISPM_15_ED_En_2017-02-10.pdf

IPPC (2017). ISPM 27 Diagnostic protocols for regulated pests DP 22: *Fusarium circinatum.* Retrieved July 3, 2019, from: https://www.ippc.int/static/media/files/publication/en/2017/04/DP_22_2017_En_2017-04-12.pdf

Islam, W., Zhang, J., Adnan, M., Noman, A., Zainab, M., & Jian, W. (2017). Plant virus ecology: a glimpse of recent accomplishments. *Appl Ecol Environ Res*, *15*(1), 691-705.

McNee, W. R., Wood, D. L., Storer, A. J., & Gordon, T. R. (2002). Incidence of the pitch canker pathogen and associated insects in intact and chipped Monterey pine branches. *Canadian Entomologist, 134*, 47-58.

Ministry for Primary Industries. (2015). MPI Technical Standard: Certification Mark for Wood Packaging, according to ISPM 15. Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz/dmsdocument/7953-mpi-technical-standard-certification-mark-for-wood-packaging

Ministry for Primary Industries. (2018). The New Zealand Government Biosecurity Response Guide. Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz/dmsdocument/31917-the-new-zealand-government-biosecurity-response-guide.

Ministry for Primary Industries. (2018). Priority Pests and Diseases of Biosecurity Concern to Plant and aquatic Health, Trees Pests and Diseases, Pitch Canker. Ministry for Primary Industries. Retrieved from https://www.biosecurity.govt.nz/protection-and-response/finding-and-reporting-pests-and-diseases/priority-pests-plant-aquatic/tree-forestry-pests/pine-pitch-canker/

Ministry for Primary Industries. (2019). Situation and Outlook for Primary Industries, June 2019*.* Retrieved from https://www.mpi.govt.nz/dmsdocument/34938-situation-and-outlook-for-primary-industries-sopi-june-2019.

Ministry for Primary Industries. (2020). Approved Biosecurity Treatments, MPI-ABTRT. Ministry for Primary Industries. Retrieved from https://www.mpi.govt.nz/dmsdocument/1555/send

Möykkynen, T., Capretti, P., & Pukkala, T. (2015). Modelling the potential spread of *Fusarium circinatum*, the causal agent of pitch canker in Europe. *Annals of Forest Science, 72*(2), 169-181. doi:10.1007/s13595-014-0412-2

Nirenberg HI, O'Donnell K (1998). New *Fusarium* species and combinations within the *Gibberella fujikuroi* species complex. Mycologia 90: 434–58.

Officials' Committee for Domestic and External Security Coordination. (2019). Coordinated Incident Management System (CIMS), 3rd edition. https://www.civildefence.govt.nz/assets/Uploads/CIMS-3rd-edition-FINAL-Aug-2019.pdf

Pfenning, L. H., Costa, S. D. S., Melo, M. P. D., Costa, H., Ventura, J. A., Auer, C. G., & Santos, Á. F. D. (2014). First report and characterization of *Fusarium circinatum*, the causal agent of pitch canker in Brazil. *Tropical Plant Pathology*, 39(3), 210-216.

Ramsfield TD, Dobbie K, Dick MA, Ball RD (2008). Polymerase chain reaction-based detection of *Fusarium circinatum*, the causal agent of pitch canker disease. Molecular Ecology Resources 8: 1270-1273. doi: 10.1111/j.1755-0998.2008.02188.x

Romón, P., Troya, M., Fernández de Gamarra, M. E., Eguzkitza, A., Iturrondobeitia, J. C., & Goldarazena A. (2008) Fungal communities associated with pitch canker disease of *Pinus radiata* caused by *Fusarium circinatum* in northern Spain: association with insects and pathogen-saprophyte antagonistic interactions, Canadian Journal of Plant Pathology, 30:2, 241-253, DOI: 10.1080/07060661.2008.10540539

Serrano Y, Iturritxa E, Elvira-Recuenco M, Raposo R (2016). Survival of *Fusarium circinatum* in soil and *Pinus radiata* needle and branch segments. Plant Pathology. Doi: 10.1111/ppa.12648

Storer, A. J., Gordon, T. R., & Clark, S. L. (1998). Association of the pitch canker fungus, *Fusarium subglutinans* f. sp. *pini* with Monterey pine seeds, and seedlings in California. *Plant Pathology, 47*, 649-656.

