Biosecurity New Zealand
Tiakitanga Pūtaiao Aotearoa

Import Risk Analysis

Decrowned Pineapples (*Ananas comosus*) for Human consumption

Version 1.0

Prepared to support the development of Import Health Standard for decrowned pineapples (*Ananas comosus*) for human consumption
by Plant Risk
Animal and Plant Health Directorate

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Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Phone: 0800 00 83 33

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Decrowned Pineapples (*Ananas comosus*) for Human Consumption

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Approved for general release

Version information

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New Zealand is a member of the World Trade Organization and a signatory to the Agreement on the Application of Sanitary and Phytosanitary Measures ("The Agreement"). Under the Agreement, countries must base their measures on an international standard or an assessment of the biological risks to plant, animal or human health.

This document provides a scientific analysis of the risks associated with importing fresh pineapples from selected countries. It assesses the likelihood of pests and diseases being introduced to New Zealand through decrowned pineapples imported from selected countries. It also assesses the impacts of those organisms could have if they enter New Zealand and establish populations here. The document has been peer reviewed and is now released publicly for feedback. If we receive any information that alters the level of assessed risk, we will review this document and release an updated version.

Import Risk Analysis

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1 Background

This import risk analysis (IRA) assesses the biosecurity risks associated with importing commercially produced decrowned fresh pineapple fruit (*Ananas comosus*) for human consumption from Australia, Ecuador, Fiji, New Caledonia, the Philippines, Thailand, Vanuatu, the Cook Islands, Costa Rica, Indonesia, Malaysia, Papua New Guinea, Panama, Samoa, Sri Lanka, Taiwan and Tonga. This assessment supports the development of an import health standard (IHS) to import pineapples for human consumption.

The pathways and commodities covered in this analysis are in **Table 1.1**.

Table 1.1 Pathways and commodities assessed in this analysis

Commodity type	Pathway description
Fresh produce for human consumption	Commercially[1] produced decrowned fresh pineapple fruit (*Ananas comosus*) of all varieties and ripeness (excluding over ripe[2]) for human consumption. This excludes material or produce that is visibly damaged (damage that may be a result of the presence of a regulated pest or could expose the commodity to regulated pests). We did not assess the risk from crown remnants in this analysis. The pineapples may be from Australia, Ecuador, Fiji, New Caledonia, the Philippines, Thailand, Vanuatu, the Cook Islands, Costa Rica, Indonesia, Malaysia, Papua New Guinea, Panama, Samoa, Sri Lanka, Taiwan or Tonga.

2 Objectives

Biosecurity New Zealand's objectives in developing an import risk analysis are to:

1. identify which pests and diseases present a level of risk to New Zealand on the commodities and pathways included in the scope; and
2. assess these pests and diseases using a method that provides enough evidence about the biosecurity risks for risk managers to make a robust and transparent decision on whether additional measures beyond the commodity description are needed to manage these pests and diseases.

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[1] Commercial production means a process (system) where activities, such as in-field monitoring, pest control activities, harvesting, cleaning², sorting, and grading³ have been undertaken. These activities are carried out to minimise:
a) the presence of regulated pests;
b) commodity damage which could expose the commodity to regulated pests
Note: NPPO phytosanitary inspection, certification and documentation form part of general import requirements.

[2] Overripe is equivalent to C4 or greater as per the UNECE Standard on the marketing and commercial quality control of pineapples (reference: UNECE (2013) UNECE Standard on the marketing and commercial quality control of pineapples. Explanatory Brochure. United Nations Economic Commission for Europe. New York and Geneva. Accessed from https://unece.org/DAM/trade/Publications/ECE_TRADE_398E_PineappleBrochure.pdf).

3 Scope of analysis

This analysis answers several risk management questions.

Risk management questions	
Purpose	Specific questions that the risk manager needs answered to make a decision. The questions are based on the commodity description for that commodity type.
Description specific to this analysis	1. Is each assessed pest or disease a hazard[3]? 2. What is the overall risk of each assessed pest and disease? Information (when available) on the following questions in each pest risk assessment (PRA) will assist in making risk management decisions: a) On which pineapple variety (or varieties) and at what stage of ripeness has pest association with the fruit been observed? b) Which parts of the fruit is the pest associated with (e.g. fruit, bract, stem or crown remnant), and is it detectable by visual inspection? c) Are different life stages of the pest associated with different parts of the fruit? d) Under what environmental conditions (temperature, season etc.) are disease symptoms expressed on the fruit? e) Does the pest burrow into the fruit without obvious symptoms or hide under the pineapple bract?

Detailed commodity description	
Purpose	The commodity description defines the form of the commodity that is covered by this analysis, e.g. the commodity species and form under consideration. The commodity description may also include commercial production and/or grading requirements or other commodity quality specifications.
Description specific to this analysis	**Commodity description[4]** Commercially produced decrowned fresh pineapple fruit (*Ananas comosus*), of all varieties and ripeness (excluding overripe[5]) for human consumption. This excludes material or produce which is visibly damaged (damage which may be a result of the presence of a regulated pest or could expose the commodity to regulated pests). The risk from crown remnant has not been considered in this analysis because crown remnant will be deemed a non-compliance as per the commodity description.

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[3] Any pest or disease that is not present in New Zealand (or is present but still represents a biosecurity risk, e.g. is capable of vectoring pathogens not present in New Zealand), has the ability to establish and cause harm in New Zealand, and is associated with imported risk goods and import pathways.

[4] In the absence of ripeness and variety from the commodity description, pest association will be reported for all varieties and stages of ripeness in the IRA.

[5] Overripe is equivalent to C4 or greater as per the UNECE Standard on the marketing and commercial quality control of pineapples (reference: UNECE (2013) UNECE Standard on the marketing and commercial quality control of pineapples. Explanatory Brochure. United Nations Economic Commission for Europe. New York and Geneva. Accessed from https://unece.org/DAM/trade/Publications/ECE_TRADE_398E_PineappleBrochure.pdf).

	Commercial production description Commercial production means a process (system) where activities, such as in-field monitoring, pest control activities, harvesting, cleaning[6], sorting, and grading[7] have been undertaken. These activities are carried out to minimise: a) the presence of regulated pests; b) commodity damage which could expose the commodity to regulated pests. Note: NPPO phytosanitary inspection, certification and documentation form part of general import requirements.
Detailed pathway description	
Purpose	The pathway description defines the markets and methods the commodity will be sourced from and travel to New Zealand. The pathway description may also include commercial-specific pathway requirements.
Pathway description	Commercially produced decrowned fresh pineapple fruit (*Ananas comosus*) for human consumption from Australia, Ecuador, Fiji, New Caledonia, the Philippines, Thailand, Vanuatu, Cook Island, Costa Rica, Indonesia, Malaysia, Papua New Guinea, Panama, Samoa, Sri Lanka, Taiwan and Tonga. The import risk analysis development project covers both sea and air cargo. All risk assessments consider both pathways.

4 IRA methodology

The import risk analysis process has two stages:

1. Hazard identification
2. Pest risk assessment

The risk analysis methodology used by Biosecurity New Zealand is described in more detail in ‘Guidelines for Risk Analysis in Plant Biosecurity1.0’.

4.1 Hazard identification

We define a pest or disease as a hazard when it meets all the following criteria.

- It is not present in New Zealand (or is present but still represents a biosecurity risk, e.g. is capable of vectoring pathogens not present in New Zealand).
- It has the ability to establish and cause harm in New Zealand.
- It is associated with imported risk goods and import pathways.

In the hazard identification (hazard ID) process, we first compile a list of pests and diseases potentially associated with the commodity. We then assess these pests and diseases against specific risk evaluation criteria to determine which potential hazards we should assess further.

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[6] Cleaning will remove all extraneous plant material, debris, and soil. Large mobile pests will also be removed.

[7] Grading will remove damaged produce or visibly infested produce.

For this risk analysis, we decided to further assess any pests that met the following criteria.

a) The pest or disease is associated with fresh pineapple fruit (of any variety and ripeness, excluding overripe[8]), which meets the commodity description; and
b) The pest or disease is present in any of the markets included in the project; and
c) The pest or disease has traits that indicate it may not be adequately managed by the commodity description (including decrowning[9] and commercial production methods[10]); and
d) The pest or disease is able to become established in New Zealand; and/or
e) The pest or disease has the potential to cause significant impacts (sociocultural, economic, environmental, human health).

After we have identified the hazards, we compile two lists.

- Pests and diseases that are associated with the commodity, are present in at least one exporting market and are potentially not managed by compliance with the commodity description: These pests are ones that we assess further. You can read about this in the Pest risk levels section below.

Pests and diseases, including groups (e.g. genera or families) that we did not need to assess further: for the list of these pests, please contact Plant Imports PlantImports@mpi.govt.nz.

4.2 Pest risk assessment

The purpose of pest risk assessment is to determine the level of risk that hazard pests and diseases (identified at the hazard ID stage as needing further assessment) pose to New Zealand.

Pest risk assessment addresses the following:

- Likelihood of entry:
    - The strength or frequency of the association with the host
    - The likelihood of entry given compliance with the commodity description.
- Likelihood of exposure and establishment:
    - The ability of the pest or disease to move from an imported commodity to a host or environment suitable for the completion of development or production of offspring (exposure)
    - The suitability of the New Zealand environment for the pest or disease (including climate, host plants and vectors)
- The potential impacts in New Zealand:
    - Economic impacts: on economically important plants (symptoms on individual plants, crop yield, costs of management practices, trade restrictions, etc.)
    - Environmental impacts: on native plants and ecosystems
    - Human health and sociocultural impacts

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[8] Overripe is equivalent to C4 or greater as per the UNECE Standard on the marketing and commercial quality control of pineapples (https://unece.org/DAM/trade/Publications/ECE_TRADE_398E_PineappleBrochure.pdf).

[9] This analysis does not consider the risk from crown remnants. Any crown remnant will be deemed a non-compliance as per the commodity description.

[10] Commercial production means a process (system) where activities, such as in-field monitoring, pest control activities, harvesting, cleaning, sorting, and grading have been undertaken. These activities are carried out to minimise: a) the presence of regulated pests; b) commodity damage which could expose the commodity to regulated pests.

5 Pest risk levels

Table 5.1 summarises the overall level of risk for each pest that underwent full pest risk assessment (PRA). A more detailed summary including the rationale for allocation of risk levels and reasons for uncertainty is presented in section 6.

Table 5.1: Pest risk levels

Pest/disease group	Species requiring PRAs	Risk	Uncertainty
Bacteria	*Dickeya zeae*	Moderate	Moderate
	Pantoea ananatis	Moderate	Moderate
Fungi	*Fusarium oxysporum*	Negligible	Low
	Fusarium verticillioides	Moderate	High
	Pestalotiopsis microspora	Low	High
	Thielaviopsis paradoxa	Low	High
Insects: Diptera	*Bactrocera dorsalis*	Moderate	Low
Insects: Hemiptera, Diaspididae (armoured scales)	*Diaspis bromeliae*	Negligible	Moderate
Insects: Hemiptera, Pseudococcidae (mealybugs)	*Dysmicoccus brevipes*	Low	Moderate
	Dysmicoccus neobrevipes	Negligible	Moderate
	Ferrisia virgata	Very low	Moderate
	Planococcus minor	Very low	Moderate
	Pseudococcus jackbeardsleyi	Negligible	Moderate
Insects: Lepidotera	*Anatrachyntis rileyi*	Very low	Moderate
Vectors of pathogens	*Planococcus citri*	Not a hazard	
	Pseudococcus longispinus	Not a hazard	

6 Summary of pest risk assessments

Organisms considered for risk assessment by MPI meet the criteria to be a hazard on fresh decrowned *Ananas comosus* (pineapple) fruit for consumption (as per the commodity description and hereinafter pineapple fruit) imported into New Zealand. These criteria are:

- They are not present in New Zealand (or if present but still represents a biosecurity risk, e.g. is capable of vectoring pathogens not present in New Zealand);
- They have the potential to establish and cause harm in New Zealand
- They have the potential to enter New Zealand on pineapple fruit.

The following sections summarise the pest risk assessments described in detail in the annex to this report.

6.1 Bacteria

6.1.1 *Dickeya zeae* (bacterial heart rot/fruit collapse)

***Dickeya zeae* poses an overall MODERATE risk (with MODERATE uncertainty) on pineapple fruit imported to New Zealand.**

- *Dickeya zeae* has a MODERATE likelihood of entering New Zealand on pineapple fruits (LOW uncertainty).

    - *Dickeya zeae* is present in many of the markets in this analysis.
    - It has a strong association with pineapple fruit.
    - It has the potential for latency and asymptomatic traits.
    - It has the potential to remain viable on pineapples during transit.
- *Dickeya zeae* has a MODERATE likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - There is a large quantity of unavoidable waste associated with fresh pineapples.
    - The pathogen has a wide host range and climatic tolerance and persists in varying environmental niches.
    - The pathogen causes systemic infection.
    - Our uncertainty is due to the sparse data on pineapple waste and associated diseases.
- *Dickeya zeae* has a MODERATE likelihood of establishing a population in New Zealand (LOW uncertainty).
    - Hosts are available for the establishment of *Dickeya zeae.*
    - *Dickeya zeae* has the ability to remain latent in the environment.
    - Climate matching evidence suggests countries with comparable temperatures to New Zealand have reported occurrence of the pathogen which indicates climate in New Zealand is not likely to prevent establishment.
- *Dickeya zeae* may cause a MODERATE overall impact on New Zealand (MODERATE uncertainty).
    - The potential economic impact of *D. zeae* on New Zealand is MODERATE (MODERATE uncertainty).
        - *Dickeya zeae* causes significant economic impacts overseas in areas with a similar climate to New Zealand.
        - The host range of *D. zeae* indicates that high-value crops such as tomatoes, onions and potatoes grown for export and used domestically could be affected up to, in the worst case, NZ$860.64 million over 20 years.
        - Our uncertainty is due to the sparse data on the climatic factors involved in disease expression and the impact of climate change in growing regions of New Zealand.
    - The potential environmental impact of *D. zeae* in New Zealand is LOW (HIGH uncertainty).
    - The potential human health impacts of *D. zeae* on New Zealand are NEGLIGIBLE (LOW uncertainty).
    - The potential sociocultural impacts of *D. zeae* on New Zealand are LOW (MODERATE uncertainty).

The following tables contain a summary of risk assessment against the criteria.

Criteria	Rating	Uncertainty
Likelihood of entry on the commodity	MODERATE	LOW
Likelihood of transferring from imported commodity onto a suitable host	MODERATE	MODERATE
Likelihood of establishing a population in New Zealand	MODERATE	LOW

Impacts on New Zealand economy, environment, human health and society	MODERATE	MODERATE
Overall level of assessed risk to New Zealand	MODERATE	MODERATE

Specific considerations summary (see Annex 4.1.4)	
Stage of ripeness at which pest association with pineapple fruit has been observed	C3–C4
Pineapple varieties the pest is associated with	Cultivars Josapine, MD2, PRI 73-114 and Smooth Cayenne
Presence of pest in markets in this IRA	Australia[11], Malaysia, Costa Rica, the Philippines, Indonesia
Parts of the fruit the pest is associated with	Whole fruit (fruit, bract, stem, crown)
Environmental conditions needed to express disease symptoms on pineapple fruit	Pathogen viable between 10 °C and 41 °C, with optimal temperature range specified as 30–35 °C
Different life stages of the pest associated with different parts of the fruit	N/A
Asymptomatic/latent infections on pineapple fruit	Remains latent in plant ovary and increases population two to three weeks before ripening

To full assessment of *Dickeya zeae*

6.1.2 *Pantoea ananatis (fruitlet rot of pineapple)*

***Pantoea ananatis* poses an overall MODERATE risk (with HIGH uncertainty) on pineapple fruit imported to New Zealand.**

- *Pantoea ananatis* has a MODERATE likelihood of entering New Zealand on pineapple fruit (MODERATE uncertainty).
  - *Pantoea ananatis* can cause internal infection in pineapple fruit without externally visible symptoms when the infection is mild to moderate.
  - *Pantoea ananatis* may be found on the surface of pineapple.
  - Destructive sampling is needed to detect symptomatic pineapples.
  - It is likely that *P. ananatis* can survive transit conditions on pineapples because it can grow between 6 °C–45 °C.
  - The prevalence of *P. ananatis* in exporting markets is uncertain.
- *Pantoea ananatis* has a HIGH likelihood of transferring from pineapple fruit to a suitable host/environment in New Zealand (MODERATE uncertainty).
  - Fresh pineapple fruit generate a large quantity of unavoidable waste.
  - The bacterium has a wide host range and climatic tolerance and is persistent in varying environmental niches.
  - *Pantoea ananatis* is likely to transfer from pineapple waste to a suitable environment and remain viable.

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[11] *Dickeya zeae* has been detected in Queensland, Australia, but it is not yet clear how closely related these strains are to other strains of *D. zeae* (IPCC_WGI 2014).

    - *Pantoea ananatis* cultures can survive temperatures between -15 °C and 56 °C, and desiccation. *P. ananatis* grows at 6 °C–45 °C.
    - There are multiple modes of transmission available, including insect vectors present in New Zealand.
    - There is limited data on the viability and spread of the bacterium from infected pineapple fruit.
- *Pantoea ananatis* has a HIGH likelihood of establishing a population in New Zealand (MODERATE uncertainty).
    - Current and future climates are suitable for the bacterium.
    - Plant hosts are widely available in New Zealand.
    - *Pantoea ananatis* can persist in abiotic environments.
    - The bacterium has wide temperature tolerances.
- *Pantoea ananatis* may have a MODERATE overall impact on New Zealand (HIGH uncertainty).
    - The potential economic impact of *P. ananatis* in New Zealand is MODERATE (HIGH uncertainty).
        - Disease outbreaks are sporadic and rare.
        - The environmental factors required for disease outbreaks are not fully understood.
        - The disease is likely to cause yield reduction in onion and maize.
        - The disease has an estimated moderate economic impact over 20 years.
    - The potential environmental impact of *P. ananatis* in New Zealand is VERY LOW (HIGH uncertainty).
    - The potential human health impact of *P. ananatis* in New Zealand is NEGLIGLIBLE (LOW uncertainty).
    - The potential sociocultural impact of *P. ananatis* in New Zealand is VERY LOW (HIGH uncertainty).

The following tables contain a summary of risk assessment against the criteria.

Criteria	**Rating**	**Uncertainty**
Likelihood of entering on the commodity	MODERATE	MODERATE
Likelihood of transferring from the imported commodity onto a suitable host	HIGH	MODERATE
Likelihood of establishing a population in New Zealand	HIGH	MODERATE
Impacts on the New Zealand economy, environment, human health and society	MODERATE	HIGH
Overall level of assessed risk to New Zealand	MODERATE	HIGH

Specific considerations (see Annex 4.2.4)	
Stage of ripeness the pest is associated with	All stages following flowering
Pineapple varieties the pest is associated with	Appears to be associated with all varieties
Presence of pest in markets in this IRA	Australia, Ecuador, the Philippines, Thailand, Costa Rica, Malaysia, Taiwan

Parts of the fruit the pest is associated with	Internal tissues
Environmental conditions (temperature, season, etc.) under which disease symptoms are expressed	Can express symptoms in any season. Infections in pineapple were more pronounced when temperatures were high (21 °C–27 °C)
Asymptomatic/latent infections on pineapple fruit	This bacterium can cause infections that are not externally visible and is found as an epiphyte and endophyte on many plants hosts and environments, likely including pineapple.

To full assessment of *Pantoea ananatis*

6.2 Fungi

6.2.1 *Fusarium oxysporum*

***Fusarium oxysporum* poses an overall NEGLIGIBLE risk (with LOW uncertainty) on pineapples fruit imported to New Zealand.**

- *Fusarium oxysporum* has a HIGH likelihood of entering New Zealand on pineapple fruit (LOW uncertainty).
  - *Fusarium oxysporum* is recorded from all markets in scope of this analysis and is associated with pineapple fruit from Ecuador, Malaysia and Costa Rica.
  - *Fusarium oxysporum* can be associated with pineapple fruit at all developmental stages.
  - *Fusarium oxysporum* sometimes causes internal fruitlet rot or no symptoms, so cannot always be detected in a visual inspection.
- *Fusarium oxysporum* has a HIGH likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
  - Pineapple is a high-waste commodity, and rinds and sometimes cores are removed and discarded.
  - Many strains of *F. oxysporum* can survive and reproduce as saprotrophs on plant debris in the soil, including the initial pineapple waste, and in and around plant roots, so *F. oxysporum* does not usually need a specific plant host to survive.
  - There is moderate uncertainty in this conclusion because assumptions about saprotrophic survival in the soil are based on reviews of the whole species complex and research on other formae speciales, and not on specific information about strains from pineapple.
- *Fusarium oxysporum* strains from imported pineapples have a HIGH likelihood of establishing a population in New Zealand (MODERATE uncertainty).
  - It is likely that *F. oxysporum* strains from pineapples can survive in the absence of particular live host plants as saprotrophs on plant debris in the soil, and the rhizosphere (around plant roots) or through the production of resting spores. As with other *F. oxysporum* strains, some strains from pineapples may be able to colonise other plant hosts, with or without disease symptoms.
  - Many strains of *F. oxysporum* are already present in New Zealand, so the climate is likely to be suitable for some new *F. oxysporum* strains.
  - There is moderate uncertainty in this conclusion because assumptions about saprophytic survival in the soil are based on reviews of the whole species complex and research on other *formae speciales*, and because imported

    pineapples usually originate in tropical areas and the New Zealand climate may not be suitable.

- The potential overall impact of *F. oxyporum* strains from imported pineapple on New Zealand is NEGLIGIBLE (LOW uncertainty). However, the taxonomy of the *F. oxyporum* species complex is currently being revised. We will need to reassess this if we receive new evidence (for example from the Emerging Risks System) of specific named strains or species in the complex that are associated with pineapple and cause disease in hosts that are economically, environmentally or culturally important to New Zealand.
    - The potential economic impact of *F. oxysporum* strains from imported pineapple in New Zealand is NEGLIGIBLE (LOW uncertainty).
        - Pineapple is the only confirmed host of these strains.
        - The New Zealand pineapple industry is currently very small and localised to a single production site in Northland. The likelihood of *F. oxysporum* strains on imported pineapples being exposed to suitable hosts is extremely low.
        - Weather conditions in New Zealand are unlikely to favour symptom development in pineapple plants, even in a changing climate.
        - Even if *F. oxysporum* strains from imported pineapple occasionally cause disease symptoms on other plant hosts in New Zealand, it is unlikely that the impacts will be greater than the impact of *F. oxysporum* strains that are already present.
    - The potential environmental impact of *F. oxysporum* strains from imported pineapple in New Zealand is NEGLIGIBLE (LOW uncertainty).
    - The potential human health impact of *F. oxysporum* strains from imported pineapple in New Zealand is NEGLIGIBLE (LOW uncertainty).
        - The risk of harmful mycotoxins contaminating New Zealand grown pineapples as a result of new *F. oxysporum* strains from imported pineapples is negligible.
        - Opportunistic *F. oxysporum* infections in humans are rare. Many strains of *F. oxysporum* are already present in New Zealand, and the likelihood of infections from new strains causing additional impacts is negligible.
    - The potential sociocultural impact of *F. oxysporum* strains from imported pineapple in New Zealand is NEGLIGIBLE (LOW uncertainty).

The following tables contain a summary of risk assessment against the criteria.

Criteria	Rating	Uncertainty
Likelihood of entering on the commodity	HIGH	LOW
Likelihood of transferring from the imported commodity onto a suitable host	HIGH	MODERATE
Likelihood of establishing a population in New Zealand	HIGH	MODERATE
Impacts on the New Zealand economy, environment, human health and society	NEGLIGIBLE	LOW
Overall level of assessed risk to New Zealand	NEGLIGIBLE	LOW

Specific considerations summary (see Annex 5.1.4)	
Stage of ripeness the pest is associated with	All stages (some strains are systemic in the plant and therefore in the stem/core at the time of flowering, and other strains infect at the time of flowering but remain latent until the fruit begins to ripen)
Pineapple varieties the pest has been recorded on	MD-2, Queen Victoria, Pérola, Moris, Josapine, Gandul, Smooth Cayenne, Spanish
Presence of pest in markets in this IRA	*Fusarium oxysporum* is recorded in all markets in scope: Australia, Cook Islands, Costa Rica, Ecuador, Indonesia, Malaysia, New Caledonia, Panama, Papua New Guinea, The Philippines, Samoa, Sri Lanka, Taiwan, Thailand, Tonga and Vanuatu. *Fusarium oxysporum* has been reported from pineapple fruit from Ecuador, Costa Rica and Malaysia, and there are also records from pineapple from the Philippines with no record of the plant part the fungus was isolated from.
Parts of the fruit the pest associated is with	All parts of the fruit (but may depend on the particular strain)
Environmental conditions (temperature, season, etc.) under which disease symptoms are expressed	Internal fruitlet core rot symptoms were expressed in ripe fruit stored at 19 °C or 25 °C (in two separate studies). However, some strains of *F. oxysporum* never show symptoms in fruit.
Different life stages of the pest associated with different parts of the fruit	Only asexual life-stages of *F. oxysporum* have been reported, but this fungus can reproduce asexually.
Asymptomatic/latent infections on pineapple fruit	*Fusarium oxysporum* strains associated with pineapple plantation dieback disease, a vascular wilt likely to be associated with the core (which is a modified stem), and crown or stem remnants without visible symptoms. These strains would not be detected by visual inspection, although the fruit of infected plants is often undersized. *Fusarium oxysporum* can also cause brown rots of individual fruitlets under the bracts of the pineapple (fruitlet core rot), which do not always show on the surface of the fruit. Internal fruitlet core rot symptoms can be detected if the fruit is cut along an axis that exposes the infected fruitlets. *Fusarium oxysporum* has also been isolated from fruitlets with no symptoms.

To full assessment of *Fusarium oxysporum*

6.2.2 *Fusarium verticillioides*

Fusarium verticillioides **poses an overall MODERATE risk (with HIGH uncertainty) on pineapple fruit imported to New Zealand.**

- *Fusarium verticillioides* has a HIGH likelihood of entering New Zealand on pineapple fruit (LOW uncertainty).
    - *Fusarium verticillioides* is recorded from most markets in this analysis.
    - *Fusarium verticillioides* can be associated with pineapple fruit at all developmental stages.
    - *Fusarium verticillioides* can survive transit conditions.
    - *Fusarium verticillioides* is sometimes associated with internal fruitlet rots.

    - *Fusarium verticillioides* is sometimes asymptomatic in pineapple fruit, so it cannot always be detected in a visual inspection even if fruit is cut in half.
- *Fusarium verticillioides* has a HIGH likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - Pineapple is a high-waste commodity, and rinds and sometimes cores are removed and discarded.
    - If pineapple waste infected with *F. verticillioides* is disposed of in domestic compost or directly into the environment, the fungus could survive on pineapple waste and other plant debris.
    - The fungus can be spread by movement of soil and plant material (including compost) and can colonise/infect host plants via the roots or via asexual spores (microconidia), which are carried by water, insects or wind.
    - However, there is moderate uncertainty in these conclusions, because we do not have data on what proportion of domestic fruit and vegetable waste is discarded into domestic compost or into the environment.
- *Fusarium verticillioides* has a HIGH likelihood of establishing a population in New Zealand (LOW uncertainty).
    - The climate throughout New Zealand is likely to be very suitable for *F. verticillioides*.
    - Suitable hosts of *F. verticillioides* are ubiquitous in New Zealand.
    - *Fusarium verticillioides* can reproduce asexually, so it does not require two different mating types.
    - Competition with *Fusarium* species already present in New Zealand is unlikely to limit establishment of *F. verticillioides*, because these species commonly co-occur in other areas with a similar climate to New Zealand.
- *Fusarium verticillioides* may cause MODERATE overall impact on New Zealand (HIGH uncertainty).
    - The potential economic impact of *F. verticillioides* in New Zealand is MODERATE (MODERATE uncertainty).
        - Ongoing yield losses in maize from ear, stalk and root rots are expected to range from 0–5% depending on growing conditions.
        - A single severe outbreak of *Fusarium* ear rot would cause yield losses of approximately 20% of the maize crop.
        - Symptoms of *F. verticillioides* are rare and sporadic in other plants of economic importance to New Zealand.
        - There is moderate uncertainty in this conclusion because there is limited information available for many non-grain hosts of *F. verticillioides*.
    - The potential environmental impact of *F. verticillioides* in New Zealand is LOW (HIGH uncertainty).
    - The potential human health impact of *F. verticillioides* in New Zealand is LOW (MODERATE uncertainty).
    - The potential sociocultural impact of *F. verticillioides* in New Zealand is LOW (HIGH uncertainty).

The following tables contain a summary of risk assessment against the criteria.

Criteria	Rating	Uncertainty

Likelihood of entering on the commodity	HIGH	MODERATE
Likelihood of transferring from the imported commodity onto a suitable host	HIGH	MODERATE
Likelihood of establishing a population in New Zealand	HIGH	LOW
Impacts on the New Zealand economy, environment, human health and society	MODERATE	HIGH
Overall level of assessed risk to New Zealand	MODERATE	HIGH

Specific considerations summary (see Annex 5.2.4)	
Stage of ripeness the pest is associated with	It is likely that *F. verticillioides* can be associated with pineapple fruit from the earliest stages of development. *Fusarium verticilliodes* was isolated from fruitlets of ripe pineapples of the Queen Victoria cultivar with and without symptoms—the pineapples were harvested when still partially green and ripened in storage (Vignassa et al. 2021), and fruitlet infection usually occurs at an early stage of development before the bracts close (Fournier et al. 2015). *Fusarium verticilliodes* was isolated from symptomatic pineapples at production sites in Malaysia, but the authors do not say what stage the fruit was at when symptoms appeared (Ibrahim et al. 2017).
Pineapple varieties the pest is associated with	In pathogenicity tests on ripe pineapples (Gandul, Josapine and Morris varieties) with *F. verticilliodes* isolates from Malaysia, Josapine showed the most severe rot symptoms (Ibrahim et al. 2017). *Fusarium verticilliodes* was associated with fruit of MD2 variety with rot symptoms (Vilaplana et al. 2018). *Fusarium verticilliodes* was isolated from fruitlets of ripe pineapples of the Queen Victoria cultivar with and without symptoms (Vignassa et al. 2021)
Presence of pest in markets in this IRA	*Fusarium verticillioides* is present in most markets in scope of this analysis (for supporting evidence, see 5.2 in Annex 5.2.5): Indonesia, Malaysia, the Philippines, Sri Lanka[1], Taiwan, Thailand, Australia, Cook Islands[2], Vanuatu[3], Costa Rica, Ecuador and Panama[4].
Parts of the fruit the pest associated is with	*Fusarium verticillioides* has been isolated from fruitlets (i.e. internal flesh) (Vignassa et al. 2021) and cores (Stępień et al. 2013) and was visible on the skin (i.e. bracts) of pineapple fruit with external rot (Vilaplana et al. 2018), but it is a systemic vascular endophyte/pathogen in many other hosts so may also be associated with crown and stem remnants.
Environmental conditions (temperature, season, etc.) under which disease symptoms are expressed	Symptoms of *F. verticillioides* (external or internal rot or fruitlet core rot) are likely to develop faster at higher temperatures (although the fungus can grow slowly at temperatures as low as 5°C). In pathogenicity tests, rot symptoms developed in pineapple fruit in cold storage at 8 °C (Vilaplana et al. 2018). Mild rot symptoms (small brown lesions) were observed in cut fruit of three cultivars (Gandul, Josapine, Moris) two weeks after wound inoculation with *F. verticillioides* in ripe pineapple fruit incubated at 27 ± 1°C with 75%–80% humidity (Ibrahim et al. 2017). Fruitlet core rot symptoms in fruit with early natural infections of *F. verticillioides* developed in fruit stored at 19 °C, although the authors did not confirm that *F. verticillioides* caused symptoms with pathogenicity tests (Vignassa et al. 2021)
Asymptomatic/latent infections on pineapple fruit	*Fusarium verticillioides* was isolated from asymptomatic fruitlets in ripe pineapples, as well as fruitlets with core rot symptoms (brown rot under the bracts) (Vignassa et al. 2021). Internal rot of pineapple caused by

	F. verticillioides was observed during cold storage (Valencia-Chamorro et al. 2021).

[1] The presence in Sri Lanka has high uncertainty. See Table 5.2 in Annex 5.2.5 for more details.
[2] The presence in Cook Islands has high uncertainty. See Table 5.2 in Annex 5.2.5 for more details.
[3] The presence in Vanuatu has moderate uncertainty. See Table 5.2 in Annex 5.2.5 for more details.
[4] The presence in Panama has moderate uncertainty. See Table 5.2 in Annex 5.2.5 for more details.

To full assessment of *Fusarium verticillioides*

6.2.3 *Pestalotiopsis microspora*

***Pestalotiopsis microspora* poses an overall LOW level of risk (with HIGH uncertainty) on pineapple fruit imported to New Zealand.**

- *Pestalotiopsis microspora* has a LOW likelihood of entering New Zealand on pineapple fruit (HIGH uncertainty).
    - *Pestalotiopsis microspora* is associated with pineapple fruit.
    - *Pestalotiopsis microspora* can go undetected in pineapple fruit if symptoms are not yet developed.
    - *Pestalotiopsis microspora* has the potential to remain viable on pineapples during transit.

  However:
    - The association with pineapple fruit is indicated from a single record in a country that is not one of the pineapple-exporting markets in this analysis.
    - It is uncertain whether the fungus is local to this country (such as new strain of the fungus or a vector capable of moving it from the leaves to the fruit) or whether fruit rot is commonly caused by the fungus but was not diagnosed previously.
- *Pestalotiopsis microspora* has a MODERATE likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - The fungus has a wide variety of hosts including some invasive plants.
    - The fungus can survive in the soil and water.
    - Climate is unlikely to limit exposure of *P. microspora*.

  However:
    - *Pestalotiopsis microspora* is unlikely to survive the heat in commercial composts.
    - The requirement for open wounds on host plants limits the opportunities of *P. microspora* to invade uninfected hosts.
- *Pestalotiopsis microspora* has a HIGH likelihood of establishing a population in New Zealand (MODERATE uncertainty).
    - Hosts are widely available for the establishment of *P. microspora*.
    - Climate is unlikely to limit establishment of *P. microspora* because it occurs in countries with similar climate to New Zealand.
    - *Pestalotiopsis microspora* can occur in water and soil.
- *Pestalotiopsis microspora* may cause a LOW overall impact in New Zealand (HIGH uncertainty).
    - The potential economic impact of *P. microspora* in New Zealand is LOW (HIGH uncertainty).
        - Some known hosts of *P. microspora* are economic plants in New Zealand.
        - *Pestalotiopsis microspora* causes disease in hosts such as avocado in the tropics.

However:
  - We found no evidence of *P. microspora* disease expression under suitable fruit storage temperature conditions,
  - The diversity of *P. microspora* strains may determine severity of impact.
- The potential environmental impact of *P. microspora* in New Zealand is VERY LOW (HIGH uncertainty).
  - Some of the fungus' host genera (e.g. *Podocarpus*) are present in New Zealand.

  However:
  - *Pestalotiopsis microspora* mostly occurs as an endophyte in the majority of its podocarp hosts, and, in very rare cases, it may cause mild leaf diseases on such hosts.
- The potential human health impact of *P. microspora* in New Zealand is NEGLIGIBLE (HIGH uncertainty).
- The potential sociocultural impact of *P. microspora* in New Zealand is VERY LOW (HIGH uncertainty).

The following tables contain a summary of risk assessment against the criteria.

Criteria	Rating	Uncertainty
Likelihood of entering on the commodity	LOW	HIGH
Likelihood of transferring from the imported commodity onto a suitable host	MODERATE	MODERATE
Likelihood of establishing a population in New Zealand	HIGH	MODERATE
Impacts on the New Zealand economy, environment, human health and society	LOW	HIGH
Overall level of assessed risk to New Zealand	LOW	HIGH

Specific considerations summary (see Annex 5.3.4)	
Stage of ripeness the pest is associated with	The fungus is known to infect mature pineapple fruit, but it is not clear if immature fruit can also be infected.
Pineapple varieties the pest is associated with	The fungus is known to infect the Smooth Cayenne variety. It is also known to infect pineapple leaves, but those varieties were not specified, and it is not clear if their fruit can also be infected.
Presence of pest in markets in this IRA	The fungus has been reported from Australia, Costa Rica, Ecuador, Indonesia, Malaysia, Papua New Guinea, Sri Lanka, and Thailand.
Parts of the fruit the pest is associated with	The fungus causes obvious dark-coloured necrotic lesions, which continually expand around the bracts from the sites of infection on the fruit.
Environmental conditions (temperature, season, etc.) under which disease symptoms are expressed	Cultures of the fungus and infections on pineapple fruit developed well at 25 °C. The fungus also thrives in high humidity at room temperature.

Different life stages of the pest associated with different parts of the fruit	No information
Asymptomatic/latent infections on pineapple fruits	We found no evidence that the fungus exhibits latent or asymptomatic infection in pineapples. However, infection only occurs in wounded fruit, and it might take up to eight days for the pathogen to express symptoms.

To full assessment of *Pestalotiopsis microspora*

6.2.4 *Thielaviopsis paradoxa*

***Thielaviopsis paradoxa* poses an overall LOW level of risk, with HIGH uncertainty, on pineapple fruit imported to New Zealand.**

- *Thielaviopsis paradoxa* has a MODERATE likelihood of entering New Zealand on pineapple fruit (MODERATE uncertainty).
    - Although fruits are unlikely to be only taken from areas of production with visible infections, the fungus can latently infect unripe fruit, and disease symptoms become obvious during ripening.
    - Severely infected fruit is likely to be discarded during the harvest and pre-exporting processes.
    - Transit conditions to New Zealand are not likely to support active growth and spread of *T. paradoxa*, but the fungus can resume growth once returned to ambient temperatures.
- *Thielaviopsis paradoxa* has a HIGH likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - Severely infected fruit is likely to be discarded into landfills or composts,
    - *Thielaviopsis paradoxa* produces chlamydospores (resting spores), which are known to remain viable for up to 10 years in soil and can survive on rotting plant debris, suggesting the fungus can survive in residential composts and in waste disposed of as animal feed,
    - Asexual conidia can be spread by rain splash, used tools, rodents and insects.
    - While fruit with early or mild infection is likely to be consumed, discarded skin can also be infected.
- *Thielaviopsis paradoxa* has a HIGH likelihood of establishing a population in New Zealand (MODERATE uncertainty).
    - *Thielaviopsis paradoxa*'s optimum growing temperature is 21–22°C. The fungus cannot survive temperatures above 52.3°C and becomes inactive below 10°C.
    - Winter temperatures in areas where hosts are grown are likely too low for the fungus to actively grow. However, the fungus can resume growth when temperatures are optimal and can survive for up to 10 years in soil.
    - Preferred horticultural hosts that are severely affected by the fungus are mostly tropical and not widely cultivated in New Zealand. Other hosts, such as *Eucalyptus* and ornamental palms, are widespread.
    - There are uncertainties around the impact of climate change in New Zealand.
- *Thielaviopsis paradoxa* may have a LOW overall impact on New Zealand (MODERATE uncertainty).
    - The potential economic impact of *Thielaviopsis paradoxa* in New Zealand is LOW (HIGH uncertainty).

        - Some hosts of *T. paradoxa* are widely cultivated and economically significant to New Zealand with a total annual export and import value of more than NZ$1 billion.
        - However, no report was found on yield loss caused by *T. paradoxa* on any host plants important to New Zealand.
    - The potential environmental impact of *Thielaviopsis paradoxa* in New Zealand is VERY LOW (MODERATE uncertainty).
    - The potential human health impact of *Thielaviopsis paradoxa* in New Zealand is NEGLIGIBLE (LOW uncertainty).
    - The potential sociocultural impact of *Thielaviopsis paradoxa* in New Zealand is VERY LOW (MODERATE uncertainty).

The following tables contain a summary of risk assessment against the criteria.

Criteria	Rating	Uncertainty
Likelihood of entering on the commodity	MODERATE	MODERATE
Likelihood of transferring from the imported commodity onto a suitable host	HIGH	MODERATE
Likelihood of establishing a population in New Zealand	HIGH	MODERATE
Impacts on the New Zealand economy, environment, human health and society	LOW	MODERATE
Overall level of assessed risk to New Zealand	LOW	HIGH

Specific considerations summary (see Annex 5.4.4)	
Stage of ripeness the pest is associated with	No information
Pineapple varieties the pest is associated with	Md2, Mauritius, Gold Honey, Perola
Presence of pest in markets in this IRA	Tonga, Sri Lanka, Fiji, Indonesia, Malaysia, New Caledonia, Taiwan, Thailand, Vanuatu, Australia, Cook Islands, Costa Rica, Papua New Guinea, The Philippines, Panama
Parts of the fruit the pest associated is with	Can infect all parts of the pineapple fruit and plant
Environmental conditions (temperature, season, etc.) under which disease symptoms are expressed	No information
Different life stages of the pest associated with different parts of the fruit	No information
Asymptomatic/latent infections on pineapple fruit	It can be present on the crown, stem end, perianth of spike region and bracts of pineapple fruit without causing symptoms. *T. paradoxa* can remain latent on the bracts of pineapples and become active causing disease during the ripening process.

To full assessment of *Thielaviopsis paradoxa*

6.3 Insects: Diptera

6.3.1 *Bactrocera dorsalis (Oriental fruit fly)*

***Bactrocera dorsalis* poses an overall MODERATE risk (with LOW uncertainty) on pineapple fruit imported to New Zealand.**

- *Bactrocera dorsalis* has a VERY LOW likelihood of entering New Zealand on pineapple fruit (LOW uncertainty).
    - *Bactrocera dorsalis* is very unlikely to be associated with pineapple fruit.
    - However, *B. dorsalis* is present in seven pineapple-exporting markets in this analysis.
    - Infestation symptoms may not be visible unless the fruit is cut in half and may not be visible even when the fruit is cut.
    - *Bactrocera dorsalis* is likely to survive transit.
    - *Bactrocera dorsalis* shows resistance to infield insecticide usage.
- *Bactrocera dorsalis* has a HIGH likelihood of transferring from pineapple fruit to a suitable host in New Zealand (LOW uncertainty).
    - *Bactrocera dorsalis* can survive and develop on the abundant waste of pineapple fruit, some of which will be disposed of using high-risk methods.
    - *Bactrocera dorsalis* has a very broad host range, and many plant host species are present in New Zealand.
    - *Bactrocera dorsalis* adults can fly long distances.
    - *Bactrocera dorsalis* adults have relatively long lifespans.
- *Bactrocera dorsalis* has a MODERATE likelihood of establishing a population in New Zealand (LOW uncertainty).
    - *Bactrocera dorsalis* is a highly invasive species.
    - *Bactrocera dorsalis* has a very broad host range.
    - Adult *B. dorsalis* can cover long distances in flight.
    - *Bactrocera dorsalis* has a high reproductive rate.
    - *Bactrocera dorsalis* has multiple overlapping generations.
    - *Bactrocera dorsalis* uses pheromones to find mates.
    - However, only some parts of New Zealand’s North Island (Northland, Auckland, the Coromandel Peninsula, northern Waikato and in coastal areas south to Cape Turnagain and Foxton) have a suitable climate for the establishment of *B. dorsalis.*
    - The New Zealand National Fruit Fly Surveillance Programme is likely to detect and eradicate incipient populations of *B. dorsalis.*
- *Bactrocera dorsalis* may cause HIGH overall impact on New Zealand (LOW uncertainty).
    - The potential economic impact of *B. dorsalis* in New Zealand is HIGH (LOW uncertainty).
        - *Bactrocera dorsalis* is a devastating pest of a wide variety of fruits and vegetables throughout its range, and 20–50% of commercially farmed crops can be damaged.
        - In New Zealand (2019), 80% of the horticultural export value (NZ$3.7 billion in 2020) comes from plants that are potential fruit fly hosts.

    - *Bactrocera dorsalis* is likely to cause impacts on many plants of major economic importance in New Zealand, especially on the apple, citrus, and avocado industries, but also on the kiwifruit industry.
    - Independent of direct damage, an incursion of *B. dorsalis* could have high impacts on exports, including market access.
    - The cost of a biosecurity response to eradicate *B. dorsalis* would be high.
    - If *B. dorsalis* becomes established in New Zealand, additional postharvest disinfestation would be necessary, at significant cost.
  - The potential environmental impact of *B. dorsalis* in New Zealand is LOW (MODERATE uncertainty).
    - *Bactrocera dorsalis* hosts include plant genera with native New Zealand plant species. However, the impact of *B. dorsalis* on these fruiting plants is likely to be limited.
    - Using insecticides to control invasive *B. dorsalis* populations could have impacts on the environment.
    - The main source of uncertainty is the infestation levels that *B. dorsalis* could achieve among New Zealand native plants and in the New Zealand climate and how much impact on the host plant population dynamics it might have.
  - The potential human health impact of *B. dorsalis* in New Zealand is VERY LOW (MODERATE uncertainty).
    - Using insecticides to control invasive *B. dorsalis* populations could have impacts on human health.
    - Consuming infested fruit could cause gastrointestinal diseases.
    - The main source of uncertainty is the infestation levels that *B. dorsalis* could achieve, the degree and type of insecticide usage, and the frequency of local fruit consumption.
  - The potential sociocultural impact of *B. dorsalis* in New Zealand is LOW (MODERATE uncertainty).
    - *Bactrocera dorsalis* is damaging to a number of plants grown in domestic gardens and parks.
    - The main source of uncertainty is that we were unable to find any studies estimating the sociocultural impacts of the potential infestation of fruit flies on taonga plant species.

The following tables contain a summary of risk assessment against the criteria.

Criteria	**Rating**	**Uncertainty**
Likelihood of entering on the commodity	VERY LOW	LOW
Likelihood of transferring from the imported commodity onto a suitable host	HIGH	LOW
Likelihood of establishing a population in New Zealand	MODERATE	LOW
Impacts on the New Zealand economy, environment, human health and society	HIGH	LOW
Overall level of assessed risk to New Zealand	MODERATE	LOW

Specific considerations summary (see Annex 6.1.4)	
Stage of ripeness the pest is associated with	In the field: overripe (C4)

	In the laboratory: half ripe, ¾ ripe (interpreted as pre-C4)
Pineapple varieties the pest is associated with	In the field: (Queen) Victoria (and potentially, other varieties) In the laboratory: different varieties, including Smooth Cayenne
Presence of pest in markets in this IRA	*Bactrocera dorsalis* is present in pineapple-exporting markets in this IRA: Indonesia, Malaysia, The Philippines, Sri Lanka, Taiwan, Thailand, Papua New Guinea, and is transient and under eradication in Australia (Queensland, Torres Strait).
Parts of the fruit the pest associated is with	Fruit flesh, skin (shell), surface
Environmental conditions under which infestation was observed	In the field: *Bactrocera dorsalis* could have (exceptionally) exploited pineapple as a host as a result of competition with other fruit flies. In the laboratory: screen cage tests on whole, intact fruits
Different life stages of the pest associated with different parts of the fruit	Eggs and maggots (three larval stages)
Symptoms not easily visible	Oviposition puncture marks may not be visible. Eggs and maggots might not be visible even cutting the fruit.

To full assessment of *Bactrocera dorsalis*

6.4 Insects: Hemiptera, Diaspididae (armoured scale insects)

6.4.1 *Diaspis bromeliae (pineapple scale)*

***Diaspis bromeliae* poses an overall NEGLIGIBLE level of risk (with MODERATE uncertainty) on pineapple fruit imported to New Zealand.**

- *Diaspis bromeliae* has a MODERATE likelihood of entering New Zealand on pineapple fruit (LOW uncertainty).
    - It can be associated with pineapple fruit.
    - Some life stages are likely to survive in-field and packhouse activities.
    - Eggs and immature stages can be undetected due to the uneven and rough surface of the fruit and could hide under bracts without obvious visible symptoms.
    - In the last 20 years there have been interceptions of live female adults of *D. bromeliae* at the New Zealand border on pineapples coming from the Philippines, Ecuador and Fiji via sea cargo and Fiji via air cargo, suggesting that this species can survive transit.
- *Diaspis bromeliae* has a VERY LOW likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - *Diaspis bromeliae* may survive and develop on the surface of pineapple fruit, either whole pineapples or skin pieces.
    - Most pineapple waste is likely to be disposed of using methods that are low risk, for example, in bagged waste to landfill, or by commercial composting, worm farming or home composting in contained bins.

  - Pineapple skin that is used for animal feed or open composting could expose *D. bromeliae* first-instar nymphs to the environment.
  - The main dispersal stage is the first-instar nymph (crawler).
  - Crawlers are flightless and can move short distances actively or long distances passively.
  - Crawlers are highly vulnerable to biotic and abiotic factors such as temperature, humidity and natural enemies.
  - Crawlers that are wind or animal dispersed are unable to actively choose to land on a suitable host plant.
  - *Diaspis bromeliae* has a relatively limited range of host plants that are readily available throughout New Zealand.
- *Diaspis bromeliae* has a VERY LOW likelihood of establishing a population in New Zealand (MODERATE uncertainty).
  - Although *Diaspis bromeliae* has established populations in countries with climates similar to some parts of New Zealand, it is generally found in the tropics and subtropic. In temperate climates, it is found only in greenhouses.
  - The mode of reproduction is sexual. This may be a significant barrier for establishment because it requires at least one adult of each sex or a mated female to establish a population.
  - The dispersal capability of crawlers is limited, and they are susceptible to abiotic and biotic factors.
  - *Diaspis bromeliae* has a limited range of host plants that are readily available throughout New Zealand.

The following tables contain a summary of risk assessment against the criteria.

Criteria	**Rating**	**Uncertainty**
The likelihood of entering on the commodity	MODERATE	LOW
The likelihood of transferring from the imported commodity onto a suitable host	VERY LOW	MODERATE
The likelihood of establishing a population in New Zealand	VERY LOW	MODERATE
Impacts on the New Zealand economy, environment, human health and society	N/A*	N/A*
Overall level of assessed risk to New Zealand	NEGLIGIBLE	MODERATE

* Given that the combined likelihood of entry, exposure and establishment is negligible, according to the 'Guidelines for Risk Analysis in Plant Biosecurity 1.0', we did not need to conduct further assessment on impacts.

Specific considerations summary (see Annex 7.1.4)	
Stage of ripeness the pest is associated with	No information—reported as "affecting pineapple mature fruit" in Australia in circumstances of high field infestations
Pineapple varieties the pest is associated with	No information—affects both smooth and rough varieties in Australia
Presence of pest in markets in the this IRA	Philippines, Taiwan, Indonesia, Malaysia, Australia, Costa Rica Cook Islands, Fiji, Western Samoa, New Caledonia

Parts of the fruit the pest associated is with (e.g. fruit, bract, stem, crown remnant)	The pest is associated with all parts of the fruit.
Different life stages of the pest associated with different parts of the fruit	All life stages can be associated with different parts of the fruit.
Symptoms not easily visible	*Diaspis bromeliae* eggs and immature stages can be undetected due to the uneven and rough surface of the fruit and could hide under bracts without obvious visible symptoms.

To full assessment of *Diaspis bromeliae*

6.5 Insects: Hemiptera, Pseudococcidae (mealybugs)

6.5.1 *Dysmicoccus brevipes (pink pineapple mealybug)*

***Dysmicoccus brevipes* poses an overall LOW risk (with MODERATE uncertainty) on pineapple fruit imported to New Zealand.**

- *Dysmicoccus brevipes* has a MODERATE likelihood of entering New Zealand on pineapple fruits (LOW uncertainty).
    - *Dysmicoccus brevipes* is present in every market in this analysis.
    - *Dysmicoccus brevipes* is widely associated with pineapple plants and has been reported on pineapple fruit.
    - *Dysmicoccus brevipes* is commonly detected on imported pineapple fruit nationally and internationally.
    - *Dysmicoccus brevipes* can remain viable through sea and air cargo freight transit times and conditions.
    - Insecticides may not control *D. brevipes* on pineapples.
- *Dysmicoccus brevipes* has a LOW likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - Disposing of organic waste into landfill is unlikely to be a *D. brevipes* exposure risk.
    - Commercial composting and worm farming are also unlikely to be a *D. brevipes* exposure risk.
    - Domestic composting is likely to be a *D. brevipes* exposure risk.
    - Disposing of fruit waste as animal feed is also likely to be a *D. brevipes* exposure risk.
    - The uncertainty about the likelihood of exposure of *D. brevipes* to suitable environment in New Zealand is due to the different ways in which organic waste is disposed of and how these methods may inhibit or facilitate *D. brevipes* exposure.
- *Dysmicoccus brevipes* has a LOW likelihood of establishing a population in New Zealand (MODERATE uncertainty).
    - *Dysmicoccus brevipes* feeds on a wide range of plants (highly polyphagous) and feeds on all plant parts. Its hosts are present, diverse and widespread in New Zealand.
    - *Dysmicoccus brevipes* has both asexual and sexual forms.
    - Climate is likely to act as a barrier to establishment in most parts of New Zealand, with the exception of the northern North Island.

- *Dysmicoccus brevipes* may cause LOW overall impact on New Zealand (MODERATE uncertainty).
    - The potential economic impact of *D. brevipes* in New Zealand is VERY LOW (MODERATE uncertainty).
    - The uncertainty is around whether *D. brevipes* would cause similar levels of grape-crop damage to that experienced in Brazil.
    - The potential environmental impact of *D. brevipes* in New Zealand is VERY LOW (MODERATE uncertainty).
    - The potential human health impact of *D. brevipes* in New Zealand is NEGLIBLE (LOW uncertainty).
    - The potential sociocultural impact of *D. brevipes* in New Zealand is LOW (MODERATE uncertainty).
    - The uncertainty around potential sociocultural impacts is due to a lack of information about direct impacts of *D. brevipes* infestation on kūmara and taro.