Storer, A. J., Gordon, T. R., Wood, D. L., & Bonello, P. (1997). Pitch canker disease of pines: Current and future impacts. *Journal of Forestry, 95*(12), 21-26.

Storer, A. J., et al. (1994). "Pitch canker kills pines, spreads to new species and regions." California Agriculture *48*(6): 9-13.

Storer, A. J., Gordon, T. R., Wood, D. L., & Dallara, P. L. (1995). *Pitch canker in California.* California Forestry Note. Sacramento, California: California Department of Forestry and Fire Protection.

Storer, A. J., Wood, D. L., & Gordon, T. R. (2002a). Effects of pitch canker pathogen on gallery excavation and oviposition by *Ips paraconfusus* (Coleoptera: Scolytidae). *Canadian Entomologist, 134*, 519-528.

Storer, A. J., Wood, D. L., & Gordon, T. R. (2002b). The epidemiology of pitch canker of Monterey pine in California. *Forest Science, 48*(4), 694-700.

Swett, C. L., & Gordon, T. R. (2015). Endophytic association of the pine pathogen *Fusarium circinatum* with corn (*Zea mays*). *Fungal Ecology, 13*, 120-129. doi:10.1016/j.funeco.2014.09.003

Swett, C. L., Porter, B., Fourie, G., Steenkamp, E. T., Gordon, T. R., & Wingfield, M. J. (2014). Association of the pitch canker pathogen *Fusarium circinatum* with grass hosts in commercial pine production areas of South Africa. *Southern Forests*. doi:10.2989/20702620.2014.916087

T. R. Gordon. (2004). Personal communication with R. Ganley & L. Bulman.

Vaartaja, O., & Bumbieris, M. (1967). Organisms associated with root rots of conifers in South Australian nurseries. *Plant Disease Reporter*, 51, 473-476.

Viljoen, A., Wingfield, M. J., & Marasas, W. F. O. (1994). First report of *Fusarium subglutinans* f. sp. *pini* on seedlings in South Africa. *Plant Disease, 78*, 309-312.

Watt, M. S., Ganley R. J., Kriticos D. J. & Manning L. K. (2011). Dothistroma needle blight and pitch canker: the current and future potential distribution of two important disease of Pinus species. *Canadian Journal of Forest Research*, 41(2), 412-424.

Wikler, K. R., Storer, A. J., Newman, W., Gordon, T. R., & Wood, D. L. (2003). The dynamics of an introduced pathogen in a native Monterey pine (*Pinus radiata*) forest. *Forest Ecology and Management, 179*, 209-221.

Wingfield, M. J., Jacobs, A., Coutinho, T. A., Ahumada, R. and Wingfield, B. D. 2003. First report of the pitch canker fungus, *Fusarium circinatum*, on pines in Chile.. *Plant Pathol.*, 51: 39

Appendix 1: MPI Response Control Structure

MPI's uses the New Zealand standard for incident management, the Coordinated Incident Management System (CIMS), as a response model. CIMS is used by all major emergency services in New Zealand. This model provides a framework for responses. MPI extends CIMS where necessary to meet needs common across MPI responses which are not already addressed in the structure.

The functions in this model may be amended or added to depending on an agency's needs, responsibilities, or the specific objectives of a particular response. Members of the industry would have a seat on the Governance, in some of the functions such as Intelligence, Liaison, Operations, etc. Diagnosis would fit in on TAG and/or science and technical advisers functions.