The following tables contain a summary of risk assessment against the criteria.

Criteria	Rating	Uncertainty
Likelihood of entering on the commodity	MODERATE	LOW
Likelihood of transferring from the imported commodity onto a suitable host	LOW	MODERATE
Likelihood of establishing a population in New Zealand	LOW	MODERATE
Impacts on the New Zealand economy, environment, human health and society	LOW	MODERATE
Overall level of assessed risk to New Zealand	LOW*	MODERATE

* Based on the risk assessment, the overall risk of *D. brevipes* can be at the high end of very low according to the 'Guideline for Risk Analysis in Plant Biosecurity 1.0'. However, given that *D. brevipes* has a very wide range of hosts, wide geographical distribution (including some areas with similar climate to New Zealand) and can be reproduce asexually, MPI considers that a low overall risk is more appropriate.

Specific considerations summary (see Annex 8.1.4)	
Stage of ripeness the pest is associated with	N/A
Pineapple varieties the pest is associated with	N/A
Presence of pest in markets in this IRA	Australia (NSW, NT, QLD, WA), Cook Islands, Costa Rica, Ecuador, Fiji, Indonesia, New Caledonia, Malaysia, Panama, Papua New Guinea, Philippines, Samoa, Sri Lanka, Taiwan, Thailand, Tonga, Vanuatu
Parts of the fruit the pest associated is	All
Different life stages of the pest associated with different parts of the fruit	All
Signs/damage not easily visible	Given the biology of mealybugs in general, notably their small size, *D. brevipes* can likely hide under pineapple bracts.

To full assessment of *Dysmicoccus brevipes*

6.5.2 *Dysmicoccus neobrevipes* (grey pineapple mealybug)

***Dysmicoccus neobrevipes* poses an overall NEGLIGIBLE risk (with MODERATE uncertainty) on pineapple fruit imported to New Zealand.**

- *Dysmicoccus neobrevipes* has a MODERATE likelihood of entering New Zealand on pineapple fruit (LOW uncertainty).
    - Pineapple is one of the main hosts of *D. neobrevipes*, and all life stages of the mealybug are associated with the fruit.
    - However, some in-field management is likely in commercial production because *D. neobrevipe*s is a vector of pineapple mealybug wilt disease.
    - Post-harvest processes are not likely to remove all mealybugs from infested fruit due to their small size, tendency to hide and occurrence inside blossom cups on fruit.
    - *Dysmicoccus neobrevipes* adults and immatures can survive freight transit times and conditions.
- *Dysmicoccus neobrevipes* has a LOW likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - Fresh pineapples produce large amounts of unavoidable waste as skins and whole fruit, most of which is disposed of using methods that pose a low risk of transfer to a new host.
    - However, some waste is disposed of by methods that pose a higher risk of transfer to a new host, including composting in gardens and use as animal feed.
    - *Dysmicoccus neobrevipes* can survive and develop on the surface of fruit waste (whole pineapples or skin pieces).
    - Crawlers, which are the main dispersal stage and flightless, can move short distances actively and longer distances passively.
    - Crawlers that are wind or animal dispersed are unable to actively choose to land on a suitable host plant and depend on landing on or very close to a host plant.
    - *Dysmicoccus neobrevipes* is polyphagous, and known hosts grow in New Zealand as commercial crops, in domestic gardens and as weeds.
    - Although there is general data on food waste in New Zealand, there is no specific data on pineapple waste to inform the likelihood of exposure for *D. neobrevipes*. However, we assume pineapple waste will be a very small part of total food waste.
- *Dysmicoccus neobrevipes* has a VERY LOW likelihood of establishing a population in New Zealand (MODERATE uncertainty).
    - *Dysmicoccus neobrevipes* is polyphagous, and hosts are available in the parts of New Zealand most climatically suited for establishment.
    - *Dysmicoccus neobrevipes*, which reproduces sexually, uses sex pheromones to attract males, which increases the likelihood of finding a mate.
    - *Dysmicoccus neobrevipes* has moderate to high fecundity. Individuals produce around 350 to 1,000 live young.
    - First-instar crawlers are the main dispersal stage and can move actively for short distances to reach new feeding sites and passively for longer distances by wind, on animals and movement of infested plant material and produce.

    - Climate may limit the establishment of *D. neobrevipes* in most of New Zealand but may not be a limiting factor for the mealybug to establish in locations in the warmer northern region of the North Island and in sheltered environments.
- *Dysmicoccus neobrevipes* may cause a VERY LOW overall impact on New Zealand (MODERATE uncertainty).
    - The potential economic impact of *D. neobrevipes* in New Zealand is VERY LOW (MODERATE uncertainty).
        - *Dysmicoccus neobrevipes* is polyphagous, and cultivated plants of importance in New Zealand are known hosts. There could be increased production costs for some crops and increased phytosanitary requirements for some that are exported. However, we found no information on damage or economic impacts for these crops elsewhere.
        - Climate is likely to limit the establishment of *D. neobrevipes* to warmer northern regions of the North Island and sheltered environments. The mealybug is likely to have difficulty reaching numbers that have a high impact on crop production.
    - The potential environmental impact of *D. neobrevipes* in New Zealand is VERY LOW (MODERATE uncertainty).
        - *Dysmicoccus neobrevipes* has a wide host range across many plant families which means there is potential for some New Zealand native plant species to be hosts. However, there is no specific information on which native New Zealand plant species could act as hosts and there is no evidence that *D. neobrevipes* is likely to have unwanted impacts on any native species.
        - *Dysmicoccus neobrevipes* is likely to have a very limited distribution due to climatic factors.
    - The potential human health impact of *D. neobrevipes* in New Zealand is NEGLIGIBLE (LOW uncertainty).
    - The potential sociocultural impact of *D. neobrevipes* in New Zealand is VERY LOW (MODERATE uncertainty).
        - *Dysmicoccus neobrevipes* is polyphagous, and some of its known hosts are grown as garden and amenity plants in New Zealand.
        - Given the wide host range across many plant families, there is potential for some New Zealand species to be hosts, but there is no evidence that *D. neobrevipes* is likely to have unwanted impacts on any culturally significant species.
        - *Dysmicoccus neobrevipes* is likely to have a very limited distribution due to climatic factors.

The following tables contain a summary of risk assessment against the criteria.

Criteria	**Rating**	**Uncertainty**
Likelihood of entering on the commodity	MODERATE	LOW
Likelihood of transferring from the imported commodity onto a suitable host	LOW	MODERATE
Likelihood of establishing a population in New Zealand	VERY LOW	MODERATE

Impacts on the New Zealand economy, environment, human health and society	VERY LOW	MODERATE
Overall level of assessed risk to New Zealand	NEGLIGIBLE	MODERATE

Specific considerations summary (see Annex 8.2.4)	
Stage of ripeness the pest is associated with	Any stage
Pineapple varieties the pest is associated with	The pineapple variety is generally not specified, although Baili and Smooth Cayenne are recorded. *Dysmicoccus neobrevipes* is likely to be associated with all pineapple varieties.
Presence of pest in markets in the scope of this IRA	Indonesia, Malaysia, Philippines, Sri Lanka, Thailand, Taiwan, Costa Rica, Panama, Cook Islands, Fiji, New Caledonia, Samoa, Ecuador
Parts of the fruit the pest associated is with (e.g. fruit, bract, stem, crown remnant)	*Dysmicoccus neobrevipes* is likely to be associated with any structure on the fruit surface, including bracts, and blossom cups.
Different life stages of the pest associated with different parts of the fruit	All life stages (first instars to adults) can be associated with the fruit surface. Immature and mature mealybugs can feed inside closed blossom cups.
Symptoms not easily visible	Although *D. neobrevipes* feeds on plant surfaces, it tends to hide in protected parts of the pineapple surface, including bracts, reducing the likelihood of visual detection. All life stages can occur inside closed blossom cups and go undetected by visual inspection, unless the fruit is cut open.

To full assessment of *Dysmicoccus neobrevipes*

6.5.3 *Ferrisia virgata* (striped mealybug)

***Ferrisia virgata* poses an overall very VERY LOW risk (with MODERATE uncertainty) on pineapple fruit imported to New Zealand.**

- *Ferrisia virgata* has a LOW likelihood of entering New Zealand on pineapple fruit (with MODERATE uncertainty) for the following reasons.
    - Pineapple is a host of *F. virgata*, and live *F. virgata* nymphs and adults have been intercepted twice on fresh pineapples at the New Zealand border.
    - Nymphs, pupae and female adults can be associated with decrowned fruit at the time of harvest, while eggs may only be present on leaves.
    - We found no information to suggest that pineapple cultivar or ripeness affects the association of *F. virgata* with pineapple fruit.
    - In general, infestation of *F. virgata* is likely to be visible, but at low population levels, nymphs (especially crawlers) and adult females may not always be detected during routine post-harvest activities due to their small size and tendency to hide.
    - Nymphs (except crawlers) and adult females may remain attached to fruit during general washing due to their wax-covered body, secure attachment to the fruit surface and tendency to hide.
    - Nymphs, pupae and adult females can survive shipping to New Zealand.

    - Uncertainty: no information found indicates the temperature threshold for *F. virgata* and no literature found on describing the biological association with pineapple fruit.
- *Ferrisia virgata* has a LOW likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - *Ferrisia virgata* may survive on pineapple waste, but it may not be able to successfully find a suitable host if it arrives in New Zealand in the cold season.
    - Fresh pineapples produce large amounts of unavoidable waste. However, most is likely to be disposed of as bagged waste to landfill or into in-sink disposal units. These methods are unlikely to result in successful exposure.
    - Commercial composting is unlikely to result in successful exposure since mealybugs will not survive the process.
    - Direct disposing of pineapple waste into the environment may result in successful exposure, but only a very small amount of infested imported material is likely to be disposed of by this method.
    - Home composting in gardens and use as animal feed could increase the likelihood of successful exposure, since suitable host plants are very likely to be available.
    - The reproductive characteristics of *F. virgata* are likely to aid its exposure to a suitable host.
    - However, the likelihood of the mealybugs locating a suitable host is low, because most life stages have limited mobility (apart from crawlers), and passive movement by wind or transport by other animals cannot guarantee the mealybug will locate a suitable host.
    - Uncertainty: we have no information from New Zealand specific to pineapple waste, on the cold tolerance of *F. virgata*, or on the development of *F. virgata* on pineapple fruit.
- *Ferrisia virgata* has a LOW likelihood of establishing a population in New Zealand (MODERATE uncertainty).
    - *Ferrisia virgata* has moderate to high fecundity.
    - Although most studies report that it can only reproduce sexually, asexual reproduction has also been reported.
    - Females produce pheromones to attract males, which increases the likelihood of finding a mate, increasing its likelihood of establishment.
    - *Ferrisia virgata* is highly polyphagous, and acceptable hosts are widely available in nature and modified environments in New Zealand.
    - Climate conditions do not favour establishment throughout New Zealand, but it is likely that summer populations in the field (at least, in the northern North Island) or permanent populations in protected environments (such as greenhouses and glasshouses) could survive.
    - Uncertainty: most uncertainty is related to the correct identification of *F. virgata*. Records of *F. virgata* before 2012 documenting its distribution and host range may be incorrect and need to be verified. There are no reports specific to the lower temperature thresholds of this mealybug. The information on its overwintering behaviours and reproduction mode is inconsistent.
- *Ferrisia virgata* may cause LOW overall impacts in New Zealand (MODERATE uncertainty).
    - *Ferrisia virgata* can potentially affect many cultivated plants of economic importance to New Zealand (such as citrus, tomato and grapevine), but the mild temperate climate in New Zealand is likely to limit the impact.

  - Controlling *F. virgata* could increase production costs for a number of crops, but the impact is likely to be limited, as current mealybug control programmes in New Zealand are likely to help control *F. virgata* populations.
  - The impact of *F. virgata* on market access overseas is unlikely to be high, because it is present in the markets of most of New Zealand's trading partners, e.g. China, Australia and the USA.
  - *Ferrisia virgata* may attack native species, but given that most areas in New Zealand are not climatically suitable for this mealybug species, the environmental impact is unlikely to be high.
  - Kūmara (sweet potato) and taro have been reported as hosts of *F. virgata*. These plants have cultural importance to Māori and Pasifika communities (however, no significant impacts on their crops have been reported in association with *F. virgata*).
  - Climate change may affect habitat suitability and provide *F. virgata* with the potential to spread and become established further south. This may also increase its impacts in New Zealand, and the unknowns around climate change increase our uncertainty about the risk of this mealybug.

The following tables contain a summary of risk assessment against the criteria.

Criteria	**Rating**	**Uncertainty**
Likelihood of entering on the commodity	LOW	MODERATE
Likelihood of transferring from the imported commodity onto a suitable host	LOW	MODERATE
Likelihood of establishing a population in New Zealand	LOW	MODERATE
Impacts on the New Zealand economy, environment, human health and society	LOW	MODERATE
Overall level of assessed risk to New Zealand	VERY LOW	MODERATE

Specific considerations summary (see Annex 8.3.4)	
Stage of ripeness the pest is associated with	No information
Pineapple varieties the pest is associated with	No information
Presence of pest in markets in this IRA	*Ferrisia virgata* has been reported from all markets in this IRA.
Parts of the fruit the pest associated is with	*Ferrisia virgata* is likely to be associated with every structure on the surface of pineapple fruit.
Different life stages of the pest associated with different parts of the fruit	Except eggs, which may only be present on leaves, and adult males, which are likely to be removed by commercial production process, all other life stages of *F. virgata* theoretically can be associated with pineapple fruit.
Signs/damage not easily visible	Like most other mealybugs, *F. virgata* lives on the plant surface and feeds by inserting its mouthparts into the plant phloem. It may hide in protected parts of the pineapple surface, including bracts, reducing

	the likelihood of visual detection. There is no evidence that *F. virgata* burrows into the plant as a borer.

To full assessment of *Ferrisia virgata*

6.5.4 *Planococcus minor* (Pacific mealybug)

***Planococcus minor* poses an overall VERY LOW level of risk (with MODERATE uncertainty) on pineapple fruit imported to New Zealand.**

- *Planococcus minor* has a LOW likelihood of entering New Zealand on pineapple fruit (MODERATE uncertainty).
    - We found no information indicating that *P. minor* is strongly associated with the commodity, suggesting pineapple is not a preferred plant host.
    - There have been just two interceptions at the New Zealand border on pineapples since 2000. However, it is uncertain if the low interception records are a result of existing control measures reducing the risk of entry of *P. minor* or a result of weak association with pineapple fruits.
    - Eggs and first-instar mealybugs (crawlers) in general are inconspicuous life stages that could go unnoticed in packhouses and survive commercial cleaning and insecticides.
    - The cold tolerance and overwintering mechanisms of *P. minor* are unknown, but interception records at the New Zealand border on pineapples suggest that adults can survive transit conditions on pineapple.
    - The viability of *P. minor* eggs will likely be negatively affected during sea freight coming from Asia or America, but eggs are likely to survive if coming from Australia or if transported via air freight.
- *Planococcus minor* has a VERY LOW likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - Pineapple skin that is bagged and sent to the landfill, commercial composting, worm farming and home composting in plastic bins are low-risk methods of waste disposal.
    - Pineapple skin that is sent for animal feed or open composting could potentially expose the crawlers to the environment, because *P. minor* is a polyphagous species, and many of its recorded hosts are present in New Zealand.
    - The ability of *P. minor* to find a suitable host is limited because crawlers can only walk and search over short distances and are flightless. To be transported over long distances by passive wind dispersal, a combination of conditions needs to occur (i.e., right wind speed, angle position on the host, host location and survival to predation and environmental conditions).
    - We found no specific information on the behaviour of *P. minor* crawlers. This assessment is based on information about other mealybugs.
    - Our information about crawlers was based on laboratory or greenhouse experiments. It is uncertain how crawlers will survive the adversities of the environment.
- *Planococcus minor* has a LOW likelihood of establishing a population in New Zealand (MODERATE uncertainty).

    - It is likely that *P. minor*'s mode of reproduction is sexual. This is a significant barrier for establishment.
    - *Planococcus minor* has a limited active long-range dispersal.
    - *Planococcus minor* is a polyphagous species, and many of its recorded hosts are present in New Zealand. It is highly likely that crawlers will find a suitable host.
    - *Planococcus minor* has established populations in regions with similar climates to New Zealand.
    - *P. minor* has a high reproductive rate and is able to produce multiple generations.
    - Crawlers can easily disperse within and across farms aided by agricultural equipment, farm workers or movement of plant material.
- *Planococcus minor* may cause LOW overall impacts on New Zealand (MODERATE uncertainty).
    - There is no evidence of economic impacts attributed to *P. minor* on any horticultural crops of economic importance to New Zealand.
    - There are no reports of economic impacts attributed to *P. minor* in places where *P. minor* has successfully established (e.g., Australia and Puerto Rico).
    - *Planococcus minor* transmits viruses in plants that are not of economic importance to New Zealand.
    - The risk of ants interfering with biological control programmes targeting *P. minor* in New Zealand is negligible, because successful biological control programmes have been reported in New Zealand for mealybugs that have established populations in the past 100 years.
    - There are no reports of health impacts on people working in fields as a result of aggressive ants being attracted by the honeydew excreted by mealybugs.
    - Additional management costs to producers because of *P. minor* will be low, because there have been management programmes to control mealybugs in New Zealand vineyards since the 1960s. These programmes are likely to control *P. minor* populations.
    - There is no evidence of impacts to New Zealand native species or taonga and staple food for Māori and Pasifika communities by *P. minor*.
    - An incursion of this mealybug could represent additional costs to producers due to phytosanitary measures and compliance agreements imposed by other countries where *P. minor* is a regulated pest.

The following tables contain a summary of risk assessment against the criteria.

Criteria	Rating	Uncertainty
Likelihood of entering on the commodity	LOW	MODERATE
Likelihood of transferring from the imported commodity onto a suitable host	VERY LOW	MODERATE
Likelihood of establishing a population in New Zealand	LOW	MODERATE
Impacts on the New Zealand economy, environment, human health, and society	LOW	MODERATE
Overall level of assessed risk to New Zealand	VERY LOW	MODERATE

Specific considerations summary (see Annex 8.4.4)	
Stage of ripeness the pest is associated with	No information
Pineapple varieties the pest is associated with	No information
Presence of pest in markets in this IRA	*Planococcus minor* has been reported in all markets in this IRA.
Parts of the fruit the pest associated is with (e.g. fruit, bract, stem, crown remnant)	No specific information. Other *Planococcus* species are found on the base of leaves, twigs, bark, flowers and fruit. We assume *P. minor* will have similar behaviour.
Different life stages of the pest associated with different parts of the fruit	No specific information. In other crops, such as cotton, *P. minor* crawlers wander around the plant toward actively growing plant parts before settling to feed. The female adult becomes sessile and can be found in similar places as the crawlers.
Signs/damage not easily visible	Fruit that is highly infested with mealybugs is likely to be detected, because adults have a visible white waxy powdery coating. Eggs in the ovisac are also likely to be visible. However, immature stages that have less coating and small eggs that are not protected by the ovisac could easily go unnoticed under bracts or crevices of the fruit.

To full assessment of *Planococcus minor*

6.5.5 *Pseudococcus jackbeardsleyi (Jack Beardsley mealybug)*

***Pseudococcus jackbeardsleyi* poses a NEGLIGIBLE overall level of risk (with MODERATE uncertainty) on pineapple fruit imported to New Zealand.**

- *Pseudococcus jackbeardsleyi* has a LOW likelihood of entering New Zealand on pineapple fruit (MODERATE uncertainty).
    - *Pseudococcus jackbeardsleyi* is associated with the exterior of the pineapple fruit.
    - The first instars of *Ps. jackbeardsleyi* may be missed during border inspections if they are under pineapple bracts.
    - *Pseudococcus jackbeardsleyi* can survive short transits to New Zealand, especially if the commodity is brought in by air cargo.

  However:

    - We found no information to associate the mealybug with pineapple fruits apart from interception data.
    - Basic pre-export cleaning may reduce the abundance of *Ps. jackbeardsleyi* on the commodity.
    - *Pseudococcus jackbeardsleyi* is unlikely to remain viable after long transits (weeks) in cold temperatures.
- *Pseudococcus jackbeardsleyi* has a VERY LOW likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
    - *Pseudococcus jackbeardsleyi* has a wide variety of hosts, and it feeds on the stems, fruits and leaves of its hosts.
    - All lifestages can disperse actively for short distances by walking.

    - Crawlers can spread passively for longer distances by wind.

  However:

    - *Pseudococcus jackbeardsleyi* is unlikely to survive commercial composting or a landfill.
    - Cold temperatures and plant secondary metabolites may impede *Ps. jackbeardsleyi*'s survival.
- *Pseudococcus jackbeardsleyi* has a VERY LOW likelihood of establishing a population in New Zealand (MODERATE uncertainty).
    - New Zealand has many hosts of *Ps. jackbeardsleyi*.

  However:

    - The climate in New Zealand is relatively unsuitable for *Ps. jackbeardsleyi*.
    - New Zealand has natural enemies of mealybugs, which may impede the spread and population size of *Ps. jackbeardsleyi*.

The following tables contain a summary of risk assessment against the criteria.

Criteria	**Rating**	**Uncertainty**
Likelihood of entering on the commodity	LOW	MODERATE
Likelihood of transferring from the imported commodity onto a suitable host	VERY LOW	MODERATE
Likelihood of establishing a population in New Zealand	VERY LOW	MODERATE
Impacts on the New Zealand economy, environment, human health, and society	N/A*	N/A*
Overall level of risk to New Zealand	NEGLIGIBLE	MODERATE

*Given that the combined likelihood of entry, exposure and establishment is negligible, according to the 'Guidelines for Risk Analysis in Plant Biosecurity 1.0', we did not need to further assess the impacts.

Specific considerations summary (see Annex 8.5.4)	
Stage of ripeness the pest is associated with	No information
Pineapple varieties the pest is associated with	No information
Presence of pest in markets in this IRA	Australia, Costa Rica, Ecuador, Indonesia, Malaysia, Panama, Papua New Guinea, The Philippines, Sri Lanka, Taiwan, Thailand
Parts of the fruit the pest associated is with	The pest feeds on the stems, leaves and fruit of its host plants. It is likely to be associated with all exterior parts of the fruit.
Life stages of the pest associated with different parts of the fruit	No specific information. All post-egg stages of the mealybug have functional legs and can move around the fruit.

Signs/damage not easily visible	*Pseudococcus jackbeardsleyi* feeds on and lives on the exterior parts of its hosts. The first three instars are small and can easily hide under pineapple bracts, groves or crown remains. Adult females are relatively obvious. The cotton-like ovisac with eggs is quite obvious.

To full assessment of *Pseudococcus jackbeardsleyi*

6.6 Insects: Lepidotera, Cosmopterigidae (cosmet moths)

6.6.1 *Anatrachyntis rileyi* (pink scavenger caterpillar)

***Anatrachyntis rileyi* poses an overall VERY LOW risk (with MODERATE uncertainty) on pineapple fruit imported to New Zealand.**

- *Anatrachyntis rileyi* has a HIGH likelihood of entering New Zealand on pineapple fruit (LOW uncertainty).
  - *Anatrachyntis rileyi* eggs and larvae are associated with pineapple fruit.
  - *Anatrachyntis rileyi* larvae can show resistance to some types of pesticides.
  - Some developmental stages, such as eggs and young larvae, could be undetected during field and packhouse activities.
  - *Anatrachyntis rileyi* can overwinter and further develop when climatic conditions are suitable.
  - There have been interceptions of live *A. rileyi* larvae at the New Zealand border on pineapple fruit.
- *Anatrachyntis rileyi* has a MODERATE likelihood of transferring from pineapple fruit to a suitable host in New Zealand (MODERATE uncertainty).
  - *Anatrachyntis rileyi* may survive and develop on pineapple fruit waste.
  - There are waste disposal methods that could facilitate the exposure of *A. rileyi* to the environment.
  - Some host plants can be found throughout New Zealand.
  - Some waste disposal methods would limit the exposure of *A. rileyi* to the environment because they are under contained structures.
  - We do not know whether larvae can survive inside compost bins in summer because the larvae’s upper temperature threshold is not known.
  - Even though *A. rileyi* host range is quite wide, there is some uncertainty about the host range due to misidentifications of the moth in the past.
  - The information on waste disposal in New Zealand is not up to date and is based on general waste. There is no specific information on pineapple waste.
- *Anatrachyntis rileyi* has a LOW likelihood of establishing a population in New Zealand (LOW uncertainty).
  - *Anatrachyntis rileyi* has mostly established populations in warm tropical and subtropical climates.
  - Sexual reproduction is a barrier for establishment.
  - Host plant availability will not be a barrier for establishment.
  - *Anatrachyntis rileyi* is a predatory and scavenger species, increasing its feeding choices in the environment.
  - The larvae can overwinter and resume development when climatic conditions are suitable.
- *Anatrachyntis rileyi* may cause VERY LOW overall impacts on New Zealand (MODERATE uncertainty).

- The potential economic impact of *Anatrachyntis rileyi* in New Zealand is VERY LOW (MODERATE uncertainty).
    - *Anatrachyntis rileyi* is mainly a scavenger but can occasionally feed on healthy plants.
    - *Anatrachyntis rileyi* is a seasonal pest of secondary importance and with limited distribution in some crops but is a major pest in field and stored corn.
    - *Anatrachyntis rileyi* can complete its life cycle on dead plant material and does not rely on living plants to complete its life cycle.
    - *Anatrachyntis rileyi* is an opportunistic species, found feeding in previously injured sugarcane and cotton plants.
    - We found no recent information about the impacts of *A. rileyi* in corn, and we are uncertain if *A. rileyi* is still considered a major pest on this crop.
    - There is uncertainty about the host range of this species due to past misidentifications.
- The potential environmental impact of *A. rileyi* in New Zealand is VERY LOW (MODERATE uncertainty).
    - We found no evidence of impacts on native plant species by *A. rileyi* or other *Anatrachyntis* species already established in New Zealand.
    - *Anatrachyntis rileyi* is a predator of scales but is unlikely to cause impacts on New Zealand native scales because its infestation is seasonal and restricted due to its limited dispersal capabilities.
    - We are uncertain if *A. rileyi* will prey on native scales, because we found no information on the predator–prey specificity of this species.
- The potential human health impact of *A. rileyi* in New Zealand is NEGLIGIBLE (LOW uncertainty).
    - We found no evidence of human health impacts associated with *A. rileyi* or other *Anatrachyntis* species.
- The potential sociocultural impact of *Anatrachyntis rileyi* in New Zealand is VERY LOW (MODERATE uncertainty).
    - We found no evidence of any impacts of *A. rileyi* or other *Anatrachyntis* species on culturally important plants in New Zealand.
    - Taro has been listed as an *A. rileyi* host plant. However, we are uncertain if taro is a host of *A. rileyi*, given misidentifications with *A. badia* in Hawaii in early literature.
    - Taro is widely grown in some parts of New Zealand, and until recently, it was grown under glasshouse conditions.
    - *Anatrachyntis rileyi* is unlikely to cause a major negative impact on taro, given that it is mainly a scavenger and rarely feeds on healthy plants during high infestations.
    - We found no information about *A. rileyi* impacts on taro.

The following tables contain a summary of risk assessment against the criteria.

Criteria	**Rating**	**Uncertainty**
Likelihood of entering on the commodity	HIGH	LOW
Likelihood of transferring from the imported commodity onto a suitable host	MODERATE	MODERATE

Likelihood of establishing a population in New Zealand	LOW	LOW
Impacts on the New Zealand economy, environment, human health, and society	VERY LOW	MODERATE
Overall level of assessed risk to New Zealand	VERY LOW	MODERATE

Specific considerations summary (see Annex 9.1.4)	
Stage of ripeness the pest is associated with	*Anatrachyntis rileyi* usually infests very young fruit and appears to do little or no damage. However, occasionally, larvae are present when the fruit is close to ripe.
Pineapple varieties the pest is associated with	*Anatrachyntis rileyi* was found feeding on Cayenne and Hilo varieties in Hawaii and the Queen variety in South Africa.
Presence of pest in markets in this IRA	Costa Rica, Ecuador[1], Thailand, Philippines, Indonesia, Australia, Fiji
Parts of the fruit the pest associated is with (e.g. fruit, bract, stem, crown remnant)	*Anatrachyntis rileyi* can be found inside the fruit and on the surface (eyes of the fruit) feeding on dead floral remains.
Different life stages of the pest associated with different parts of the fruit	Larvae are the most damaging life stage and can be found on the floral parts, inside and outside the pineapple fruit. Eggs are deposited mainly on the blossom cup of the young fruit, but it is uncertain if the female deposits eggs on the surface of the fruit once the fruit is fully formed.
Signs/damage not easily visible	There is evidence of *A. rileyi* burrowing into the fruit without causing obvious symptoms, especially when larvae have recently entered the ripening fruit. Young larvae can hide in the complex surface of the pineapple fruit and find refuge under the bracts.

[1] Reported present in the Galapagos Islands (Roque-Alberto 2006)

To full assessment of *Anatrachyntis rileyi*

6.6.2 *Vector analysis*

Planococcus citri is not a hazard in this analysis.

- *Planococcus citri* can transmit one pineapple pathogen, *Pineapple bacilliform comosus virus* (PBCoV), but we found no evidence that PBCoV can affect plants other than pineapple plants.
- *Planococcus citri* is not known to transmit any pathogen in the HPP/SRO[12] list in a persistent or semi-persistent manner.

Pseudococcus longispinus is not a hazard in this analysis.

- *Pseudococcus longispinus* may transmit one pineapple pathogen, *Pineapple mealybug wilt-associated virus* 2 (PMWaV-2), but no clear evidence could be found that PMWaV-2 can affect plant species other than pineapple.
- *Pseudococcus longispinus* is not known to transmit any pathogen in the HPP/SRO list in a persistent or semi-persistent manner.

To full vector analysis

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[12] This list is compiled from the MPI's high-priority pest and disease (HPP) list and the list of sector risk organisms (SRO) as listed/described by each Government Industry Agreement (GIA) partner in either their draft operational agreement, biosecurity plan or website. See Table 10.2 in Annex 10.

7 Annex: Details of risk assessments

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1 RISK ANALYSIS PROCESS

1 Risk analysis process

The World Trade Agreement on the Application of Sanitary and Phytosanitary Measures (SPS agreement) states that phytosanitary measures must be supported by risk assessment and not maintained without sufficient evidence (WTO 1995). That is, to require additional measures, MPI must have evidence that a pathogen would not be sufficiently managed by the application of the minimum requirements.

The Biosecurity New Zealand process for undertaking an IRA builds on the existing international frameworks for risk analysis under the World Organisation for Animal Health (OIE) and the International Plant Protection Convention (IPPC), and extends the scope, under the SPS Agreement, to include all of the values required by the Biosecurity Act (1993)[13].

The main output is an IRA which is used in the development or review of an IHS under the Biosecurity Act (1993). An IHS specifies the requirements to be met for the effective management of risks associated with importing risk goods[14].

The Biosecurity Act (1993) requires a chief technical officer to begin the process of developing an Import Health Standard by: "*analysing or assessing the risks associated with importing a class or description of goods"*[15]. While the Biosecurity Act does not state how the risks are to be assessed or analysed, it does state that the chief technical officer must have regard to certain matters when developing an IHS for recommendation to the Director-General. A number of these are part of an IRA as described by the OIE and IPPC:

- The likelihood that the goods will import organisms[16]
- The nature of the organisms that the goods may import
- The possible effect on human health, the New Zealand environment[17], and the New Zealand economy of the organisms that the goods may import
- In relation to requirements proposed for inclusion in an IHS, the extent to which the requirements reduce or manage the likelihood or impacts of adverse effects from organisms that may be imported on or in association with goods[18]

An IRA is also a relevant factor in how a country meets its obligations under the SPS agreement and other agreements such as the Convention on Biological Diversity (CBD). Under the SPS agreement, risk management measures either must be based on existing international standards, guidelines or recommendations, or must be supported by a scientific

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[13] Biosecurity Act section 24(4)(b)(iii) "…human health, the New Zealand environment, and the New Zealand economy…" As defined in section 2(1), environment includes (a) ecosystems and their constituent parts, including people and their communities; and (b) all natural and physical resources; and (c) amenity values; and (d) the aesthetic, cultural, economic, and social conditions that affect or are affected by any matter referring to paragraphs (a) to (c).

[14] Section 22, Biosecurity Act 1993

[15] Section 23(1) Biosecurity Act 1993

[16] From Section 2(1) Biosecurity Act 1993: "**organism**—(a) does not include a human being or a genetic structure derived from a human being: (b)includes a micro-organism: (c) subject to paragraph (a), includes a genetic structure that is capable of replicating itself (whether that structure comprises all or only part of an entity, and whether it comprises all or only part of the total genetic structure of an entity): (d) includes an entity (other than a human being) declared by the Governor-General by Order in Council to be an organism for the purposes of this Act: (e) includes a reproductive cell or developmental stage of an organism: (f) includes any particle that is a prion"

[17] From section 2(1) Biosecurity Act 1993, "**environment** includes— (a) ecosystems and their constituent parts, including people and their communities; and (b) all natural and physical resources; and (c) amenity values; and (d) the aesthetic, cultural, economic, and social conditions that affect or are affected by any matter referred to in paragraphs (a) to (c)"

[18] Section 23(4)(b) and (d) Biosecurity Act 1993

justification[19]. Measures must not be maintained without sufficient scientific evidence[20]. Measures must also not be unnecessarily trade restrictive[21]. In order to meet these obligations, the SPS agreement requires that measures are based on a risk analysis. Under the CBD, countries must consider environmental impacts in decision-making and prevent the introduction of, and control or eradicate alien species that threaten ecosystems, habitats and species.

The MPI process is equivalent to the process for plant health risk analysis under the International Standards for Phytosanitary Measures (ISPM) under the IPPC[22] (the main differences being in terminology).

1.1 Overview of the risk analysis process

The individual steps in the process for developing an IRA are the same for both the OIE and IPPC. However, the standards, guidelines and recommendations for animal health (sanitary) and plant health (phytosanitary) measures are developed by different international bodies. This means that there are differences in the detail of how IRA is done for animal health (OIE) and plant health (IPPC). The MPI process and methodology for undertaking an IRA is summarised in Figure 1.1.

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[19] SPS Agreement 1995 Article3(1) and (3)

[20] SPS Agreement 1995 Article 5(7)

[21] SPS Agreement Article 5(6)

[22] ISPM2: Framework for Pest Risk Analysis (Link).

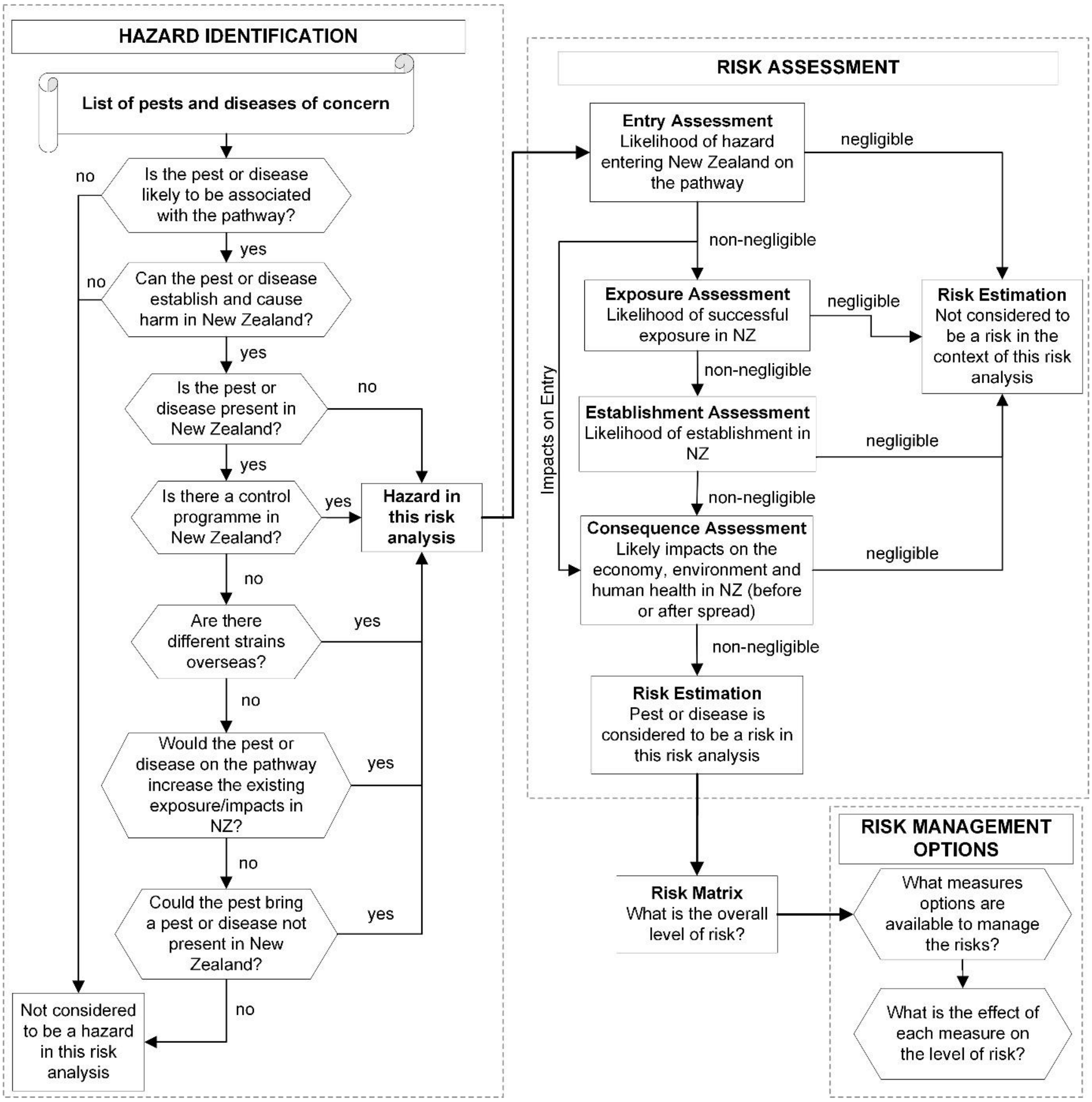

Figure 1.1 BNZ process and methodology for undertaking an import risk analysis

1.2 Risk assessment ranking

For each of the likelihoods of entry, exposure, establishment, the following ranking scales will be used. The column containing the “quantitative guidance” provides a quantitative scale to help guide the analyst on the scale of each ranking.

Scale	Qualitative guidance	Quantitative guidance
High	Extending above the normal or average level	More than 2 events in 3 years
Moderate	Around the normal or average level	1 to 2 events in 3 years
Low	Less than average, coming below the normal level	1 event in 3 to 20 years
Very low	Close to insignificant	1 event in 20 to 100 years
Negligible	Not worth considering; insignificant	Less than 1 event in 100 years

For consequences, the following ranking scales will be used:

Scale	Qualitative guidance	Quantitative guidance
Very High	Well above the normal or average level	More than 10 billion $NZ
High	Extending above the normal or average level	Between 1 and 10 billion $NZ
Moderate	Around the normal or average level	Between 100 million and 1 billion $NZ
Low	Less than average, coming below the normal level	Between 10 and 100 million $NZ
Very low	Close to insignificant	Between 1 and 10 million $NZ
Negligible	Not worth considering; insignificant	Less than 1 million $NZ

While the values provided in the quantitative guidance are New Zealand dollars over a 20 to 30 year period, the analyst considers how non-economic impacts can be monetarised (e.g., the dollar value of damage to ecosystem services) or considered equivalent (e.g., how much social impact is equivalent to these economic values).

1.3 Hazard identification

Hazard identification[23] is the process of identifying pests and diseases that are associated with imported risk goods and have the ability to cause harm to New Zealand. In this process, we compile a list of potential hazards and then assess them against criteria to see whether they warrant further consideration. Hazard identification answers two questions.

- Does the species meet the criteria to be considered a biosecurity risk to New Zealand?
- Is the species potentially associated with the commodity that is being assessed?

The criteria for a quarantine pest for New Zealand are derived from the Biosecurity Act and the IPPC and WOAH. These criteria are:

- Is the pest or disease absent from New Zealand?
- OR is the pest or disease present in New Zealand, but it meets one of the following criteria?
    - The species is under official control.
    - The species is a vector of a quarantine pest or disease.
    - There are subspecific taxa (subspecies, varieties, strains, etc.) within the pest species that are an increased risk to New Zealand compared with those already present.
    - There are other factors that would mean that the pest or disease may still be of concern in associated with imported goods (e.g. increased exposure to people through imported goods[24]).
- AND does the pest or disease have the potential to establish in New Zealand and harm "human health, the New Zealand environment, and the New Zealand economy[25]"?

Association with the commodity is based on:

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[23] Under the IPPC, the hazard identification process is known as pest categorisation in ISPM 2 (FAO 1995) and ISPM 11 MfE (FAO 2013).

[24] One example is venomous spiders on fresh fruit. Even if present in a country, there may be a higher likelihood of people getting bitten if the spiders are associated with fruit sold at a supermarket.

[25] Biosecurity Act 1993

- association with the commodity species or genus;
- association with the specific parts of the commodity; and
- whether a particular pest will stay associated with a commodity during preparation and/or transit to New Zealand – for example, a large flying insect is unlikely to stay on a piece of fruit when it is picked.

Different approaches may be taken to compiling and presenting the list of potential hazards depending on the information needed for pests or diseases in each pest/disease group. The approach for each group may be determined in the project plan, once the risk management question and risk evaluation criteria have been established. The specific approaches to hazard identification used in this import risk analysis are discussed further in chapter 3.

1.4 Risk assessment

At the end of hazard identification, we compile a list of hazards that require risk assessment. A risk assessment evaluates the likelihood of introduction (entry, exposure and establishment) and consequence for a particular hazard, as well as the uncertainty in the conclusions. The SPS agreement describes the factors to take into account when assessing risk. These factors include:

- available scientific evidence;
- relevant processes and production methods;
- relevant inspection, sampling and testing methods;
- prevalence of specific diseases or pests;
- relevant ecological and environmental conditions; and
- potential damage in the event of the entry, establishment or spread of a pest or disease.

A qualitative approach is suitable for most import risk analyses and is currently the most common type of assessment we use to support the development and review of import requirements.

1.5 Assessment of uncertainties

The SPS agreement states that measures must be applied “only to the extent necessary and must be supported by sufficient scientific evidence”[26]. Therefore, if there is insufficient evidence indicating that an organism meets the criteria for additional measures, then MPI usually does not consider it a hazard (see section 1.3). In some cases there may be good reason to consider a pest or disease a hazard even when evidence is insufficient (e.g. similarity to known pests or diseases). In these cases, we may still assess the pest or disease further. If there is insufficient evidence but significant uncertainty, then the decision maker may apply measures, but under those circumstances the measures are provisional and further conditions may be required[27].

Therefore, documenting significant uncertainty is an essential part of risk assessment. We have documented uncertainties such as contradictions in the evidence or a lack of evidence in this analysis. If we identify significant uncertainty that affects the conclusions of our risk

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[26] SPS Agreement 1995 Article 2.2

[27] SPS Agreement 1995 Article 5.7

assessment, we have indicated this in the wording of the conclusion. The rationale for our uncertainty rating is as follows.

Scale	Criteria
High	• Scarce or no data available; evidence provided in unpublished reports of unknown authenticity; or • Few observations and personal communications; and/or • Authors' or experts' conclusions vary considerably
Moderate	• Some or only incomplete data available; evidence provided in small number of references; authors' or experts' conclusion vary; or • Limited evidence from field/lab observations; or • Solid and complete data available from other species that can be extrapolated to the species being considered
Low	• Solid and complete data available; strong evidence in multiple references with most authors coming to the same conclusions; or • Considerable and consistent experience from field observations

1.6 Expert review

Expert review is a fundamental component of risk analysis. It ensures the analysis is based on the most up-to-date and credible information available.

Expert reviewers may check that the import risk analysis is based on the best available and most credible information, that the document is clear and logical, that assumptions are valid and that conclusions are consistent with the evidence, with other conclusions in the risk analysis and with relevant conclusions in other assessments.

1.7 References for Annex 1

FAO (1995) Guidelines for pest risk analysis. International Standard for Phytosanitary Measures No. 2. Published by FAO on behalf of the Secretariat of the International Plant Protection Convention (IPPC); Rome, Italy.

FAO (2013) Pest risk analysis for quarantine pests. International Standard for Phytosanitary Measures No. 11. Published by FAO on behalf of the Secretariat of the International Plant Protection Convention (IPPC); Rome, Italy.

WTO (1995) World Trade Organization (WTO) Sanitary and Phytosanitary Measures Agreement (SPS). www.wto.org/english/tratop_e/sps_e/sps_e.htm.

2 IRA scope and information

We have developed this import risk analysis (IRA) in response to a request to update the import health standards (IHS) for the importation of fresh pineapples (*Ananas comosus*) for the seven currently approved markets (Australia, Ecuador, Fiji, New Caledonia, the Philippines, Thailand, Vanuatu) and to add an additional 10 markets (Cook Islands, Costa Rica, Indonesia, Malaysia, Papua New Guinea, Panama, Samoa, Sri Lanka, Taiwan, Tonga). The purpose of the risk analysis is to identify and assess biosecurity risks associated with commercially produced decrowned pineapple (*Ananas comosus*) for human consumption (of all varieties and ripeness (excluding overripe)). The decisions that this risk analysis will inform are:

- **a.** whether MPI should require additional measures for any pests and diseases on commercially produced, decrowned pineapple (*Ananas comosus*) for human consumption ((of all varieties and ripeness (excluding overripe)), beyond the measures covered by the commodity description;
- **b.** whether MPI should remove any pests and diseases from the current standards for commercially produced, decrowned pineapple (*Ananas comosus*) for human consumption that do not require additional measures due to new scientific evidence; and
- **c.** what measures are available that could manage the pest risks to an appropriate level.

The objective of the risk analysis is to:

- **a.** Identify which pests and diseases present a level of risk to New Zealand on the commodity and pathways included in the scope; and
- **b.** assess these pests and diseases using a method which provides sufficient evidence about the biosecurity risks to assist risk managers to determine a robust and transparent decision on whether additional measures beyond the commodity description proposed for the IHSs are required to manage these pests and diseases.

For any particular risk good[28], there is a commodity description that describes the minimum condition of the commodity that is covered by this IRA. The commodity description is important as many pests and diseases may not be associated with a commodity that is defined in a certain way (e.g. more pests may potentially be associated with a commodity definition of fresh beans for consumption than a commodity definition of frozen beans for consumption).

2.1 Descriptions of the commodity and pathway

This risk analysis considers the effects on the New Zealand economy, environment, society and human health[29] from organisms potentially associated with the importation of commercially produced, decrowned pineapple fruit (*Ananas comosus*) for human consumption. A detailed description of the commodity and pathway is provided in Table 2.1.

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[28] Regulated article under IPPC

[29] Specifically, this IRA covers sections 23(4)(b)(i), (ii) and (iii) of the Biosecurity Act:
(i) the likelihood that the goods will import organisms:
(ii) the nature of the organisms that the goods may import:
(iii) the possible effect on human health, the New Zealand environment, and the New Zealand economy of the organisms that the goods may import

Table 2.1 Detailed description of the commodity and the pathway(s) of entry to New Zealand.

Commodity description
Commodity description[30] Commercially produced decrowned fresh pineapple fruit (*Ananas comosus*), of all varieties and ripeness (excluding over ripe[31]) for human consumption. This excludes material or produce which is visibly damaged (damage which may be a result of the presence of a regulated pest or could expose the commodity to regulated pests). The risk from crown remnant has not been considered in this IRA because crown remnant will be deemed a non-compliance as per the commodity description. **Commercial production description** Commercial production means a process (system) where activities, such as in-field monitoring, pest control activities, harvesting, cleaning[32], sorting, and grading[33] have been undertaken. These activities are carried out to minimise: a) the presence of regulated pests; b) commodity damage which could expose the commodity to regulated pests. Note: NPPO phytosanitary inspection, certification and documentation form part of general import requirements.
Pathway description
Commercially produced decrowned fresh pineapple fruit (*Ananas comosus*) for human consumption from Australia, Ecuador, Fiji, New Caledonia, The Philippines, Thailand, Vanuatu, Cook Islands, Costa Rica, Indonesia, Malaysia, Papua New Guinea, Panama, Samoa, Sri Lanka, Taiwan and Tonga. The import risk analysis project is applied to both sea and air cargo[34]. Therefore, all risk assessments will consider both pathways.

2.2 General information related to likelihood of entry

The following aspects of the commodity and pathway description will affect the likelihood that pests or diseases will enter New Zealand:

1. The pineapples are required to be commercially produced. Commercial production means a process (system) where activities, such as in-field monitoring, pest control activities, harvesting, cleaning, sorting, and grading have been undertaken. Note: NPPO phytosanitary inspection, certification and documentation form part of general import requirements. This excludes material or produce which is overripe or visibly damaged (damage which may be a result of the presence of a regulated pest or could expose the commodity to regulated pests).

These activities are carried out to minimise:

a) the presence of regulated pests;

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[30] In the absence of ripeness and variety from the commodity description, pest association will be reported for all varieties and stages of ripeness in the IRA.

[31] Overripe is equivalent to C4 or greater as per the UNECE Standard on the marketing and commercial quality control of pineapples: Link

[32] Cleaning will removal extraneous plant material, debris, and soil. Large mobile pests will also be removed.

[33] Grading will remove damaged produce or visibly infested produce.

[34] See Annex.Appendix 3 for transit conditions.

b) commodity damage which could expose the commodity to regulated pests.

2. **2.** The pineapples are also to be decrowned. This prevents the association of leaf and foliage infecting pests and diseases as well as minimises contamination with weed seeds (see section 2.2.1).

The import risk analysis project is applied to both sea and air cargo. Therefore, all risk assessments will consider both pathways. Transit conditions of these pathway are described in Annex.Appendix 3.

2.2.1 *Risk of introducing weed seeds on fresh pineapple*

According to an MPI trip report to pineapple exporting countries (MPI 2018), despite control measures reducing weed prevalence to very low levels amongst fruiting pineapple plants, small amounts of weed plants were observed amongst the fields. The report also indicates that the common area of seed contamination is in the crown of pineapple. However, contaminating seeds is unlikely to be associated with imported fresh decrowned *Ananas* pineapple fruit as per the commodity description in this IRA because these seeds would likely be detected or removed during decrowning, cleaning and inspection in the commercial production process.

Supporting information

The MPI Horticultural Imports team confirmed with importers that from at least 2018 only decrowned pineapple fruit have been imported in spite of it not being a requirement to decrown. This provided a basis to use interception data as a tool to assess whether seeds were still associated with imported decrowned pineapple fruit.

Interception reports (from 2002 to August 2021) from QuanCargo (2021) shows that there was a decrease in seed contamination particularly from 2018 onwards when pineapple fruit was being voluntarily decrowned even though the volume of pineapple fruit is generally higher than earlier years (Figure 2.1). The percentage of consignments with seed contamination has also decreased in recent years (Figure 2.2).

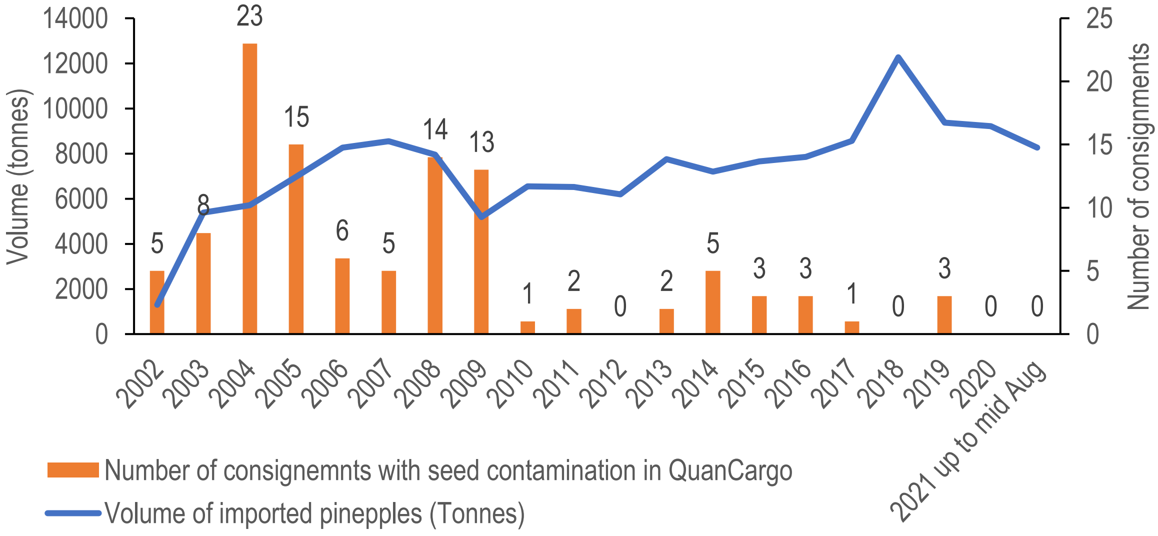

Figure 2.1 Total volumes in tonnes for imported pineapple fruit and numbers of consignments with seed contamination from 2002 until August 2021 (QuanCargo 2021)

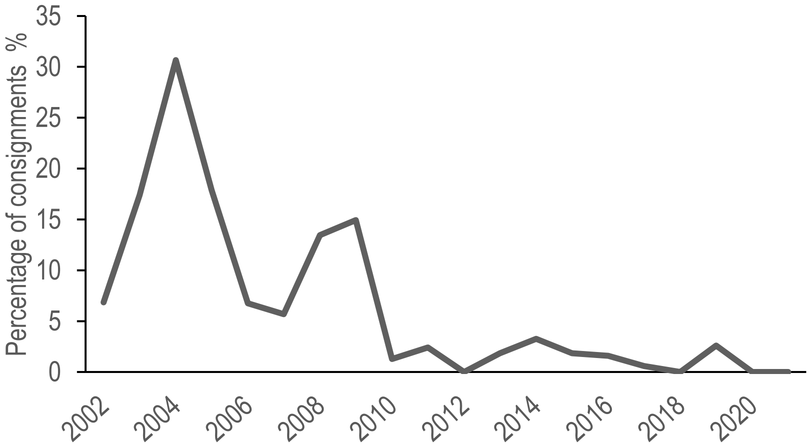

Figure 2.2 Percentage of consignment entries of pineapple fruit with seed contamination from 2002 until August 2021 (QuanCargo 2021)

Similarly, LIMS (2022) interception database records also show only a spike between 2000 and 2003 and virtually nothing thereafter (Figure 2.3). Of particular note is that no records of seed interceptions were recorded after 2018 in this database.