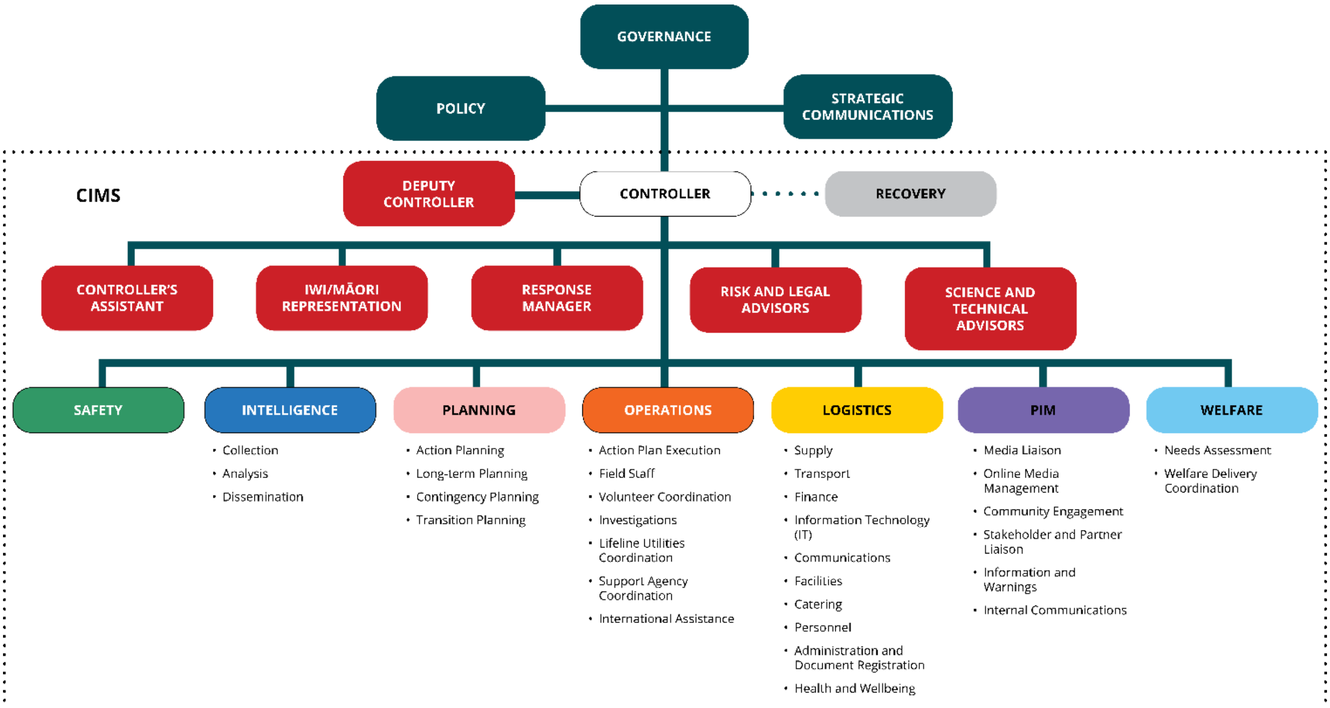

Figure 5. The New Zealand Coordinated Incident Management System 3rd Edition.

Appendix 2: Legislative Tools

The following legislations should be considered when formulating or implementing a plan for *F. circinatum* (this is not an exhaustive list):

Legislation	Reason
Biosecurity Act 1993	• Ensuring that the actions within the plan are allowed under the powers bestowed under this Act • Considering potential compensation claims • Joint decision making under GIA • Requirements of long-term pest management
Conservation Act 1987	Should native or DOC estate plants be infected, this Act may come into play.
Hazardous Substances and New Organisms Act 1996	Any chemical treatments will need to be used in compliance with this Act.
Health and Safety at Work Act 2015	MPI & GIA signatories involved in readiness and response activities need to ensure the: • Safety of staff; and • Safety of contractors hired and that they have suitable health and safety procedures.
Local Government Act 2002	Should Regional or District Councils be involved, this Act may need to be considered in terms of what a Council may or may not do.
Resource Management Act	May require consulting – however certain exemptions are possible under Section 7A of the Biosecurity Act.