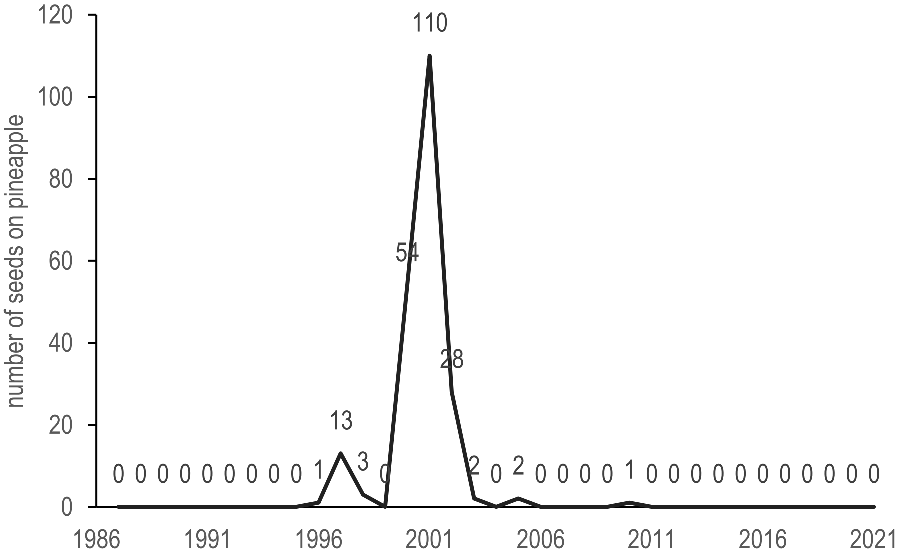

Figure 2.3 Graph showing total number of seeds found on imported pineapple fruit in from 1986 until 2021(LIMS 2022).

For the years when pineapple fruit were voluntarily decrowned (2018 to August 2021), three interceptions of seeds were identified and all were in 2019 (QuanCargo 2021; Table 2.2).

Table 2.2 Records of seed interceptions since 2018 from QuanCargo (2021).

Exporting countries	Inspection date	Genera of seeds
Ecuador	13/05/2019	*Cyperus* sp.
		Dinehra sp.

Philippines	5/11/2019	*Brachiaria* sp. *Digitaria* sp. *Setaria* sp.
Ecuador	17/01/2019	*Crepis* sp.

The Quarantine officers who completed the inspections were contacted to determine where the seeds were found on these particular consignments. They confirmed that for one of the consignments the seeds were found in the remnants of the crown still attached to the fruit. The pineapple fruit were not very well decrowned, meaning that it was not cleanly cut close to the fruit and had more crown than other consignments in general. While this does not classify as a non-compliance (decrowning is not currently required) it does explain and confirm that crowns are indeed a reservoir for seed contamination. The other consignment had seeds found in a section of the stem which was, again, not cut off to the standard one would expect it to be, leaving bracts underneath the fruit which trapped the seeds. The third consignment recalls that the seeds (*Crepis* sp.) may have been windblown and attached to the side of the pineapple fruit. These seeds are “fluffy” in appearance and could become stuck onto the spiky bracts on the side of the fruit. Generally, these seeds would be detected during cleaning and inspection and should be removed as part of the commercial production system. Therefore, if the pineapple fruit are effectively destemmed, decrowned, cleaned and inspected in accordance with the commodity description, weed seeds is unlikely to be associated with the commodity as per the commodity description.

2.3 General information related to likelihood of exposure and establishment

When a pest or disease arrives in a new area, it usually needs to transfer from the imported commodity or inanimate object, to a host or environment suitable for the completion of development or production of offspring. This is termed “exposure” in Biosecurity New Zealand risk assessments.

For pineapple fruit, the intended use is human consumption, not propagation. There are two ways a pest or disease arriving with plant products may come into contact with a growing host plant:

1. A pest may fly or be washed, blown or carried off the plant product and find a host plant. Examples include mobile pests such as thrips and psyllids, as well as some fungi and bacteria.
2. The plant product is discarded into an environment that allows the pest or disease to continue its life cycle and eventually come into contact with a host plant. Examples include flies, scales and citrus canker.

The likelihood of the first case (mobile pest) occurring depends largely on the mobility of the pest. However, the more mobile the pest is, the less likely it is to be associated with harvested and packed plant product in the first place, due to the level of handling the plant product receives during these processes.

The likelihood of the second case (discarded plant product material) occurring depends on waste material generated from the commodity (either parts of the commodity not generally consumed, e.g. rinds or seeds, or parts generally consumed that have degenerated to the point of being considered inedible). Waste material discarded into bagged rubbish that goes to landfill, or into kitchen disposal units that flush into the sewerage system, is unlikely to be a risk. However, waste discarded into compost bins, under plants as mulch or distributed as animal feed presents a potential exposure pathway.

Climate factors may impact on the likelihood of pest or disease exposure or establishment in New Zealand.

2.3.1 *Waste analysis*

Summary of the analysis

- Pineapple is one of the higher waste fresh produce compared to many other types of fresh produce. Over 50% of the weight of a decrowned pineapple is often discarded as unavoidable waste.
- Disposal methods pose different levels of risk: food waste that is bagged and goes to landfill, or is disposed of into in-sink disposal units, is unlikely to be a risk; commercial compost and worm farming are a low risk methods; garden or home composting can be a high risk method; fruit waste distributed as animal feed may also represent a potential exposure pathway.
- A recent survey shows that 13.8% of the total supermarket food waste is directed to animal feed.
- Available data suggests that 71% and 13% of household organic waste was landfilled and disposed of into in-sink disposal units, respectively. Approximately 13% of household organic waste was composted.

Note: The proportions in the studies that used in this analysis are for total food or organic waste, and as such, the proportion that comprises imported produce or pineapple is much smaller and will be affected by seasonal differences in fruit supply. The accurate proportion of food waste or pineapple waste disposed of by different methods is not known.

Supporting information

Some fresh produce commodities can be entirely consumed and they generate no unavoidable waste, for example blueberries or leafy vegetables. Others such as apples or summerfruit generate small or moderate amounts (the cores or stones). However, fresh pineapples produce large amounts of unavoidable waste; the thick rind is always removed and disposed of, and the fruit is also sometimes cored. The weight percentage of peel and core of a typical fruit of the Cayena Lisa variety of pineapple with the crown on is 41% and 6% respectively (Medina and García 2005). Based on these data, the percentage weight of peel and core of a decrowned Cayena Lisa variety pineapple is 51.25% and 7.5% respectively, that is, over 50% of the pineapple is likely to be discarded as unavoidable waste.

The disposal of whole fruits (e.g. culled and unsold fruits, uneaten and fruit remains) is not uncommon during wholesale and retail marketing, or even by consumers. In addition, pineapple is a commonly sold commodity. Therefore, pests and pathogens associated with pineapple waste could be expected to have a higher likelihood of exposure than those associated with many other kinds of fresh produce.

Disposal methods

Food waste disposal methods in New Zealand include landfill, commercial compost, garden compost or worm farming, animal feed, disposal into waste water via in-sink units and direct disposal into the environment, e.g. by roadsides, in parks etc. In New Zealand, landfill is the most common method of disposing of municipal solid waste and organic waste (Askarany and Franklin-Smith 2014). Different disposal methods pose different levels of risk. Food waste that is bagged and goes to landfill, or is disposed of into in-sink disposal units, is unlikely to be a risk. However, garden or home composting can be a high risk method. Garden composting encompasses a wide range of practices, from open compost piles to commercially produced containers. Also, compost sites are not always covered and are often situated close to weeds, grasses and garden plants. A study conducted in Palmerston North found that although 63% of households that have home composts used manufactured plastic bins for composting, the majority of the others used 'open' composting systems, such as open compost piles and piles fenced with wire (Mensah 2017), which will increase the likelihood of exposure. Fruit waste distributed as animal feed also represents a potential exposure pathway. In contrast, commercial compost is a low-risk method. WasteMINZ (2009) describes that waste is put into tunnels for a period of three to four days at greater than 55°C for pasteurisation. WasteMINZ (2009) defines pasteurisation as the process whereby organic materials are treated to kill plant and animal pathogens and weed propagules, so these conditions are likely to kill many pathogens (WasteMINZ 2009). Worm farming is considered to be a low-risk method, as contained worm bins are likely to be used.

Disposal pathways

Fresh produce waste may be disposed of by wholesalers, retailers (e.g. supermarkets), food services (e.g. restaurants, hospitals and schools) and/or consumers (MPI 2014). The percentage of the total loss of fruit and vegetables during distribution/retail marketing and at the consumer stage for North America, Australia and New Zealand collectively, is 12% and 28% respectively (NRDC 2012 in Porat et al. 2018). In New Zealand, landfill is the most common disposal method, but the accurate proportion of food waste disposed of by different methods is not known. Recent food waste audits (WasteNotConsulting 2015; SunshineYates 2018) in New Zealand only include analysis of food waste disposed of through domestic kerbside refuse collection. They do not include analysis of food waste disposed of through disposal units, home compost and animal feed, as this information is difficult to survey (WasteNotConsulting 2009). Despite the lack of accurate data, there are studies investigating disposal pathways used by people and households.

It is important to note that the proportions in the following studies are for total food or organic waste, and as such, the proportion that comprises imported produce or pineapple is much smaller and will be affected by seasonal differences in fruit supply.

Wholesalers

MPI (2014) conducted an analysis of fruit waste in New Zealand, but noted that wholesale fruit disposal pathways and practices were not covered. A recent search on literature and data on wholesale fruit disposal returned no related studies.

Retailers – supermarkets

Although normal commercial practice is to reduce waste, fruit waste in New Zealand may be collected from unpacking areas (e.g. supermarket preparation rooms) and taken to rural areas where it is placed on the ground for eventual consumption by pigs or other farmed animals (MPI 2014). A recent survey on waste from supermarkets in New Zealand (Goodman-Smith

2018) found that 13.8%, 1.38%, 13% and 0.65% of the total supermarket food waste directed to animal feed, landfill, food donation and composting is fresh fruit waste, which make up 28.83% of the total supermarket food waste.

Food services

A recent study indicates fruit waste accounts for 9% of the 24,366 tonnes food waste produced from cafés and restaurants annually in New Zealand (WasteMINZ 2018). Food services are estimated to waste up to 20% of all food entering their operations. Some cafés and restaurants donate food scraps as animal feed (although this may not be legal) and may also be taken home for domestic compost (Chisnall 2018), and these two disposal methods are considered to be high risk methods.

Goodman-Smith et al. (2020) conducted a food waste audit in 16 retail stores and found that fresh fruits contributed 17% of discarded product. Disposal methods used for food waste produced from these stores were low risk methods including landfill, protein reprocessing and commercial compost.

Goonan et al. (2014) studied food waste from hospitals in New Zealand and indicated that regulations on food safety and quality control limit the use of composting and animal feed as disposal methods from plate waste. However, hospital food waste (kitchen waste) prior to patient consumption may be composted (Goonan 2013). In a broader food service context, a 2009 environmental survey showed that 13% of operators participated in composting organic waste (Anonymous 2009, cited in Goonan 2013). However, it is not known what composting system was used by these operators.

Households

Most of household organic waste was disposed of using low risk methods in New Zealand: Available data suggests that 71% and 13% of this waste was landfilled and disposed of in disposal units (both are low risk methods), respectively, and approximately 13% of household organic waste was composted (Hogg et al. 2010, cited in MPI 2014). There are a few surveys and audits on food waste from households in New Zealand (summarised in Table 2.2), however, these surveys have not measured the proportion of food waste disposed of by different methods. These surveys indicate that a large proportion of the people or households surveyed used high risk disposal methods, and that high risk disposal methods including garden composting and animal feed tend to be more common in rural areas (WasteNotConsulting 2009). Since different methods were used and the surveys were conducted in different regions, it is difficult to compare the results in order to understand the trend of change in food waste disposal behaviour. However, a recent survey (Rabobank 2021) found that total household food waste, as a percentage of New Zealand household spend, was similar in 2021 and in 2019 (8.6% and 10.2% respectively). Fruit and vegetables account for around two thirds of all food waste, and New Zealanders are more likely to be using compost or worm farms in 2021 than in 2019. The only survey found that investigated the proportion of food waste disposed of through different disposal methods is Hogg et al. (2010, cited in MPI 2014).

Table 2.2 Summary of household food waste survey in New Zealand.

Reference	Locations	Main findings on disposal methods

Moore et al. (2002), cited in WasteNotConsulting (2013)	Christchurch	57% of people surveyed were found to compost at home, and 60% used council collection or via in-sink disposal.
Cameron (2002), cited in WasteNotConsulting (2009)	Rural Areas	67% of households surveyed are reported to compost for Franklin District, 59% for Hauraki District, and 50% for the Waikato Region.
Feldhaeuser (2003), cited in WasteNotConsulting (2013)	National	43% of people composted at every opportunity; 14% at most; 6% at 'some' and 3% at a 'few' opportunities.
Taranaki Rural Sustainability Group (2004), cited in WasteNotConsulting (2009)	Taranaki	75% of farmers fed food waste to farm animals.
Johnson et al. (2008), cited in WasteNotConsulting (2013)	Not specified	63% composted garden waste and kitchen scraps at home. In the urban North Island, the survey found that 58% of people composted and 12% worm farmed.
Mobius Research and Strategy Ltd (2011), cited in WasteNotConsulting (2013)	Auckland	39% of people composted at least some of their garden waste, with 31% stating that they composted half or more of garden and kitchen food waste.
WasteNotConsulting (2015); Sunshine Yates (2018)	National	New Zealand food waste audits in 2015 and 2018 shows that 42 and 39% households surveyed used compost or worm farm, 29 and 28% households use animal feeds disposal methods (Table …), and 28 and 32% used in-sink disposal, which indicates that the proportions of households that used high risk methods for disposing food waste in these two audits are similar.
Mensah (2017)	Palmerston North	36% of households surveyed were home composters.

2.3.2 *Potential for the exposure of seed-transmitted and vector-transmitted pathogens*

Commercial production pineapples are not grown from seeds. Pineapple can be potentially grown from slips, suckers, crowns and ratoons. The commodity description and commercial production description of this IRA do not allow these propagation materials remain on the pineapple fruit. There is no evidence that seed from discarded pineapple fruit results in seedlings. Seeds are occasionally present in imported pineapple fruits. If seeds are present, they could be deliberately planted; however, given that this is not the intended end-use and is unlikely to happen frequently, deliberate propagation is not considered further in this IRA. Pathogens that could only be transferred into the environment via seed growth have therefore been excluded from this IRA.

There are also vector-transmitted pathogens that may be detected in fruit, for example via PCR tests, but have no way of getting from fruit and onto a growing host in the absence of a vector. These have also been excluded from this IRA if the vector is not in New Zealand and not likely to be associated with the commodity under the commodity description.

2.3.3 *New Zealand climates*

New Zealand in general exhibits a mid-latitude oceanic temperate climate (Cfb temperate with maritime climate in the Köppen classification (Köppen 1936; Rubel and Kottek 2010). Annual precipitation varies substantially due to topography, from dry eastern and inland areas to very high precipitation (on a global scale) in west coast areas[35]. The driest New Zealand climates barely reach a conventional water deficit on average (although they can do so in extreme years and months). The New Zealand climate 'space' can be visualised as a three-dimensional simplified climate niche (Figure 2.1). This represents the average monthly temperature and precipitation for each month of the year for 42 New Zealand climate stations.

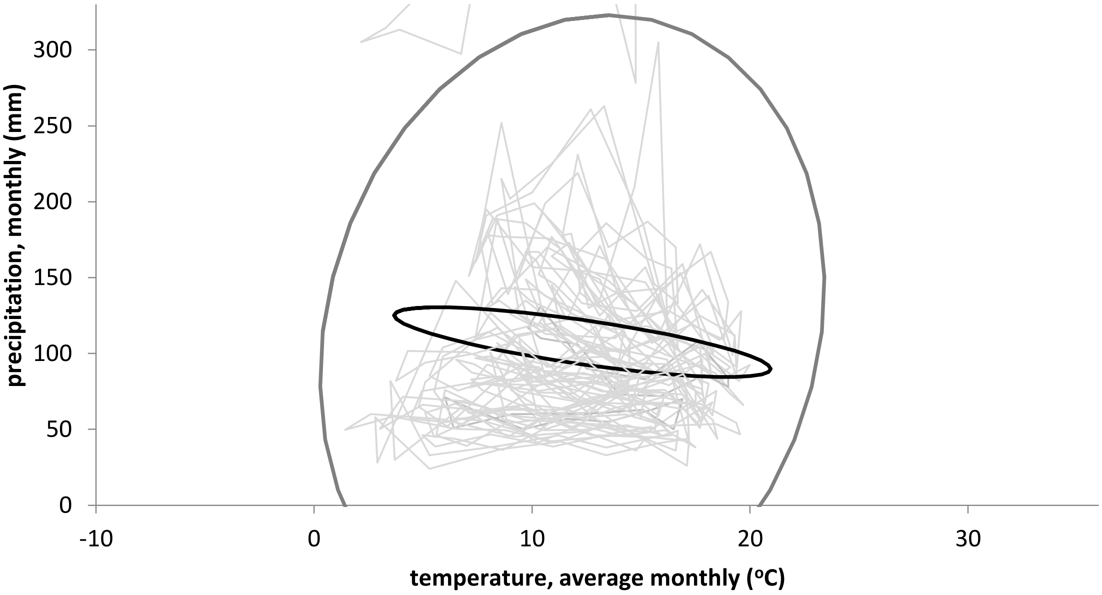

Figure 2.1 Climate niches of New Zealand. Thin grey lines: average monthly temperature (1981–2010) for 42 New Zealand climate stations (data from NIWA (2020)). Each polygon is composed of the 12 months of the year. Small black ellipse: average conditions for those 42 sites. Large ellipse: 95% inclusive ellipse.

As a consequence of being a small landmass in a large ocean, New Zealand has relatively low diurnal and seasonal temperature fluctuations (equable climate). Rainfall is close to evenly distributed between summer and winter. These features are similar in equatorial climates. However, there can be relatively rapid variations between days as large weather systems alternate over the oceans. Although such variations may also occur in continental climates, a key difference for organisms is the proximity of these variations to biological thresholds (such as frost).

Unlike many Northern Hemisphere continental climates with reliable lengthy warm and cold periods, a small temperature variation in a mild oceanic climate means a more significant change in the number of days crossing threshold degrees, which may in some cases restrict the ability of some organisms to establish. This feature is also common to smaller land masses and mountains of the Southern Hemisphere, which is why, globally, some of the most similar climate conditions to New Zealand are in the montane regions of the Andean Yungas

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[35] This summary is written with crop pests and diseases in mind, focusing on the climate in inhabited and cultivated areas of New Zealand. Rainy outliers (e.g. Milford and Mt Cook) and high mountain climates are not considered, as they represent extremes with relatively low human and agricultural activity

cloud forests and grasslands (Halloy et al. 2008). This is reflected in high morphological similarities of adaptations (Halloy and Mark 1996).

Together with tussock grasslands, temperate rainforests are the global biome climate types most represented in New Zealand. The northernmost areas of New Zealand approximate subtropical temperature conditions, with an ability to grow a range of subtropical plants.

The northern part of New Zealand is the most climatically suitable for the establishment of new pests and diseases coming from a subtropical/tropical climate. The area includes Kaitaia, Kerikeri, Whangarei, Auckland (New Zealand's largest city) and Tauranga. The latter two cities both contain large active sea ports.

The climate overlap between New Zealand and where a pest or disease has been reported can be assessed using the tool described in Phillips et al. (2018). This tool is based on the composite (or climate) match index (CMI) CLIMEX-MCR of CLIMEX version 3.3. The tool allows the comparison of New Zealand's climate in general or more specifically, with areas where a pest or disease occurs overseas. The higher the CMI, the more similar the climate of the region to which the CMI pertains and the New Zealand climate. A CMI of 0.7 or more between the New Zealand climate and the existing range of the pest or disease may indicate a high likelihood of climatic suitability for that pest or diseases to establish in New Zealand (Phillips et al. 2018).

For many of the pests or diseases assessed, this tool may be a sufficient indication of climatic suitability in New Zealand for the pest or disease to establish. A whole-world map with CMI data from Phillips et al. (2018) is provide in **Error! Reference source not found.**.2. When u sing the tool, the map can be enlarged to show more detail at a regional level.

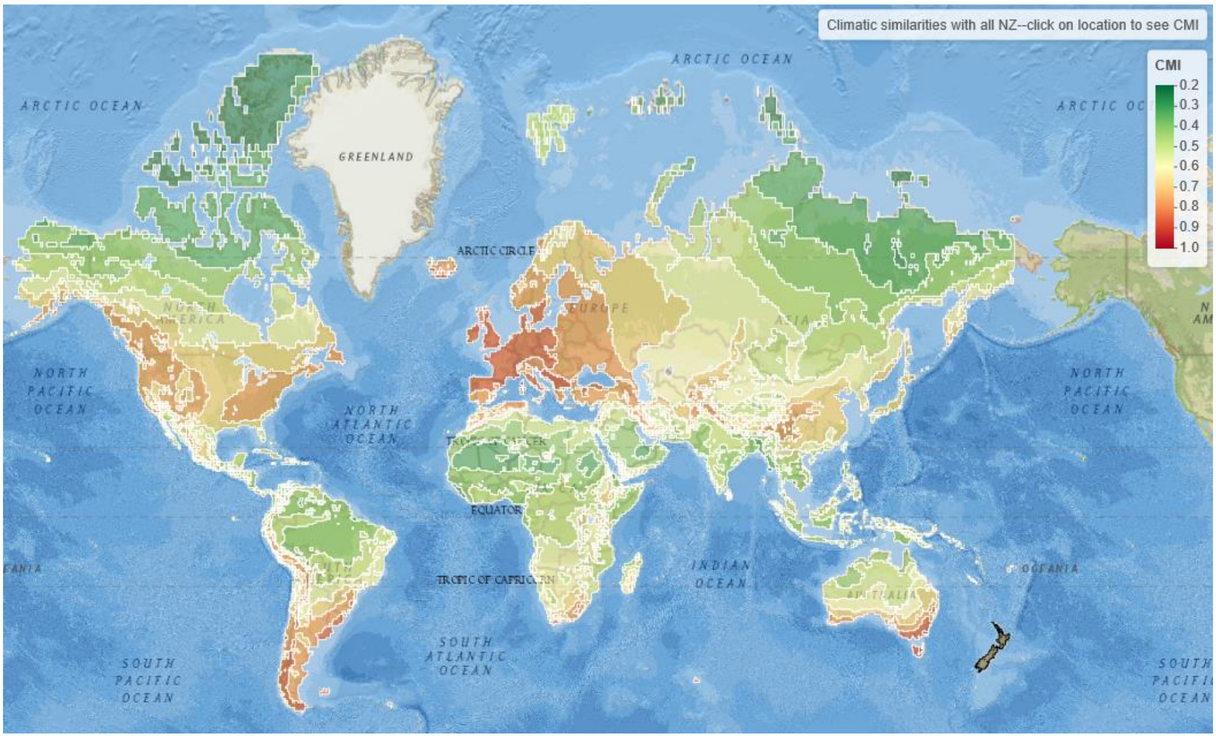

Figure 2.2 Climate match index (CMI). World climate similarities with All New Zealand (Phillips et al. 2018).

2.3.4 *Shifting New Zealand climates with climate change*

The global climate is warming rapidly and will continue to warm even faster as a result of greenhouse gas emissions (IPPC 1995; Allen et al. 2018; WMO 2019). Several studies have examined the effects of these changes on the New Zealand climate (NIWA 2017; MfE 2018).

Warming temperatures and changing precipitation patterns will affect existing biodiversity, pests and diseases, and will change the likelihood of establishment of new arrivals (Gerard et al. 2013; Kean et al. 2015).

However, climate change is not just a scenario for the future. Average New Zealand temperatures have risen substantially over the last century, with concomitant but more variable changes in threshold and extreme conditions (including frosts, heatwaves, droughts, tropical storms, etc). Sea surface temperatures (SSTs) around New Zealand are closely correlated with atmospheric warming, and in recent decades (since 1981), have been rising in the order of 0.1–0.3°C per decade (Sutton and Bowen 2019). This would equate to 1–3°C per century, close to the modelled predictions for 2100. Such trends are, to some degree, hidden by inter-annual variability, but are already significant for the biota, agriculture and human occupation.

These 'shifting goal posts' may lead to some confusion when reading climate change scenarios. Climate scenarios are expressed as degrees of change up to 2100, for example, a 2°C increase. However, the baseline for that increase may not be explicit to the reader. The baseline is sometimes referred to as 'conditions pre-industrial age', or 'beginning of 20th century'. Other times, it may be the '1961–1990 average', or more recently, the '1981–2010' average. Because of the continuous change since the pre-industrial period, the first baseline would lead to a 2°C increase by 2100. However, adding the same 2°C to a 1981–2010 baseline would mean ~3°C increase by 2100 in respect to pre-industrial conditions.

In New Zealand, some of the last years have already approximated a 2°C increase on pre-industrial levels. Although cool years will still occur, for an organism, some conditions in some years already approximate some models for 2100. Model scenarios for temperature increases for 2100 depend on many factors, but most scientists now expect there is little chance of keeping the increases below 2°C (Wallace-Wells 2019). For illustration's sake, exploring a conservative 2°C average increase (as in NIWA scenarios[36]) and a 10-mm monthly increase in precipitation allows us to investigate the consequences without making any judgement as to which is more likely.

We can then consider the likelihood of such scenarios. To give an idea of how conservative a +2°C is, consider that the average temperature in the last century has already climbed >1°C over pre-industrial values. As averages shift, so do the extremes of the distribution and the thresholds for frosts, degree days, etc. Note, for example, that the midpoint of July 2009–2018 is where extreme warm years were in 1928–1937; the extreme has already become the norm (Figure 2.3)[37]. Moreover, the pace of increase is accelerating, greenhouse gas emissions are still rising, and a series of potential tipping points may soon be breached. Due to prolonged lag times, the abrupt decline in emissions triggered from March 2020 due to the Covid-19 pandemic are not likely to affects trends in the next decades. If such declines were to continue, they could reduce the centennial temperature increase.

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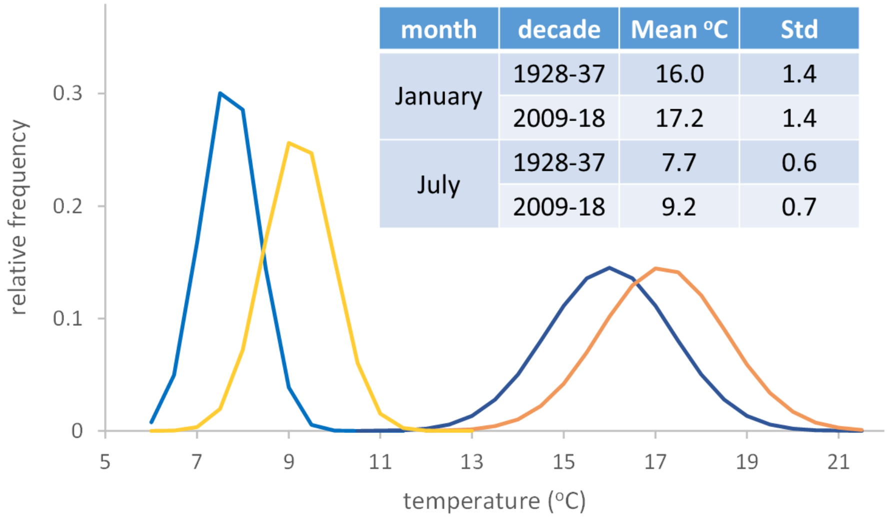
[36] 2°C is an 'in between' of the 0.7°C to 3°C range of scenarios in NIWA: https://niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios, 20171221. However, in more detail, https://ofcnz.niwa.co.nz/#/localCharts shows an increase to 2100 of 2°C (RCP 6) to 3°C (RCP 8.5) annual mean (for six-model average) for Christchurch. Annual precipitation remains almost the same. Spring °C and mm follow the same pattern. Summer (DJF) increases less (1.5°C to 2.3°C). For rainfall, possible increases are around 10 mm; however, there will be considerable geographic variation and this is only illustrative.

[37] Note that climatologists typically prefer to use 30 years to represent a climatic period. Decadal periods are, however, useful for biological systems, as a decade is a long enough time to determine whether an organism can perish, establish or invade.



month	decade	Mean °C	Std
January	1928-37	16.0	1.4
	2009-18	17.2	1.4
July	1928-37	7.7	0.6
	2009-18	9.2	0.7

Figure 2.3 Schematic normalised frequency distribution of mean monthly temperatures for July (left) and January (right) for Wellington, New Zealand. The blue line is 1928–1937, the orange line 2009–2018. Calculated from NIWA National Climate Database (https://cliflo.niwa.co.nz/). Note that actual frequency distributions tend to skew further right.

As a result of such shifts, in future scenarios, frosts decrease substantially, by 30% (RCP 2.6) to 50% (RCP 8.5[38]) for the year 2040 (MfE 2018).

2.4 General information related to impacts of pests and diseases

2.4.1 *Potential for spread*

Until recently, pineapples were not grown in New Zealand. There is now a plantation in Northland that produces a number of premium fruits for the local domestic market. They currently have 20, 000 plants. Pineapples require a tropical climate, which means their distribution is likely to be restricted to warmer parts of New Zealand, such as Northland and potentially Auckland (TropicalFruitGrowers 2021). Currently, pineapple specific pests (pests that pineapple is the only documented host) are unlikely to establish and spread in New Zealand, given the limited availability of host plants. However, pests and diseases of pineapple, which have other hosts, may be able to spread and establish in New Zealand based on host and climate suitability.

2.4.2 *Potential impacts in New Zealand*

Ananas comosus (pineapple) is a member of the family Bromeliaceae. The (NZflora 2021) database lists this plant family as ‘sometimes present, exotic (casual)’. There are no native Bromeliaceae in New Zealand (NZflora 2021; NZPCN 2022) and they are not widespread in the New Zealand environment. Therefore, pests and diseases only documented to affect pineapples are unlikely to cause environmental/cultural/social impacts to New Zealand. However, pineapples may harbour pests and diseases that affect multiple hosts, which may cause such impacts.

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[38] In the latest IPCC report, RCPs (representative concentration pathways) are used to indicate emission scenarios, where 2.6 and 8.5 are the lowest and highest (e.g (IPCC_WGI 2014; MfE 2018)).

2.4.3 *Potential for economic impacts to the pineapple industry*

Currently the New Zealand pineapple industry is small. There is one registered grower in Northland with 22,000 plants. They supply premium fruit to the local domestic market. The industry does not experience significant pest problems, with ants being the biggest issue. The introduction of pineapple pests and diseases, although unlikely to cause economic impacts for the whole of New Zealand, may cause issues for expanding the range of pineapples in New Zealand. It should be noted however, that the likelihood of transfer of pineapple specific pests from fresh imported pineapple to the single growing area in Northland is extremely low.

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3 Hazard identification

A hazard is a pest or disease that:

- is not present in New Zealand (or is present but still represents a biosecurity risk, e.g. is capable of vectoring pathogens not present in New Zealand);
- has the ability to establish and cause harm in New Zealand; and
- is associated with imported risk goods and import pathways.

Hazard identification (hazard ID) is the process where, depending on the scope of the IRA, a list of pests and diseases potentially associated with the commodity is compiled and then assessed against specified criteria, in order to determine which species require further assessment. The objective for hazard identification in this IRA is to identify all pests and diseases that meet the risk evaluation criteria for further assessment.

In this IRA pests or diseases that were determined to require a PRA were those that are associated with pineapple fruit (as per the commodity description), are not present in New Zealand and have the ability to establish and cause harm here.

Pineapple specific pests and diseases (pests and diseases that pineapple is the only documented host) were excluded, because host availability in New Zealand is limited to pineapple, meaning that they are unlikely to be exposed to a suitable host and therefore unlikely to establish. This however may need to be reassessed if and when the New Zealand pineapple industry grows or becomes more widespread.

A list of species identified at the hazard identification stage as associated with the commodity, present in at least one exporting market and potentially not being managed by compliance with the commodity description, and therefore requiring further assessment (a Pest Risk Assessment), is provided in Table 3.1.

Table 3.1: Pest groups and species for risk assessment following hazard identification.

Pest/disease group	Pests or diseases requiring Pest Risk Assessments (PRAs)
Bacteria	*Dickeya zea*
	Pantoea ananatis
Fungi	*Fusarium oxysporum*
	Fusarium verticillioides
	Pestalotiopsis microspora
	Thielaviopsis paradoxa
Insects: Order Diptera	*Bactrocera dorsalis*
Insects: Order Lepidoptera	*Anatrachyntis rileyi*
Insects: Hemiptera, Diaspididae	*Diaspis bromeliae*
Insects: Hemiptera, Pseudococcidae	*Dysmicoccus brevipes*
	Dysmicoccus neobrevipes
	Ferrisia virgata
	Planococcus minor
	Pseudococcus jackbeardsleyi
Vectors of pathogens	Mealybugs: *Planococcus citri, Pseudococcus longispinus*

4 Pest risk assessments: Bacteria

4.1 *Dickeya zeae* (bacterial heart rot/fruit collapse)

The bacterial genus *Dickeya* contains many species that are important plant pathogens. *Dickeya zeae* causes soft rot disease on plants all over the world and significant economic losses in tropical, subtropical, and temperate regions, especially on crops such as maize, rice and banana in Southeast Asian countries. The known host range of *D. zeae* includes over 40 plant species.

4.1.1 *Taxonomic description*

Scientific name: *Dickeya zeae* Samson et al. 2005
Order: Enterobacteria **Family:** Enterobacteriaceae
Other names: *Bacterium carotovorum* f. sp. *zeae*; *Erwinia carotovora*; Erwinia *carotovora* f. sp. *zeae*; *Erwinia carotovora* var. *chrysanthemi*; *Erwinia chrysanthemi*; *Erwinia chrysanthemi* corn pathotype; *Erwinia chrysanthemi* pv. *zeae*; *Erwinia maydis*; *Pectobacterium carotovorum* f. sp. *zeae*; *Pectobacterium carotovorum* var. *graminarum*; *Pectobacterium chrysanthemi*; *Pectobacterium chrysanthemi* pv. *zeae*; Bacterial soft rot of tobacco; bacterial stalk rot of maize; soft rot; wet rot; bacterial heart rot; pineapple fruit collapse.

Taxonomic notes:
Bacterial heart rot was first recorded in 1927, and pineapple fruit collapse was first recorded in 1935. These diseases were attributed to *Erwinia carotovora* subsp. *carotovora.* However, taxonomic changes resulted in the pathogen being reclassified as *Erwinia chrysanthemi* (Cano-Reinoso et al. 2021). A significant taxonomic change was later proposed in which *E. chrysanthemi* was divided into six species that were transferred to a new genus, *Dickeya*. Tesoriero (2018) described or redescribed *D. zeae, D. dadantii, D. chrysanthemi, D. diffenbachiae, D. dianthicola* and *D. paradisiaca*. Both *D. zeae* and *D. oryzae* were distinct enough to be initially grouped into two clades (Samson et al. 2005), after which *D. oryzae* was elevated to a new species (Wang et al. 2020; Van Gijsegem et al. 2021). *Dickeya zeae* strains have diverged enough to be distinct, phenotypically, and genetically, even if they infect the same host species (Hu et al. 2018).

4.1.2 *Hazard identification*

Dickeya zeae is not considered to be present in New Zealand.

- Although *Dickeya zeae* is recorded as present in New Zealand (BiotaNZ 2022; ICMP 2022), the conditions (collection event details) under which these specimens were collected cannot be verified.
    - There are 35 specimens, recorded in New Zealand, in the ICMP (2022), which were originally determined to be *Erwinia chrysanthemi,* and of these, nine were renamed as *D. zeae* (Table 4.1). However, the reasons why these specimens were renamed and how the specimens were determined to be *D. zeae* is uncertain (R. Taylor (PHEL), pers. comm) (MPI 2021).
    - Of these nine isolates, one (ICMP 11094) has subsequently been reassigned to the genus *Pseudomonas*. Three isolates (ICMP# 3915, 7131 & 7149) were confirmed to be *D. zeae* in 2022 by sequencing at 3 protein coding loci

    (Landcare 2022). The remaining five (ICMP# 7135, 7139, 7140, 7142 & 7143) appear to have been collected at the same time and locality as isolate 7131 from Zea mays plant showing the same stem rot symptoms and it is assumed that these too are *D. zeae*.
    - The eight isolates identified as *D. zeae* were all collected between 1974 and 1981 (Table 4.1).
    - *Dickeya zeae* has a wide host range, including widely cultivated crops such as carrots, maize, tomatoes, potatoes and onions, broad temperature tolerance (between 10°C and 41°C) (Aeny et al. 2020), can persist in the environment, has caused symptoms in hosts grown in temperate, tropical and subtropical climates, has a short (22 – 38 days) survival time in soil (Van Gijsegem et al. 2021) and can have severe impacts (Kumar et al. 2017; Van Gijsegem et al. 2021; Velez-Negron et al. 2022).
    - Impacts caused by *Dickeya* species can be sporadic and require specific conditions for symptoms to be expressed and for the disease symptoms to spread (Van Gijsegem et al. 2021). The New Zealand climate appears to be suitable for symptoms to be expressed in hosts such as maize and onion. Isolates collected in Pukekohe and Mount Albert in 1981 (Table 4.1) all came from *Zea mays* plants presenting stalk rot symptoms. Studies have reported *D. zeae* causing similar symptoms on maize in several provinces in China (Li et al. 2020), Korea (Hu et al. 2018) and Japan (Takeuchi and Kodama 1992) where climate matching (Philips et al. 2018) indicates temperatures are similar to New Zealand. No symptoms were recorded in the collection details for the single isolate of *D. zeae* collected from onion (*Allium cepa*) in Pukekoe in 1974. However, (Palacio-Bielsaa et al. 2007) report bacterial soft rot in basal stem and leaves of onion caused by *Pectobacterium chrysanthemi* biovar 3 (later re-isolated and identified as *Dickeya* sp. "probably *D. zeae*" based on 97% partial 16S rDNA sequence similarity with the type strains of *D. zeae*) from Zaragoza, Spain. Climate matching with this area of Spain returns an 80% similarity to the New Zealand climate (Phillips et al. 2018), suggesting that symptoms of *D. zeae* are likely to be expressed in onion growing in New Zealand.
    - It seems likely, given the above traits, that if *D. zeae* were still present in New Zealand then symptoms would have been observed and reported on in the years since the bacterium was last recorded here in 1981 (ICMP 2022).
    - Taking the above evidence into account, for the purposes of this risk assessment, MPI does not consider *D. zeae* as being present in New Zealand.
- There is no entry of *Dickeya zeae* in PPIN (2022). However, *Erwinia chrysanthemi* pv. *zeae* has been recorded on *Zea mays* leaf stalk in Gisborne (PPIN 2022). No further information was recorded, and it cannot be determined if the strains molecularly match *D. zeae* or the isolates recorded in BiotaNZ (2022) and ICMP (2022).
- *Dickeya zeae* is not regulated and is not an unwanted organism (ONZPR (2022)).

Dickeya zeae has the potential to establish a population, spread and cause harm to New Zealand.

- *Dickeya zeae* has a wide geographic distribution (Pedron and Van Gijsegem 2019; Hugouvieux-Cotte-Pattat et al. 2020; ERS 2021; Van Gijsegem et al. 2021). It can complete its lifecycle in a variety of climates and is known to persist in soil and irrigation waters.

- *Dickeya zeae* is known to infect more than 40 plant species, from 24 families, including pineapple fruit, *Allium cepa* (onion), *Solanum tuberosum* (potato) and *S. lycopersicum* (tomato) (Hu et al. 2018; Aeny et al. 2020; Van Gijsegem et al. 2021). Host range assessments were conducted by using *D. zeae* bacterial suspension isolated from symptomatic pineapple leaves found in Lumpang, Indonesia (Aeny et al. 2020). These host range assessments confirmed soft rot symptoms in *Aloe vera*, *Brassica chinensis* (cabbage), *Hylocereus undatus* (dragonfruit), *Solanum melongena* (eggplant), *Lactuca sativa* (lettuce) and *Allium fistulosum* (spring onion). However, it is important to note that these symptoms were obtained after artificial inoculation in a laboratory setting and not from natural field observations.
- *Dickeya zeae* has the potential to cause harm to plant species of economic importance in New Zealand (e.g., tomato, potato, and maize) and to common amenity species such as chrysanthemums and orchids (Hu et al. 2018; Aeny et al. 2020; Van Gijsegem et al. 2021).

Dickeya zeae is associated with pineapple fruit.

- *Dickeya zeae* has been reported from pineapple fruit and has been identified as the causal agent of pineapple fruit collapse and bacterial heart rot. (Aeny et al. 2017; Aeny et al. 2020).

Given the arguments and evidence above, MPI considers *Dickeya zeae* a hazard on pineapple fruit imported to New Zealand.

Table 4.1. Collection details of nine isolates identified as *Dickeya zeae* collected in New Zealand between 1974 and 1992.

ICPM #	Original determination	Current determination	Host	Collection Locality	Collection date	Symptoms
3915	*Erwinia carotovora* subsp. *carotovora* (Jones 1901) Bergey et al. 1923	*Dickeya zeae* Samson et al. 2005	*Allium cepa* L. (onion)	Pukekohe	Feb 1974	Collected from bulb. No symptoms recorded
7131, 7135, 7139, 7140, 7142, 7143	*Erwinia chrysanthemi* pv. *zeae* (Sabet 1954) Victoria et al. 1975	*Dickeya zeae* Samson et al. 2005	*Zea mays* L. (corn)	Pukekohe	Jan 1981	sour-smelling stalk rot
7149	*Erwinia chrysanthemi* pv. *zeae* (Sabet 1954) Victoria et al. 1975	*Dickeya zeae* Samson et al. 2005	*Zea mays* L. var. *rugosa* Bonaf. (sweetcorn)	Mount Albert	Feb 1981	stalk rot of seedling
11094	*Erwinia chrysanthemi* pv. *zeae* (Sabet 1954) Victoria et al. 1975	*Pseudomonas* Migula 1894 near *Pseudomonas mediterranea*	Zea mays L. (corn)	Gisborne	Unspecified, but before May 1992	stalk rot, foul odour, translucent leaf spots

4.1.3 *Risk assessment*

4.1.3.1 Biology

Hosts and geographical distribution

Dickeya zeae has a wide host and geographic range (Appendix: Table 1). The pathogen is likely to have originated in Malaysia (Aeny et al. 2020; Cano-Reinoso et al. 2021) and has been recorded in the African, Asian, American, and European continents (Appendix: Table 1) (Pedron and Van Gijsegem 2019; Hugouvieux-Cotte-Pattat et al. 2020; ERS 2021; Van Gijsegem et al. 2021). It can complete its lifecycle in a variety of climates and has been known to persist in soil and irrigation waters (Kaneshiro et al. 2008; Lin et al. 2016).

Symptoms

Dickeya zeae is a facultative, anaerobic bacterium that survives in soil and causes water-soaking and rot symptoms in pineapple fruits. The disease can remain latent and cause systemic rot which move from leaves to heart (or vice versa) (Cano-Reinoso et al. 2021).

Symptoms on infected pineapple fruit, commonly known as fruit collapse, include soft rot accompanied by gas bubbles and fruit collapse two to three weeks prior to normal ripening (Figure 1A and B) (Cano-Reinoso et al. 2021). *Dickeya zeae* establishes its growing pattern by fermenting the carbohydrates in the fruit flesh, releasing gas bubbles in the process. The colour of the fruit shell turns olive-green (similar to pineapple fruit colour classified as C1 on the pineapple ripeness scale mentioned in Annex 2.2), and the internal part of the fruit shows cavities within the flesh's skeletal fibres (Figure 1) (Cano-Reinoso et al. 2021). These symptoms were comparable to symptoms observed on pineapple fruit, caused by *Dickeya* spp. (recorded as *Erwinia chrysanthemi* in the primary literature) in Hawaii (Kaneshiro et al., 2008) and Malaysia (Sahilah et al., 2008).

Disease symptoms on pineapple plants, while not part of the commodity description, known as bacterial heart rot, can appear as bloated and dark water-soaked lesions on the plant leaves (Figure 1C and D). Late symptoms showed blister-like lesions on the upper surface of the leaf lamina (Ramachandran et al. 2015).

Symptoms from different countries can vary (Kaneshiro et al. (2008). For example, wrinkled and dry necrotic lesions were found on Philippine pineapple plant samples. Costa Rican and Honduran pineapple plant samples had light tan or brown water-soaked blisters on the leaf lamina and broad, brown, or dark brown water-soaked areas extending from the leaf down to the stock tissues in the plant heart.

Dickeya zeae is viable between 10 – 41˚C, with the optimal temperature range specified as 30–35°C on rice crops (Lin et al. 2016; Aeny et al. 2020). The optimal temperature range on pineapple fruit has not been described in the available literature. *Dickeya zeae* favours low soil temperatures, with the pathogen surviving in a loamy sand for 38 days at 8°C, for 22 days at 20°C and for 12 days at 30°C. Slightly longer survival periods (32 days) were found at low soil moisture levels (30 %) than at those exceeding 60% (22 days) (Van Gijsegem et al. 2021).

In laboratory conditions, *D. zeae* symptoms can be observed 72 hours after inoculation, on pineapple plants. The final stage of the disease was recorded 21 days after inoculation (Ramachandran et al. 2015).

Latency of symptoms

Latent infection appears to be a common trait of *D. zeae*. The disease has previously been found to be asymptomatic for approximately 10 years in rice plantations in China, eventually resulting in 90% losses (Hu et al. 2018).

In pineapple fruit collapse, *D. zeae* invades the plant ovary through the style, generating water-soaked necrosis symptoms. The pathogen remains viable but quiescent for up to two months, and then breaks out to invade the entire fruit (Aeny et al. 2017; Aeny et al. 2020; Cano-Reinoso et al. 2021). Disease activity increases between two to three weeks before ripening, when sugar levels increase rapidly and enzyme levels like polyphenol oxidase decline (Aeny et al. 2020; Boluk et al. 2021; Cano-Reinoso et al. 2021). The pathogen can multiply rapidly before symptoms become visible (Cano-Reinoso et al. 2021).

According to Parkinson et al. (2009), isolates or strains that have been present and latent in the environment for a relatively long period might accumulate molecular variation and this may contribute to diversity within a species. This is likely applicable for *D. zeae* in Malaysia, where it has been present since 1927 (Ramachandran et al. 2015).

Pineapple variety susceptibility

Fruit collapse and bacterial heart rot are common diseases in low-acid pineapple fruit hybrids due to increased susceptibility to natural flowering abrasion injuries and their physiochemical properties (Cano-Reinoso et al. 2021). The Malaysian hybrid pineapple fruit cultivars Josapine and MD2 have been found to be seriously infected by *D. zeae* (Ramachandran et al. 2015; Nor et al. 2019). The low acid cultivar PRI 73-114 pineapple fruit, imported from Costa Rica and Honduras to Hawaii, in 2003, was found to be infected with *D. zeae* (Sueno et al. 2014). The Josapine and Smooth Cayenne cultivars have been found to be more susceptible to bacterial heart rot (Sueno et al. 2014).

Reproduction and transmission

Dickeya zeae infection occurs through the stomata and invades the plant ovary. In pineapple plants, *D. zeae* penetrates tissue via the plant’s natural openings, lesions, and injuries, and mainly during the opening phase of flowering weeks prior to harvest (Cano-Reinoso et al. 2021). The primary inoculum source of bacterial heart rot and fruit collapse is considered to be exuded juice of previously infected plants. The process and symptomology are similar across different host plant types and species (Van Gijsegem et al. 2021).

The bacterium can be transmitted by insects, e.g. *Pheidole megacephala* (big-headed ant) and *Linepithema humile* (Argentine ant) (Cano-Reinoso et al. 2021); both present in New Zealand (NZOR 2022), wind and windblown rain (Aeny et al. 2020; Boluk et al. 2021; Cano-Reinoso et al. 2021). However, the extent and rate at which this occurs is unclear.

The pathogen can be present on the surface of field and processing machinery, stores and storage boxes and graders etc. It may also occur in artificial media used to grow plants and can be a major problem for cut flowers. Superficial, or epiphytic, colonisation is likely a natural part of the *Dickeya* species lifecycle as the disease can remain on the surface of different plants both with and without subsequent disease development (Van Gijsegem et al. 2021).

Figure 4.1 The symptoms of fruit collapse and bacterial heart rot in pineapple, caused by *Dickeya zeae*. A. Release of gas bubbles together with olive-green colour in the shell (red circle), after harvest. B. Cavities within the skeletal collapse fibres in the flesh (black circle), after harvest. C. Aerial view of pineapple plant peduncle (red circle). D. Internal view after removing the peduncle (yellow circle). C. and D. In both images, a water-soaked lesion can be on white basal portion of leaves, located in the central whorl. The green mid-part of the leaves shows the olive-green colour and dark border formation. Images adapted and used with permission from (Medina and García 2005; MfE 2018).

4.1.3.2 Likelihood of entry

Dickeya zeae has a wide distribution and host range (Appendix: Table 1). The countries considered within the scope of this IRA project and where *D. zeae* is present are Malaysia, Costa Rica, the Philippines, and Indonesia (Rohrbach and Johnson 2003; Korres et al. 2010; Prasetyo and Aeny 2014; Cano-Reinoso et al. 2021; Van Gijsegem et al. 2021). In these regions, *D. zeae* cause bacterial wilt and fruit rot on pineapples. Of these countries the bacterium has been reported causing pineapple fruit collapse in Malaysia, Brazil and Indonesia (Rohrbach and Johnson 2003; Korres et al. 2010; Prasetyo and Aeny 2014; Cano-Reinoso et al. 2021) and bacterial heart rot disease in Malaysia, Costa Rica, Brazil, the Philippines and Hawaii (Rohrbach and Johnson 2003; Kaneshiro et al. 2008; Ramachandran et al. 2015; Pires de Matos 2017; Cano-Reinoso et al. 2021). *Dickeya zeae* has been detected on pineapples in Queensland, Australia (included within the scope of this IRA) but it is as yet unclear how closely related these strains are to other strains of *D. zeae* (Tesoriero 2018).

A search of New Zealand interception records show no records of *D. zeae* or known synonyms, between 2000–2020 (LIMS 2022). The European & Mediterranean Plant Protection Organization records interceptions of *Erwinia* sp. and *E. chrysanthemi* on potato seeds and tissue culture from the United Kingdom, Netherlands, Belgium, France, Taiwan and Thailand (EPPO 2022).

Symptoms on infected pineapple fruit include soft rot accompanied by gas bubbles and fruit collapse two to three weeks prior to normal ripening (see detail in Annex 4.1.3.1 Symptoms; Figure 4.1A and B) (Cano-Reinoso et al. 2021). *Dickeya zeae* can also occur in many host plants in the tropics and subtropics region as this pathogen can thrive at higher temperatures than other soft rot bacteria (Rohrbach and Johnson 2003; Sipes and de Matos 2018).

Latent infection appears to be a common trait of *D. zeae* infection (see detail in Annex 4.1.3.1 Latency of symptoms). The pathogen remains viable but quiescent for up to two months and can invade the entire fruit (Aeny et al. 2017; Aeny et al. 2020; Cano-Reinoso et al. 2021). We found no evidence in the literature to suggest *D. zeae* can develop resistance to in-field bactericides or fungicides.

It is likely that visibly symptomatic pineapple fruit, due to *D. zeae,* will be excluded during packhouse activities. However, asymptomatic fruit will likely not be excluded. Furthermore, due to the disease's temperature tolerance (Rohrbach and Johnson 2003; Lin et al. 2016; Aeny et al. 2020) and latency traits (Rohrbach and Johnson 2003; Lin et al. 2016; Aeny et al. 2017; Aeny et al. 2020; Cano-Reinoso et al. 2021), it is likely to be viable on pineapple fruit during transit conditions (as described in Appendix 3).

Given that:

- *Dickeya zeae* is present in many of the countries included within the scope of this IRA;
- it has a strong association with pineapple fruit;
- it has the potential for latent and asymptomatic infection; and
- it has the potential to remain viable on pineapple fruit during transit;

MPI considers the likelihood of *Dickeya zeae* entering New Zealand associated with pineapple fruit to be MODERATE, with LOW uncertainty.