For further information, refer to Section 7 of the Biosecurity Act 1993.

Appendix 3: Collection Procedures for Suspected *F. circinatum* Samples

Suspected *F. circinatum* detections are likely to be made by a Forest Health Inspector, an employee of a forestry company, a forest pathologist, urban arborists, or nursery growers.

The current sample collection procedures are outlined below. However, an improved sampling methodology should be developed to minimise unintentional dissemination of the pathogen and allow high throughput processing in the laboratories.

1. Sample Collection

Collect representative samples of diseased material such as branches showing dieback or wood with resin bleeding.

- Ideally cut one or more lengths of branch, ca. 200 mm long.
- Include material that has a margin of healthy and dead material.
- Do not collect material that is completely dead.

For Stem Lesions:

- Sample material where there is visible resin exudation, cracked bark, cankers or fruit bodies.
- Ensure that it is of adequate size e.g., minimum of 200 x 200 x 100 mm^3 and that at least the cambium layer is captured (this may be quite deep, depending on bark thickness).
- Include sections that contain margins of healthy wood with regions of stain, discolouration or decay.
- Any insects present around the stem lesion region should also be collected and placed into sample collection vials.

Seedlings:

- Whole seedlings should be placed in individually labelled plastic bags that are then sealed and kept cool, away from direct sunlight. Samples should be sent to the laboratory as soon as possible.

2. Information to be Provided with Samples (ideally this should be collected and submitted electronically)

a. Unique sample number, collector, date of collection.
b. Sample details: what was sampled.
c. Site details: ownership, location and GPS/map (latitude and longitude), aspect, stand composition.

d. Contact details.
e. Host details: species, age, height, stocking (number of trees per hectare), stand area.
f. Damage: description general tree health, symptoms, part of host showing symptoms, per cent incidence, percent severity, as well as the environment the tree/trees are growing in, including age of trees, size (diameter) and height.
g. Comments: any other helpful information.

Take photos of the whole plant and close up of disease symptoms. Label each picture file with the unique sample number and contact details and ensure details above (a to g) are sent to the Diagnostic lead.

3. Sterilisation of sampling tools

Equipment used for sampling should be sterilised before a collection is made at another site. All organic matter and/or soil should be removed from the equipment before sterilisation. Sterilising agents include 2% TriGene®; 30% Janola®; and 70% ethyl alcohol. Passage through the flame of a gas burner may be a more practical method of sterilising cutting equipment such as pruning loppers or secateurs. Flame sterilisation can be achieved by dipping the blades in 70% alcohol before passing through the flame and wiping the handles and other parts of the tools with a sterilising agent, e.g., 70% ethanol. Footwear should be thoroughly cleaned before leaving the site using the method above, i.e. removing mud and organic materials before applying sterilising agents listed above.

4. Sending Samples

Package samples in a plastic bag and seal securely, place the first securely sealed bag into another heavy gauge plastic bag. Seal this securely and pack in a crush-resistant carton. Wrap and seal the carton to make sure that the contents do not spill out.

Couriered samples should be sent using a trackable service to ensure that they can be traced. Notify Diagnostic Lead of the suspect samples and provide them with the relevant parcel tracking details.

Courier samples to:

Plant Health and Environment Laboratory
31 Morrin Road
St Johns
Auckland 1072
Email: Specimen.ReceptionTamaki@mpi.govt.nz
Tel: 029-9095368

Note: during a response, a dedicated email and phone number could be made available to communicate with the surveillance Lead and the Operation Lead.

5. Notification

Biosecurity Act 1993, Section 44:

> *“Every person is under a duty to inform the Ministry, as soon as practicable in the circumstances, of the presence of what appears to be an organism not normally seen or otherwise detected in New Zealand”*

Symptoms of *F. circinatum* infection include resin bleeding that can look like damage caused by insects or abiotic factors. However, if there are reasons that pitch canker is suspected that are beyond typical disease symptoms, then MPI should be notified immediately via the Biosecurity hotline 0800 80 99 66.