4.1.3.3 Likelihood of exposure

This assessment is made on the assumption that Dickeya zeae *has entered New Zealand undetected.*

Fresh pineapple fruit generates substantial amounts of unavoidable waste; the thick rind is always removed and disposed of, and the fruit is also sometimes cored (see waste analysis in Annex 2.3.1). The disposal of whole fruit (e.g., culled/unsold fruit, uneaten fruit remains) is not uncommon during wholesale, retail and by consumers. This suggests that *D. zeae* may have a higher likelihood of exposure when associated with fresh pineapple fruit than when it is associated with other kinds of fresh produce.

D. zeae is a systemic bacterial pathogen with a wide host range (Appendix to Risk Assessment of *Dickeya zeae*: Table 1) (Kaneshiro et al. 2008; Aeny et al. 2020). *Dickeya* species can survive in a variety of environmental niches, including water, soil and on insects, which is likely to aid their spread to susceptible hosts and/or enable persistence in an environment (Van Gijsegem et al. 2021). Discarded waste from imported infected fruit could act as a vehicle for exposure of the bacteria to the environment. Characteristics of the pathogen that increase this likelihood are its variable temperature tolerance (between 10–41°C) (Lin et al. 2016), wide host range (Kaneshiro et al. 2008; Aeny et al. 2020), ability to remain latent in aquatic and biotic niches (Van Gijsegem et al. 2021) and ability to infect all parts of the plant. Infected soil or crop residue disturbed from compost over host plants would act as a primary source of inoculum. *Dickeya zeae* can be carried internally or externally on crop residues or as free bacterial cells in soil. Free water can also provide access into and spread bacteria in host plants. The pathogen can also be introduced and spread through insect feeding activity (see detail in Annex 4.1.3.1 Reproduction and transmission). These characteristics of the pathogen can enable not only its spread in the environment, but also its survivability until suitable host/climate is found.

Uncertainty

Uncertainty associated with likelihood of exposure in New Zealand to *D. zeae* is attributed to the sparse data available regarding pineapple fruit waste and associated diseases.

Given that:

- the large quantity of unavoidable waste associated with fresh pineapple fruit;
- the pathogen’s wide host range, climatic tolerance, and persistence in varying environmental niches;
- the pathogen’s systemic nature of infection, and
- the pathogen can be transmitted by insects, wind, windblown rain, and free water;

the likelihood of exposure of *Dickeya zeae* in New Zealand from pineapple fruit is considered to be MODERATE, with MODERATE uncertainty.

4.1.3.4 Likelihood of establishment

This assessment is made on the basis that Dickeya zeae *has been successfully exposed to a suitable host plant in the New Zealand environment.*

Dickeya zeae has a broad host range (Appendix: Table 1). Many known hosts of *D. zeae* are either grown commercially in New Zealand (e.g., tomatoes and potatoes) or as backyard plants in many home gardens. Therefore, hosts for the establishment of *Dickeya zeae* are readily available.

Climate similarity to New Zealand is assessed using the climate match index (CMI) (Phillips et al. 2018). If a country has a CMI of ⩾0.7 then it is considered to have climate similar to all of New Zealand. Currently, *D. zeae* is mostly present (on various hosts, including pineapples) in countries where climate does not closely match New Zealand. For example, pineapple fruit collapse associated with *D. zeae* has been recorded in Malaysia (CMI 0.5), Brazil (CMI 0.4–0.5) and Indonesia (0.4–0.6) (Rohrbach and Johnson 2003; Korres et al. 2010; Prasetyo and Aeny 2014; Cano-Reinoso et al. 2021). Bacterial heart rot of pineapple associated with *D. zeae* has been recorded in Malaysia, Costa Rica (0.4–0.6), Brazil, the Philippines (CMI 0.3–0.6) and Hawaii (0.5–0.8) (Rohrbach and Johnson 2003; Kaneshiro et al. 2008; Ramachandran et al. 2015; Pires de Matos 2017; Cano-Reinoso et al. 2021).

However, *Dickeya zeae* has been reported in Chinese provinces of Jiangsu (CMI 0.7), Fujian (CMI 0.7), Hunan (0.7), Guizhou (0.7) and Guangdong (CMI 0.6) (Hu et al. 2018), Korea (CMI 0.7) (Myung et al. 2010) and Hokkaido, Japan (CMI 0.7 – 0.8) (recorded as *E. chrysanthemi pv. zeae*) (Takeuchi and Kodama 1992). Also, variable temperature tolerance of the pathogen and the continued impacts of climate change, which has been predicted to increase the minimum temperature of the coldest month, increases the risk of *D. zeae* establishing a population in New Zealand in the future (Grüter et al. 2022).

The pathogen can also persist in soil and water, increasing likelihood of establishment. Furthermore, northern parts of New Zealand have a warmer and more humid climate than the rest of the country, similar to optimal climate range of *D. zeae* while the rest of the country has comparable climate to regions overseas where the bacterium has been recorded.

Given that:

- assumptions made indicate that *D. zeae* is no longer present in New Zealand;
- hosts are available for the establishment of *Dickeya zeae;*
- *Dickeya zeae's* ability to remain latent in the environment, and
- climate matching evidence suggesting countries with comparable temperatures to New Zealand reporting evidence of the pathogen indicates climate in New Zealand is not likely to prevent establishment;

the likelihood of *Dickeya zeae* establishing in New Zealand is considered to be MODERATE, with LOW uncertainty.

4.1.3.5 Impacts in New Zealand

This assessment is made on the assumption that Dickeya zeae *has successfully established in the New Zealand environment.*

Economic impacts

For this assessment, MPI does not consider *D. zeae* present in New Zealand, and no major economic impacts associated with *D. zeae* have been recorded in New Zealand.

Dickeya zeae causes significant economic impacts for the Malaysian and Indonesian pineapple fruit industry. Given the broad host range of *D. zeae* species, it is likely that pineapple fruits would not be the only commercially produced hosts affected by this pathogen

(Appendix: Table 1). Severe infection of some high value crops (e.g., rice and maize) can cause economic losses of up to 90%. Crop yield and quality can diminish after infection, reducing marketability (Toth et al. 2011; Van Gijsegem et al. 2021). For example, in Israel, yield reductions of 20–25% resulting from *Dickeya* infections have been recorded on various potato cultivars, where disease incidence was greater than 15% (Toth et al. 2011).

An experimental study by Lin et al. (2016) found, that the optimal temperature range for disease expression of *D. zeae* on maize is between 30–35°C. This indicates that current climate in New Zealand (NIWA 2022) may not be optimal for development and growth of *D. zeae*. However, maize stalk rot symptoms caused by *D. zeae* have been reported in Korea (Myung et al. 2010), Hokkaido, Japan (recorded as *E. chrysanthemi* pv. *zeae*) (Takeuchi and Kodama 1992) and several provinces in China (Jiangsu, Fujian, Hunan, Guizhou, Guangdong) (Hu et al. 2018). Based on climate matching index (Phillips et al. 2018), Korea (0.7 CMI), Hokkaido (0.7 – 0.8 CMI) and the provinces in China (0.6 – 0.7 CMI) have comparable climatic conditions to New Zealand. Regions where majority of maize crops are grown (Waikato, Gisborne, Bay of Plenty and Hawkes Bay) (StatsNZ 2018) do not currently have climate optimal for growth and development of *D. zeae* (NIWA 2022). However, given disease symptoms have been reported in maize grown in comparable environments overseas, it is likely that maize rot symptoms would be observed in these regions if *D. zeae* were to or had already established in the country. If the climate warms and *D. zeae* established in New Zealand, there are likely to be significant economic consequences for the grain and arable crop industry, which provides essential raw material for the wider food industry.

In 2020, the cumulative domestic value of fresh fruit and vegetables listed as known hosts of *D. zeae* was NZ$645.1m with a much smaller proportion (NZ$211.7m) exported internationally (Appendix: Table 1). This included the domestic sale and exports of high value crops such as tomatoes, maize, potatoes and onions (Plant & Food Research 2021).

Disease incidence in *D. zeae* varies between 20 – 60%, depending on host and environmental conditions (Kumar et al. 2017; Van Gijsegem et al. 2021; Velez-Negron et al. 2022). An in-house MPI model predicted, at most a total economic impact of NZ$860.64m (disease incidence estimated to be 60%) or at least NZ$286.88m (disease incidence estimated to be 60%) over 20 years in the domestic market.

- This is based on the estimated combined annual value of domestically grown hosts of *D. zeae* amounting to NZ$645.1m (Appendix: Table 1);
- The bacteria is assumed to take one year to achieve greatest impacts, to allow time for effective spread across New Zealand;
- Time for recovery was assumed to be four years as the horticultural industries are likely to make use of resistant cultivars, effective infield treatments and other measures to limit spread, similar to other countries around the world (Van Gijsegem et al. 2021).

Dickeya zeae is not listed as a quarantine pest for any other country according to the importing countries phytosanitary requirements (ICPR) and thus there would be no immediate trade impacts.

Uncertainty
Uncertainty associated with economic impacts caused by *D. zeae* in New Zealand is attributed to the sparse data available regarding climatic factors involved in disease

expression and the impact of climate change in growing regions of economically important crops.

Given that:

- *Dickeya zeae* is known to cause significant economic impacts overseas with similar climate to New Zealand, and
- the host range of *D. zeae* indicates export and domestically high value crops such as tomatoes, onions and potatoes could be affected to, in the worst case, a total sum of NZ$860.64 over 20 years;

MPI considers the economic impact of *Dickeya zeae* on New Zealand to be MODERATE, with MODERATE uncertainty.

Environmental impacts

It is not known if *D. zeae* is able to infect any endemic plant species, however some known host genera include species that are native to New Zealand, e.g. *Apium*, *Ipomoea*, *Solanum* and *Dendrobium* (Hu et al. 2018; Aeny et al. 2020; NZPCN 2022), which indicates that endemic plant species may be hosts.

Given the likelihood that *D. zeae* can survive in soils, waterways and on surfaces, under variable temperature ranges and can infect numerous plant hosts, this pathogen could have a wide range of environmental impacts. Furthermore, control and eradication measures for *D. zeae* are unlikely to be implemented due to its ability to persist in soil and water (Van Gijsegem et al. 2021). Thus, impacts in the environment will likely last for more than one season.

Uncertainty associated with likelihood of exposure in New Zealand to *D. zeae* is attributed to the limited field or laboratory observations specifically addressing spread and establishment of *D. zeae* in native environments.

Given the arguments and evidence above, MPI considers the impact on environment from the establishment of *D. zeae* in New Zealand is LOW, with HIGH uncertainty.

Human health impacts

We used the terms ‘Dickeya zeae,’ ‘Erwinia chrysanthemi’ and combinations of these to search PubMed, Google Scholar, CAB Abstracts and Google and found no mention of adverse effects on humans or animals.

MPI considers the health impacts of *Dickeya zeae* on New Zealand to be NEGLIGIBLE, with LOW uncertainty.

Sociocultural impacts

Many hosts of *D. zeae* are commonly grown in home gardens (e.g., tomatoes, potatoes, carrots). *Dickeya zeae* symptoms may make vegetables less attractive to consumers but are unlikely to cause scarcity in local markets.

Hu et al. (2018) artificially inoculated *Ipomoea batatas* (kūmara). This is a culturally important crop for tangata whenua in New Zealand. Kūmara has been grown in New Zealand for many years in home gardens and is associated with cultural identity. No other taonga species are known to be hosts of *D. zeae.*

MPI considers the sociocultural impacts of *Dickeya zeae* on New Zealand to be LOW, with MODERATE uncertainty.

Overall impact to New Zealand

The overall impact of *Dickeya zeae* on the New Zealand economy, environment, health, and society is considered to be MODERATE, with MODERATE uncertainty.

4.1.3.6 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is MODERATE with LOW uncertainty,
- assuming entry, the likelihood of exposure is MODERATE with MODERATE uncertainty,
- assuming successful exposure, the likelihood of establishment is MODERATE with LOW uncertainty,
- the overall impact on the New Zealand economy, environment, human health, and society is considered to be MODERATE with MODERATE uncertainty,

MPI assesses the overall level of assessed risk to New Zealand from *D. zeae* on pineapple fruit is MODERATE, with MODERATE uncertainty.

4.1.4 *Specific considerations*

On which pineapple fruit variety (or varieties) and at what stage of ripeness has *Dickeya zeae* association with pineapple fruit been observed?

Fruit collapse and bacterial heart rot are common diseases in low-acid pineapple fruit hybrids due to increased susceptibility to natural flowering abrasion injuries and their physiochemical properties (Cano-Reinoso et al. 2021). The Malaysian hybrid pineapple fruit cultivars Josapine and MD2 have been found to be seriously infected by *D. zeae* (Ramachandran et al. 2015; Nor et al. 2019). The low acid cultivar PRI 73-114 pineapple fruit, imported from Costa Rica and Honduras to Hawaii, in 2003, was found to be infected with *D. zeae* (Sueno et al. 2014). The Josapine and Smooth Cayenne cultivars have been found to be more susceptible to bacterial heart rot (Sueno et al. 2014).

The pathogen has been found to affect pineapple fruit between C3 – C4 stage of ripeness (Cano-Reinoso et al. 2021).

Which parts of the pineapple fruit is *Dickeya zeae* associated with (e.g., fruit, bract, stem, or crown remnant), and is it visually detectable?

Dickeya zeae can cause systematic rot which move from leaves to heart (or vice versa). The pathogen has been reported from whole pineapple fruit and plant and has been identified as the causal agent of pineapple fruit collapse and bacterial heart rot. (Aeny et al. 2017; Aeny et al. 2020).

Under what environmental conditions (temperature, season, etc.) are *Dickeya zeae* symptoms expressed on pineapple fruit?

Dickeya zeae is viable between 10–41°C, with optimal temperature range specified as 30–35°C (Lin et al. 2016; Aeny et al. 2020). However, it should be noted that this temperature range was described on rice in Taiwan. An optimal temperature range on pineapple fruit has not been described in the available literature.

Does *Dickeya zeae* exhibits latent/asymptomatic traits?
Latent infection appears to be a common trait of *D. zeae*. In pineapple fruit collapse the pathogen invades the ovary through the style, generating water-soaked necrosis symptoms. The pathogen remains viable but dormant for up to two months, and then breaks out to invade the entire fruit (Aeny et al. 2017; Aeny et al. 2020; Cano-Reinoso et al. 2021). Disease activity increases between two to three weeks before ripening, (Aeny et al. 2020; Boluk et al. 2021; Cano-Reinoso et al. 2021). The pathogen can multiply rapidly before symptoms become visible (Cano-Reinoso et al. 2021).

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4.1.6 *Appendix to risk assessment of Dickeya zeae*

Table 4.2. Host range of *Dickeya zeae,* as recorded in the current, available English literature. Countries included within the scope of this Import Risk Analysis are in bold. The value in the New Zealand market of significant hosts were calculated using a report by Plant & Food Research (2021). Total domestic value of fresh produce hosts of *Dickeya zeae* was NZ$645.1 million. Total export value was NZ$211.7 million. Total value of *D. zeae* hosts is NZ$856.8 million.

Host family	Host species	Common name	Country recorded from	Value in NZ market (in NZ$)	Reference
Amaranthaceae	*Beta vulgaris*	Beets	India, **Indonesia**	-	Hu et al. (2018)
Amaryllidaceae	*Clivia* sp.	Bush Lily	China	-	Hu et al. (2018)
Apiaceae	*Daucus carota*	Carrots	USA, Brazil, France, Italy, Senegal, Cuba, Egypt, Mexico, India, Korea, Iran, Japan, China, **Thailand**	Domestic ($58 m) Export ($7.7 m (fresh))	Hu et al. (2018); CABI (2021)
	Apium graveolus	Celery	China	Domestic ($12.5 m)	Aeny et al. (2020)
Araceae	*Colocasia esculenta*	Taro	India	-	Hu et al. (2018)
	Dieffenbachia sp.	Dumb canes	China	-	Hu et al. (2018)
	Monstera sp.	Swiss cheese plant	China	-	Hu et al. (2018)
	Philodendron sp.	Philodendron	China, **Indonesia**	-	Hu et al. (2018); CABI (2021)
	Syngonium sp.	Arrowhead vine	**Indonesia**	-	Hu et al. (2018)
Asparagaceae	*Dracaena marginata*	Dragon tree		-	CABI (2021)
	Hyacinthus sp.	Hyacinth	India	-	Hu et al. (2018); Toth (2021)
Asparagales	*Allium fistulosum*	Spring onion	Netherlands	-	Hu et al. (2018); Aeny et al. (2020)
	Allium cepa	Onion	China	Domestic ($23.4 m) Export ($147.6 m)	Hu et al. (2018); Aeny et al. (2020)
	Belamcanda sp.	Blackberry lily	China	-	Hu et al. (2018)
	Iris sp.	Iris	India	-	Hu et al. (2018)
Asphodelaceae	*Aloe vera*	Aloe	USA, UK	-	Aeny et al. (2020)
	Hemerocallis sp.	Daylilies	China, **Indonesia**	-	Hu et al. (2018)
Asteraceae	*Chrysanthemum morifolium*	Florist's daisy	USA, UK	Export ($0.1 m)	Hu et al. (2018); CABI (2021)
	Chrysanthemum indicum	Chrysanthemum	China		Aeny et al. (2020)
	Lactuca sativa	Lettuce	India	Domestic ($43 m) Export ($0.7 m)	Aeny et al. (2020)
Balsaminaceae	*Impatiens balsamina*	Garden balsam	China	-	Hu et al. (2018)
Brassicaceae	*Brassica oleracea*	Cabbage		Domestic ($22 m)	Hu et al. (2018)

	Brassica rapa	Mustard	Ivory Coast, Jamaica, **Panama**, Martinique, China	-	Hu et al. (2018)
	Brassica chinensis	Chinese cabbage	China	-	Aeny et al. (2020)
Bromeliaceae	*Ananas comosus*	Pineapple	Martinique, Queensland, **Malaysia**	-	Hu et al. (2018); Toth (2021)
	Aechmea fasciata	Silver vase	China	-	CABI (2021)
Cactaceae	*Gymnocalycium sp.*	Chin cactus	India	-	Hu et al. (2018)
	Hylocereus undatus	Dragon fruit	China	-	Aeny et al. (2020)
	Opuntia littoralis	Prickly pear	China	-	Aeny et al. (2020)
Cannaceae	*Canna edulis syn. indica*	Indian shot	China, **Indonesia**	-	(Yang et al. 2019); CABI (2021)
Caricaceae	*Carica papaya*	Papaya	Japan, **the Philippines**, Bangladesh, China, India, **Indonesia**, South Korea, North Korea, Italy	-	Hu et al. (2018)
Caryophyllaceae	*Dianthus* sp.	Carnation	**Australia**, **Papua New Guinea**	-	Hu et al. (2018)
Convolvulaceae	*Ipomoea batatas* (artificial inoculation)	Sweet potato	India	Domestic ($35 m)	Hu et al. (2018) CABI (2021)
Crassulaceae	*Aeonium* sp.	Tree houseleek	Greece, USA, Florida	-	Hu et al. (2018)
	Kalanchoe thyrsiflora	Paddle plant	India	-	Hu et al. (2018)
Cucurbitaceae	*Cucumis sativus*	Cucumber	China	Domestic ($22 m)	Hu et al. (2018)
	Luffa cylindrica	Sponge gourd	China, **Indonesia**	-	Hu et al. (2018)
Euphorbiaceae	*Euphorbia pulcherrima*	Poinsettia	Cuba, India	-	Hu et al. (2018); CABI (2021)
Fabaceae	*Arachis hypogaea*	Peanut	Greece, USA, Florida	-	Hu et al. (2018)
	Phaseolus vulgaris	Common bean	China	Domestic ($12.4 m)	Hu et al. (2018); Aeny et al. (2020)
Gesneriaceae	*Saintpaulia ionantha*	African violet	India, China, **Indonesia**	-	CABI (2021)
	Streptocarpus sp.	Cape primrose	**Indonesia**	-	Hu et al. (2018)
Musaceae	*Musa* sp.	Banana	China	-	Hu et al. (2018); Toth (2021)
Myrtaceae	*Psidium guajava*	Guava	China	-	Aeny et al. (2020)
Orchidaceae	*Calanthe* sp.	Christmas orchids	China	-	Toth (2021)
	Dendrobium sp.	Dendrobium	China	-	Aeny et al. (2020)

	Phalaenopsis sp.	Moth Orchids	India	-	CABI (2021)
Poaceae	*Brachiaria* sp.	Signalgrass	Netherlands	-	Hu et al. (2018)
	Paspalum sp.	Cowgrass	Guyana	-	CABI (2021)
	Pennisetum purpureum	Napier grass	China	-	CABI (2021)
	Imperata cylindrica	Cogon grass	China	-	CABI (2021)
	Megathyrsus maximus	Guinea grass	China	-	CABI (2021)
	Oryza sativa	Rice	China	-	Hu et al. (2018); Aeny et al. (2020); CABI (2021)
	Pennisetum sp.	Fountaingrasses	China	-	Hu et al. (2018)
	Saccharum officinarum	Sugarcane	China	-	Hu et al. (2018); CABI (2021)
	Sorghum bicolor	Sorghum	**Indonesia**	-	Hu et al. (2018); CABI (2021)
	Sorghum sudanense	Sudan grass	**Indonesia**	-	CABI (2021)
	Urochloa mutica	Buffalo grass	**Indonesia**	-	CABI (2021)
	Zea mays	Corn	**Indonesia**	Domestic ($27.5 m) Export ($0.1 m)	Hu et al. (2018); Aeny et al. (2020); CABI (2021)
Primulaceae	*Cyclamen* sp.	Sowbread		-	CABI (2021)
Solanaceae	*Capsicum* sp.	Capsicum	China	Domestic ($35 m) Export ($24.7 m)	Hu et al. (2018)
	Nicotiana tabacum	Tobacco	China	-	Hu et al. (2018)
	Petunia hybrida	Petunia	China	-	CABI (2021)
	Solanum lycopersicum	Tomato	China, **Indonesia**	Domestic ($120 m) Export ($11.2 m)	Hu et al. (2018); Aeny et al. (2020); CABI (2021)
	Solanum melongena	Eggplant	**Indonesia**	Domestic ($12 m)	Hu et al. (2018); Aeny et al. (2020)
	Solanum tuberosum	Potato	**Indonesia**	Domestic ($222.3 m) Export ($19.6 m)	Hu et al. (2018); Toth (2021)

4.2 *Pantoea ananatis* (fruitlet rot of pineapple)

Pantoea ananatis is an emerging pathogen of multiple important agricultural crops worldwide. It is one of the causative agents of pineapple fruitlet brown-rot/marbling disease, which causes internal tissues to turn black and harden. A versatile bacterium, it can be found as an epiphyte, endophyte, or pathogen in its hosts and can persist in an abiotic environment. *Pantoea ananatis* can cause disease outbreaks in onion, maize, eucalyptus, melon and rice.

4.2.1 *Taxonomic description*

Scientific name: *Pantoea ananatis* corrig. (Serrano 1928) Mergaert et al. 1993
Order: Enterobacterales **Family:** Erwiniaceae
Other names: *Pantoea annaus*, *Erwinia herbicola* var. *ananas*, *Erwinia uredovora*, *Erwinia ananus;* Marbling disease, Bacterial fruitlet brown-rot of pineapple.

Taxonomic Notes:
Pantoea ananatis was first recorded as *Erwinia ananus* by Serrano (1928). Dye (1969) divided the genus *Erwinia* into four clusters and revised *E. ananus* to *E. herbicola* var. *ananas.* Following the creation of the genus *Pantoea* by Gavini et al. (1989), Mergaert et al. (1993) revised *E. herbicola* var. *ananas* to *P. ananas.* This was changed to *ananatis* (Trůper et al. 1997), meaning “of pineapple”. *Pantoea uredovora* was also synonymised in the revision to *Pantoea ananatis* (Mergaert et al. 1993).

There is an emerging body of work suggesting that there may be different strains of *Pantoea ananatis* that are only pathogenic to some hosts (Goszczynska et al. 2006; Kido et al. 2010). Pineapple isolates were pathogenic to *Allium cepa* (onion) and *Zea mays* (maize) (Kido et al. 2010). More recent genomic work (Asselin et al. 2018; Stice et al. 2021) suggests that pineapple strains are pathogenic to onion, but not to the same level of aggressiveness of the *P. ananatis* strains isolated from onion from Georgia, USA. While there is emerging work on *P. ananatis* strains, there are no formally described strains of *P. ananatis* reported in literature.

4.2.2 *Hazard identification*

Pantoea ananatis is not known to be present in New Zealand.

- There is no entry of *Pantoea ananatis* in NZOR (2022).
- *Pantoea ananatis* and its synonyms are recorded as absent from New Zealand in BiotaNZ (2022).
- There is no entry of *Pantoea ananatis*, *Erwinia herbicola* var. *ananas* and *Erwinia ananas* in Hussien et al. (2017).
- *Pantoea ananatis* is a regulated pest for New Zealand and has unwanted status ONZPR (2022).

Pantoea ananatis has the potential to establish a population and spread in New Zealand.

- *Pantoea ananatis* has been recorded in the African, Asian, Australian, American, and European continents. It can be found acting as an epiphyte, endophyte, saprophyte, and pathogen and is present in a wide range of environments (Coutinho and Venter 2009). *Pantoea ananatis* can complete its lifecycle in a variety of climates and has been known to persist in soil and irrigation water (Lai and Hsu 1974; Pileggi et al. 2012).

- *Pantoea ananatis* has been recorded on over 90 living plant hosts since 1928, including as a pathogen of *Zea mays* (maize) and *Allium cepa* (onion) and is associated with *Ananas comosus* (pineapple), *Vitis vinifera* (grapes), *Solanum tuberosum* (potato), *Populus* spp. (poplars), *Solanum lypercosum* (tomato), *Prunus* spp. (stonefruit) and *Eucalyptus* spp.

Pantoea ananatis has the potential to cause harm to New Zealand.

- Economically important species of New Zealand can be affected by *P. ananatis* including maize and onions (Gitaitis and Gay 1997; Alippi and López 2010).

Pantoea ananatis is associated with pineapple fruit.

- *Pantoea ananatis* has been reported as the causative agent of brown fruitlet rot in pineapple (Serrano 1928), and the type strain was isolated from pineapple fruit in Brazil. Rohrbach (1989) reports *P. ananatis* was present on the external surfaces of pineapple fruit.

Given the arguments and evidence above, MPI considers *Pantoea ananatis* is a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

4.2.3 *Risk assessment*

4.2.3.1 Biology

Hosts and geographical distribution

Pantoea ananatis has a wide host range of over 20 families (Gitaitis et al. 2002). *Pantoea ananatis* has been recorded on over 90 living plant hosts since 1928, including as a pathogen of *Ananas comosus* (pineapple), *Allium cepa* (onion), *Eucalyptus* spp., and *Zea mays* (maize) and is associated with, *Vitis vinifera* (grapes), *Solanum tuberosum* (potato), *Populus* spp. (poplars), *Solanum lypercosum* (tomato), *Prunus* spp. etc (MPI 2021). *Pantoea ananatis* was intercepted multiple times on *Dracaena* from Costa Rica (LIMS 2022). The infected material contained viable bacteria, that were confirmed to be *Pantoea ananatis.* The bacterium can be found acting as a plant epiphyte, endophyte, pathogen and saprophyte, in the gut and blood of humans, and can be present in the environment without a plant host (Coutinho and Venter 2009).