The collector should also warn Scion that a suspect pitch canker sample has been sent to their laboratory or to MPI.

Contact information for the Forest Health Reference Laboratory is:

fhdiagnostics@scionresearch.com, Ph (07) 343 5513 or (07) 343 5524. Scion reception is (07) 343 5899.

Appendix 4: *Fusarium circinatum* Diagnostic Identification Methods

1. Isolation

To isolate *F. circinatum*, cut stem or branch canker samples from the margin of symptomatic tissue, soak in 25% commercial bleach (1% sodium hypochlorite) or 50% alcohol for 1 min, rinse twice with sterile water. Selective media, such as dichloran chloramphenicol peptone agar (DCPA) or Komada's medium, are recommended for isolations. Potato dextrose agar supplemented with 0.5 mg/ml streptomycin sulphate salt (775 units/mg solid) can also be used (EPPO, 2005).

Incubate plates at 22 °C ± 6 °C under 12/12hr near ultraviolet/white light or in daylight (not direct sunlight). During incubation, the plates are observed daily, and all the *Fusarium* spp. colonies are transferred to fresh agar plates, e.g., potato dextrose agar (PDA), Spezieller Nährstoffarmer agar (SNA), and carnation leaf agar (CLA; water agar plate with a piece of sterilised carnation leaf placed on the surface). Any resulting fungal colonies resembling *F. circinatum* in culture should be identified by DNA sequence analysis.

2. Microscopic Characteristics

Fusarium circinatum is characterised microscopically by sterile coiled hyphae; branched conidiophores bearing polyphailides; abundant, mostly oboviod, non-septate microconidia ranging from 7.0-12.0 x 2.5-3.9 µm; and slender, cylindrical, multi-septate macroconidia ranging from 32.0-48.0 x 3.2-3.8 µm. The anamorphic state is characterised by ovoidal to obpyriform, non-papillate, dark purple perithecia ranging from 325-453 µm high by 230-358 µm wide. Ascospores produced are ellipsoidal, ranging from 9.4-16.6 x 4.5-6.0 µm, pale brown and are septate, with additional septa developing after discharge. In culture, *F. circinatum* on PDA medium produces aerial mycelium that is usually white to greyish-violet and most cultures also produce a grey to dark purple pigmentation.

3. Molecular Methods

Because of the high diversity and complexity of the *Fusarium* genus, and challenges in using morphological characters to distinguish *F. circinatum* from other members of the *Fusarium fujikuroi* species complex, significant detection can be confirmed by DNA sequence analysis of the isolated fungus (e.g., new country record, new host record). However, isolation of *F. circinatum* takes time for the fungus to grow in isolation media.

Any cultures of *F. circinatum* should be analysed using DNA sequence data from the elongation factor 1-alpha gene and compare with published reference sequences to distinguish it from closely related species. Some DNA sequences in public databases are misidentified. Therefore, diagnosticians must be vigilant on checking the reliability of reference sequences used in analysis.

A number of published PCR protocols are available for rapid detection of *F. circinatum.* However, a recent study by Ioos et. al. (2019) has identified that many of these are unreliable (i.e., false positives and false negatives). Work is underway at Biosecurity New Zealand's Plant Health and Environment Laboratory to determine the best approach on addressing the non-specificity issues.

The current standard is to use the PCR methods published by Ramsfield (2004), Ioos (2009), and Baskarathevan et. al. (unpublished).

There are currently no published methods that are robust for isolation of *F. circinatum* from soil (IPPC 2017; ISPM 27 Diagnostic protocol 22: *Fusarium circinatum*). A diagnostic protocol for detection of viable propagules for *F. circinatum* in soil needs to be developed. The current test method for viable spores in soil is a planting test. This method requires a lot of space in a laboratory and the process is laborious. This method is not scalable to meet the diagnostic need during a response.

Appendix 5: GIA Decision-Making Process for *F. circinatum* Response