Pantoea ananatis has been found in a substantial range of abiotic hosts, although this commonly relies on genetic sequencing of the 16S rDNA. *Pantoea* species often retain the section of genome (16S rDNA) used for identification, which can cause difficulties in differentiating between related species (e.g., *Pantoea agglomerans*)(Stackebrandt and Goebel 1994). Other methods include Multilocus sequence analysis (MLSA) for identification to a species level (Brady et al. 2008).

Pantoea ananatis has been isolated from soil (Hara et al. 2012; Kim et al. 2012) and was fully sequenced to confirm identity, showing it can be viable in soil. Viable *Pantoea ananatis* has been isolated from freshwater (Morohoshi et al. 2007; Pileggi et al. 2012) and was present in salt water (Jatt et al. 2015). These aquatic isolates rely on sequencing of the 16s rDNA genome for identification. Viable *P. ananatis* was isolated from outdoor air, and confirmed via sequencing to be *P. ananatis* (Luhung et al. 2018).

Pantoea ananatis has been recorded in the African, Asian, Australian, American, and European continents (Coutinho and Venter 2009). This places *Pantoea ananatis* in both highly similar climatic environments to New Zealand, and also highly divergent environments.

Table 4.3 Geographical distribution of *Pantoea ananatis* (MPI 2022). Names in bold are markets in the scope of this IRA.

Continent/Region	Country/area/market
Africa	Benin, Burkina Faso, Cameroon, Egypt, Morocco, South Africa, Sudan, Togo, Uganda, Zimbabwe
Asia	Cambodia, China, East Timor, India, Indonesia, Iran, Iraq, Israel, Japan, Korea, **Malaysia**, **the Philippines**, Singapore, **Taiwan**, **Thailand**, Turkey, Yemen
America	Argentina, Brazil, Canada, Colombia, **Costa Rica**, **Ecuador**, Guatemala, Haiti, Mexico, Uruguay, USA, Venezuela
Australia	**Australia**
Europe	Belgium, Czech Republic, Finland, Germany, Italy, Poland, Russia, Slovakia, Spain, UK, Ukraine

Symptoms

External symptoms of the bacterial fruitlet brown-rot disease on pineapple fruit caused by *P. ananatis* may not be visible, with mild to moderate infections resulting in no visible external symptoms (Serrano 1928). Severe infections may result in a dull ripening colour, with extremely small purple dots. These severe infections cause the fruit to desiccate internally, and result in the fruit becoming extremely hard (Serrano 1928).

Internal infections infect individual fruitlets (fruit segments from a single flower). Multiple, or all fruitlets can be infected (Serrano 1928). Infected fruitlets appear brown, with infections beginning in the placental tissues and radiating inwards. Infections can cause entire fruitlets to turn black (Serrano 1928).

Infected fruitlets are initially soft, but as the disease progresses, the fruitlets desiccate, and can become hard enough to resist cutting (Serrano 1928). While the disease appears to be mostly limited to fruitlets, severely infected fruit will show symptoms similar to fruitlet infections in the core of the fruit and in connective tissues (Serrano 1928).

Fruitlet brown-rot disease on pineapple develops when the fruit is ripening and is not found to continue spreading after ripening. Disease symptoms do not appear to be present in green and immature fruits (Serrano 1928).

It is likely that *Pantoea ananatis* is present as an epiphyte on the surface of pineapple (Serrano 1928). Infection appears to occur via flowers and wounds under certain unknown environmental conditions, which are likely to be high temperatures combined with rainfall (Serrano 1928, 1935). If these conditions are not met, it is likely that *Pantoea ananatis* may be present on the surface of pineapples without causing symptoms.

The first report of *P. ananatis* in pineapple had the disease described as bacterial fruitlet brown-rot of pineapple (Serrano 1928) and again in (Thompson 1937) , but this appears to not have entered wide spread use, with a paper in 1950 (Smith and Ramsey 1950), and the last use appearing to be in Huang and Du (1960). This common name appears to have dropped out of usage, although CABI (2022) does still refer to “fruitlet rot of pineapple”. Marbling disease is also listed as a common name of *P. ananatis*.

Rohrbach and Pfeiffer (1974) described marbling disease of pineapple, "*characterized by a brittle, granular hardening of affected fruit tissues"*. In order to inoculate, and identify the causative agent of marbling disease in pineapple, two tentively identified *Acetobacter* spp. were used. *Pantoea ananatis* was not used in this inoculation, or mentioned in the text. Rohrbach (1984) states marbling is caused by *Acetobacter* spp. and *P. ananatis* referencing (Rohrbach and Pfeiffer 1974). This is repeated in two later papers (Rohrbach 1989; Rohrbach and Phillips 1989). Despite this discrepancy, modern articles and handbooks have accepted this addition, and the pineapple disease caused by *P. ananatis* is now commonly known as marbling disease (Rohrbach and Johnson 2003b; Sipes and Wang 2017; Ploetz 2018). Due to this unclear referencing, the association of marbling diseases and *P.ananatis* is uncertain.

In maize, infection with *P. ananatis* causes leaf blight. The bacterium causes centre rot in onion, where tissues become soft and brown (Coutinho and Venter 2009).

Pineapple variety susceptibility
Smooth Cayenne, Costa, Prickly Queen, Pula and Puti were reported to be susceptible (Serrano 1928).

Reproduction and transmission
The bacterium can grow between 6°C and 45°C degrees and the optimum temperature range is 30°C to 35°C (Serrano 1928).

Pantoea ananatis can spread actively and passively. *Pantoea ananatis* has swimming and twitching motility, which enable *P. ananatis* to locate and attach to onion leaf surfaces and spread across the surface (Weller‐Stuart et al. 2017). *Pantoea ananatis* is transmitted in seed (Goszczynska et al. 2006), by *Thrips tabaci* (Dutta et al. 2014) and Western corn rootworm (*Diabrotica virgifera virgifera*) (Krawczyk et al. 2021). It remains viable in soil (Hara et al. 2012), water (Morohoshi et al. 2007), and air (Luhung et al. 2018) and is assumed to spread to new biotic hosts from these media.

The bacterium can be vectored by insects (Serrano 1928; Ploet et al. 1994). *Pantoea ananatis* is assumed to enter fruitlets during flowering. It was proposed that insects and arachnids including red mites, mealybugs, thrips and ants, found on pineapple fruit could carry the pathogen on their feet, but no original references are cited (Serrano 1928). *Pantoea ananatis* is also present in insect hosts including the European honeybee (*Apis mellifera*) (Kačániová et al. 2017), brown plant hoppers (*Nilaparvata lugens*) (Watanabe et al. 1996), mulberry pyralid (*Glyphodes pyloalis*) (Takahashi et al. 1995) and cotton fleahoppers (*Pseudatomoscelis seriatus*) (Bell et al. 2007). *Thrips tabaci* and the European honeybee are present in New Zealand (NZOR 2022).

Pantoea ananatis can spread by infected plant material and is suggested to spread by soil, water (Kido et al 2010) and potentially by air. *Pantoea ananatis* can be dispersed by infected seed (Walcott et al. 2002) as it is seed-borne and seed-transmitted (Goszczynska et al. 2006). It was present on cut plant material (LIMS 2022), that contained viable bacteria. *Pantoea ananatis* remains viable in soil (Lai and Hsu 1974; Verma et al. 2014) (Perez-y-Terron et al 2009; Hara et al 2012) and water (Coutinho and Venter 2009; Morohoshi et al 2007; Pileggi et al 2012). The bacterium was found in water near known plant hosts, but the researchers (Pileggi et al. 2012) did not mention whether the nearby hosts had the bacteria. It is likely that *Pantoea ananatis* requires moisture in soil for exposure and transmission. Wounds and natural openings allow bacterial suspensions of *P.ananatis* (liquid and vapor) to infect healthy plants (Serrano 1928; Rohrbach and Pfeiffer 1974). Furthermore, *Pantoea ananatis* was isolated from outdoor air in Singapore, and was viable (Luhung et al. 2018).

4.2.3.2 Likelihood of entry

Pantoea ananatis has been recorded in over 50 countries and every continent except for Antarctica. Of the 17 exporting markets, seven had records of *P. ananatis* or its synonyms (Table 4.4).

Table 4.4: Pineapple exporting markets with records of *P. ananatis*

Exporting Markets	Reference
Australia	Cother et al. (2004)
Ecuador	Toaza et al. (2021)
The Philippines	Serrano (1928)
Thailand	Arayaskul et al. (2020)
Costa Rica	LIMS (2022)*
Malaysia	Bradbury (1986); Azizi et al. (2019); Toh et al. (2019) Thompson (1937)
Taiwan	Wang et al. (2018)

* A literature search using searching terms “Pantoea ananatis” or common synonyms, and “Costa Rica” returned no results.

Papua New Guinea, Panama and Sri Lanka all share land borders with or are geographically close to countries with known distributions of *P. ananatis*. As *P.ananatis* can be spread by air, water, soil and plant material, countries with shared borders are more likely to have *P. ananatis*. Due to the epiphytic nature of *P. ananatis*, the distribution may be wider than reported, as testing of healthy plants and hosts is less likely to occur compared to the testing of symptomatic plants.

Pantoea ananatis was reported causing disease on pineapple in the Philippines (Serrano (1935), Malaysia (Thompson 1937) and Taiwan (Hesu et al. 2008). Cother et al. (2004) notes that there are no reliable references showing *P.ananatis* as a pathogen of pineapple in Australia. There are recent reports of *P.ananatis* in pineapple in Japan (Kido et al. 2010), Taiwan (Hesu et al. 2008) and India (Chand et al. 2021).

Sources consistently state that pineapple fruit infected with *P. ananatis* cannot be detected visually without destructive sampling (Serrano 1928; Weber 1973; Rohrbach 1989; Ploetz 2018). External symptoms of the bacterial fruitlet brown-rot disease on pineapple fruit may not be visible, with mild to moderate infections resulting in no visible external symptoms (Serrano 1928). Severe infections may result in a dull ripening colour, with extremely small purple dots (refer to Symptoms in Annex 4.2.3.1) Barker (1924) reported that immature fruitlets at the top of the pineapple are not infected.

Pantoea ananatis may be present on the exterior of the pineapple (Serrano 1928; Rohrbach and Pfeiffer 1974). No specific information was found regarding the removal of *P.ananatis* from fresh produce surfaces. An outbreak of *P.agglomerans* infections in a medical environment was linked to inadequate chlorination of water (below 0.2ppm) suggesting chlorination is able to provide a level of control of *Pantoea* spp.

Pantoea ananatis cultures grew at 6°C – 45°C, with an optimum at 30°C – 35°C (Serrano 1928), as such it is likely to survive transit conditions of pineapple fruit (see Appendix 2 Transit conditions). We have no records of *P.ananatis* interceptions on pineapple (LIMS 2022).

Uncertainty
Uncertainty is attributed to the lack of data around prevalence in exporting markets.

Given that:

- *Pantoea ananatis* can cause internal infection in pineapple fruit without externally visible symptoms when the infection is mild to moderate;
- *Pantoea ananatis* may be found on the surface of pineapple;
- Destructive sampling is needed to detect symptomatic pineapples;
- It is likely that *P. ananatis* can survive transit conditions on pineapple fruit because they can grow between 6°C – 45°C; and
- The prevalence of *P. ananatis* in exporting markets is uncertain;

MPI considers the likelihood of *Pantoea ananatis* entering New Zealand associated with *A. comosus* fresh fruit for consumption (as described in the commodity description) is MODERATE, with a MODERATE level of uncertainty.

4.2.3.3 Likelihood of exposure

This section assesses the likelihood of P. ananatis *being exposed to a suitable host or environment if it enters New Zealand undetected.*

Discarded waste from imported infected fruit could expose the bacterium to the environment. Infected pineapple fruit remains may be a source of inoculum in field conditions (Serrano 1928; Sanewski et al. 2018). Fruit waste in New Zealand may be collected from unpacking areas (e.g., supermarket preparation rooms) and taken to rural areas where it is placed on the ground for eventual consumption by pigs or other farmed animals (MPI 2014).

The commodity is intended to be sold to consumers in New Zealand. Fresh pineapple fruit generates substantial amounts of unavoidable waste; the thick rind is always removed and disposed of, and the fruit is also sometimes cored (see waste analysis Annex 2.3.1). The disposal of whole fruit (e.g., culled/unsold fruits, uneaten fruit remains) is not uncommon during wholesale, retail and by consumers. This suggests *Pantoea ananatis* on pineapple fruit may have a higher likelihood of exposure than *P. ananatis* on many other kinds of fresh produce.

Pantoea ananatis is likely to survive in the outdoor environment in New Zealand as it has biological characteristics that indicate climatic conditions would not be a limiting factor. *Pantoea ananatis* has a wide temperature range for survival (between -15°C and 56°C) (Serrano 1928)and active growth (between 6°C – 45°C), resistance to desiccation and survival in freezing temperatures (Serrano 1928). The bacterium showed extreme resistance to desiccation, with bacteria remaining viable on sterile cover strips for over four months at room temperature (Serrano 1928).

Pantoea ananatis is likely to survive and grow on pineapple waste and is likely to survive and grow as a saprophyte/environmental bacterium in the environments where pineapple waste is disposed of, for example on garden compost and soil. *Pantoea ananatis* remains viable in soil (Hara et al. 2012), water (Morohoshi et al. 2007), and air (Luhung et al. 2018), and would be able to transfer from waste material to these environments by direct contact and vectors.

Pantoea anantis can be transmitted from pineapple waste to other plants or the environment by insect vectors. Insect vectors are known, notably *Frankliniella fusca* (Gitaitis et al. 2003), *Thrips tabaci* (Dutta et al. 2014) and *Diabrotica virgifera virgifera* (Krawczyk et al. 2021). *Thrips tabaci* is present in New Zealand (NZOR 2022) and feed on pineapple (Linford 1931). Dutta et al. (2014) noted that thrips faeces passively transferred *P. ananatis* into onion, showing movement of bacteria into a host.

Uncertainty

There is limited data on viability and spread from infected pineapple fruit and around the amount of pineapple waste being exposed to the environment. However, any pineapple waste discarded into the environment would expose the bacterium to the environment where it can grow on. Therefore, the overall uncertainty is MODERATE.

Given that:

- there is limited evidence of spread from infected pineapple;

However,

- fresh pineapple fruit generate a large quantity of unavoidable waste;
- the bacterium has a wide host range and climatic tolerance and is persistent in varying environmental niches;
- *Pantoea ananatis* is likely to transfer from pineapple waste to a suitable environment, and remain viable;
- *Pantoea ananatis* cultures can survive temperatures between -15°C and 56°C, and desiccation, and grows at 6°C – 45°C;
- there are multiple modes of transmission available, including insect vectors present in New Zealand;

MPI considers the likelihood of exposure of *Pantoea ananatis* in New Zealand from pineapple fruit is HIGH, with MODERATE uncertainty.

4.2.3.4 Likelihood of establishment

This assesses the likelihood of P. ananatis *establishing a population if it enters New Zealand and is exposed to a suitable habitat.*

Many known hosts of *Pantoea ananatis* are present in New Zealand (Coutinho and Venter 2009) as recorded in (NZOR 2022), including commercially grown crops like onion (*Allium cepa*) (Gitaitis et al. 2003), *Eucalyptus* (Coutinho et al. 2002) and maize (*Zea mays*) (Alippi and López 2010; Krawczyk et al. 2021; Toaza et al. 2021). Because it is viable epiphytically (Coutinho and Venter 2009) and in soil (Hara et al. 2012), water (Morohoshi et al. 2007), and air (Luhung et al. 2018), and is found in countries with similar climatic conditions, MPI considers New Zealand hosts and environments are suitable for establishment.

It is unlikely that there will be major climatic limitations to its establishment in New Zealand. The current distribution of *P. ananatis* includes climates that are similar to the general New Zealand climate. Climate similarity are assessed using the composite match index

(CMI) (Phillips et al. 2018). An area with CMI over 0.7 is considered having similar climate to the whole of New Zealand. *Pantoea ananatis* is present in countries with close climate matches to New Zealand such as Italy (CMI 0.8–0.9), Poland (CMI 0.8–0.9), Belgium (CMI 0.8–0.9) and the USA (CMI 0.7–0.8), although the pathogen is also found in dissimilar climates, such as areas of Central and South America (Brazil, Costa Rica, Colombia, and Guatemala at 0.3–0.4). *Pantoea ananatis* survived epiphytically under different temperature and moisture regimes that mimicked conditions in Georgia, USA (CMI 0.7 – 0.8). Furthermore, *P.ananatis* cultures grew at 6°C – 45°C, with an optimum at 30°C – 35°C (Serrano 1928). Cultures died after fifteen days at freezing temperatures. The bacterium showed extreme resistance to desiccation, with bacteria remaining viable on sterile cover strips for over four months at room temperature (Serrano 1928).

Variable temperature tolerance of the pathogen and the continued impacts of climate change, which has been predicted to increase the minimum temperature of the coldest month, increases the risk of *Pantoea ananatis* establishing in New Zealand.

Given that:

- current and future climates are suitable for the bacterium;
- plant hosts are widely available in New Zealand;
- *Pantoea ananatis* can persist in abiotic environment; and
- the bacterium has wide temperature tolerances;

MPI considers the likelihood of *Pantoea ananatis* establishing a population in New Zealand is HIGH with LOW uncertainty.

4.2.3.5 Impacts in New Zealand

This assessment is made on the assumption that Pantoea ananatis *has successfully established in the New Zealand environment.*

Economic impacts

Given the broad host range of *P. ananatis* and known pathogenicity of pineapple strains to onions (Kido et al. 2010), it is likely that *P. ananatis* on pineapples would affect other commercially produced hosts.

The impacts of *P. ananatis* can vary dramatically and disease outbreaks tend to occur sporadically. Since 2010 there have been no major reported epidemics in onion (Carr et al. 2010),although there have been smaller outbreaks(Kim et al. 2012). There have been recent outbreaks in rice in Asia (Arayaskul et al. 2020) and maize in South America (Toaza et al. 2021). If the pathogen establishes a population in New Zealand, impacts are could be limited by climate, but the USA (onion) South Africa (maize), and Poland (wheat) have reported disease outbreaks of *Pantoea ananatis* in areas with similar climate conditions to New Zealand. The most severe impacts on onion were reported in Georgia, USA. The state has a similar climate (CMI 0.8 (Phillips et al. 2018)), but is more humid, and is classified as a humid subtropical climate, compared to New Zealands maritime climate.It is likely that climate change will result in a more humid environment in areas of new Zealand, notably Pukekohe and Matamata, two major onion growing regions.

Onion (*Allium cepa*) and maize (*Zea mays)* are the highest value crops that could be impacted by the establishment of *P. ananatis* in New Zealand. The onion industry in Georgia (USA) reported 25 – 100% losses for growers in 1997 due to *P. ananatis*, as well as 10% pre- and post-harvest yield losses between 1998 and 2001 (Gitaitis et al. 2002). The disease appears to emerge randomly, with South Korea reporting 30 – 50% losses in five affected fields in 2009 –2010 (Gitaitis and Gay 1997; Kim et al. 2012). In New Zealand, fresh, frozen, and processed onion exports were worth NZ$170m, with onion seed worth an additional NZ$3.6m (Plant & Food Research 2020; Plant & Food Research 2021). Onion cultivars resistant to *Pantoea* sp. are not commercially available (Gitaitis et al. 2003). Thrip management, weed control, crop rotation and bactericides may provide a level of control, but information is limited. The use of only one control method will not provide effective control (Stumpf et al. 2021).

Impacts on maize appear to vary. In South Africa, 10 – 70% of the crop was affected, with the disease being attributed to *P. ananatis* and an undescribed *Pantoea* sp. (Goszczynska et al. 2007). The impacts in South America have not been described, and only symptoms were reported (Alippi and López 2010). In Indonesia, 1 – 8% of fields were infested, with a disease incidence of 5 – 8% (Aini et al. 2013). It is unclear if these infestations are ongoing. Maize is not commercially exported, but the New Zealand domestic market was estimated at NZ$722m in 2016 (Nixon 2015).

Wheat (*Triticum* spp.) has been reported as a host, but there is limited literature on the impacts of infection in wheat, or occurrence, as the first record was only in 2020 (Krawczyk et al. 2020) and only in association with cereal leaf beetle (*Oulema melanopus*) and western corn rootworm (*Diabrotica virgifera virgifera*) (Krawczyk et al. 2021). Neither of these potential vectors are present in New Zealand (NZOR 2022). Early reports suggest *P. ananatis* infection rates of ~6% on wheat and symptoms are only associated with insect feeding damage (Krawczyk et al. 2021).

Some level of chemical control is possible in other crops with bactericides, but due to the bacteria's presence on volunteer plants and insect hosts, reinvasion is a constant threat (Stumpf et al. 2021).

An in-house MPI model predicted a moderate level of economic impact over 20 years.

- It was assumed that the greatest level of combined annual economic impact on onion and maize would be NZ$19m. This is based on the assumption of an worst case scenario, where 8% (Gitaitis et al. 2003) of all onions in New Zealand are affected, causing an impact of ~NZ$14 million to the NZ$173.6m industry. The value of 8% considers that the disease appears to be climatically limited and would reach higher and lower impacts in specific regions. An estimated 0.6% of maize would be affected, based on (Aini et al. 2013), causing ~NZ$5m worth of impacts.
- The bacterium is assumed to take 5 years to achieve greatest impacts, to allow time for effective spread across New Zealand.
- Due to little information on effective control, it is assumed the industries never recover (>100 years).

Economic impacts assume that once the bacteria establish a population, they will be prevalent throughout the environment, and it will not be possible to eradicate them. Information on reducing impacts through management is limited in the literature. Resistant onion cultivars are not currently available. Insecticide management of thrips and foliar bactericide applications appear to help limit impacts, but can be expensive, and have associated negative externalities. These would likely have to occur alongside weed management and crop rotation. While outbreaks may be managed, pre-emptive control would likely be difficult and expensive. Research is still ongoing on effective management of the disease in onion, which may result in effective management in the future (Stumpf et al. 2021). Any period of recovery between 10 –100 years would result in moderate economic impacts. *Pantoea ananatis* is present in a wide range of niches, and specific host control would not remove reservoirs.

Uncertainty
There is a high level of uncertainty around economic impacts. There is limited information on environmental or other factors that encourage disease outbreaks. Impacts are often sporadic. Impacts often have wide ranges and may be highly restricted spatially to small production areas.

Given that:

- disease outbreaks are sporadic and rare;
- The environmental factors required for disease outbreaks are not fully understood;
- the disease is likely to cause yield reduction in onion and maize; and
- the disease has an estimated moderate economic impacts over 20 years;

MPI considers the economic impact of *Pantoea ananatis* in New Zealand is MODERATE, with HIGH uncertainty.

Environmental impacts
Pantoea ananatis has never been recorded in New Zealand, which has a high level of endemic species. Invasions by microorganisms into new environments can have dramatic effects on hosts and recipient environments due to host naivety (Thakur et al. 2019). There are no recorded hosts at a species level that would suggest environmental impacts. However, at a family level there are 14 families, with over 1050 species endemic to New Zealand. These include species that are considered to be threatened – Nationally Endangered. Furthermore, *Pantoea ananatis* has been recorded on 20 families of plants, and multiple abiotic hosts suggesting a high level of non-host specificity. As there is no evidence of the impacts of *P. ananatis* on native hosts, there is a high level of uncertainty due to the lack of information about host range and pathogenicity.

Given the arguments and evidence above, that is:

- *Pantoea ananatis* has never been recorded in New Zealand, which may increase impacts due to host naivety;
- A very wide host range; and
- There is no evidence of environmental impacts;

MPI considers the potential environmental impact of *Pantoea ananatis* in New Zealand is VERY LOW, with HIGH uncertainty.

Human health impacts
Blood infections with *Pantoea ananatis* have been reported in humans (Lind and Ursing 1986; De Baere et al. 2004). *Pantoea ananatis* appears to be an opportunistic human pathogen. It was associated with septicaemia after a person was wounded with plant material and with hospital-acquired infections from contaminated hospital materials (De Baere et al. 2004). There are no recorded deaths from *P. ananatis,* and all patients recovered following treatment with broad spectrum antibiotics.

Given that:

- infection with *P. ananatis* in humans is rare and treatable; and
- no deaths have been recorded;

MPI considers the potential human health impacts of *P. ananatis* in New Zealand are NEGLIGIBLE, with LOW uncertainty.

Sociocultural impacts

Many hosts of *P. ananatis* are commonly grown in home gardens (e.g., onions and maize). *Pantoea ananatis* symptoms may make vegetables less attractive to consumers but are unlikely to cause scarcity in local markets. There are no recorded hosts of *Pantoea ananatis* that would suggest cultural impacts. However, because *P. ananatis* has never been recorded in New Zealand, there may be increased impacts due to host naivety. As there is no evidence of impacts of *P. ananatis* on plant species with high cultural value, there is a high level of uncertainty due to the lack of information about the host range and pathogenicity.

Given that:

- *Pantoea ananatis* has never been recorded in New Zealand, which may increase impacts due to host availability;
- *Pantoea ananatis* has a very wide host range across multiple families, including the native genus *Dracaena,* and
- there is no evidence of impacts on species with sociocultural value to New Zealand;

MPI considers the sociocultural impact of *Pantoea ananatis* in New Zealand is VERY LOW, with HIGH uncertainty.

4.2.3.6 Overall impact to New Zealand

MPI considers the overall impact of *Pantoea ananatis* on the New Zealand economy, environment, health, and society is MODERATE, with HIGH uncertainty.

4.2.3.7 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of *Pantoea ananatis* entering New Zealand is MODERATE with MODERATE uncertainty;
- assuming entry, the likelihood of the bacteria being exposed to a suitable habitat is HIGH with LOW uncertainty;
- assuming exposure, the likelihood of it establishing a population is HIGH with LOW uncertainty; and
- the overall impact on the New Zealand economy, environment, human health, and society is MODERATE with HIGH uncertainty;

MPI considers the overall level of risk to New Zealand from *Pantoea ananatis* on imported *A. comosus* fresh fruit for consumption (as per the commodity description) is MODERATE, with HIGH uncertainty.

4.2.4 Specific considerations

On which pineapple fruit variety (or varieties) and at what stage of ripeness has *Pantoea ananatis* association with pineapple fruit been observed?

Pantoea ananatis has been associated with the varieties Smooth Cayenne, Costa, Pula and Puti (Serrano 1928). The bacteria are thought to enter internal tissues via flowers, natural openings, and wounds.

Which parts of the pineapple fruit is *Pantoea ananatis* associated with (e.g., fruit, bract, stem, or crown remnant), and is it visually detectable?
Once present in internal tissues (the flesh of pineapple), slight and moderate symptoms are not detectable by external visual inspection.

Under what environmental conditions (temperature, season, etc.) are *Pantoea ananatis* symptoms expressed on pineapple fruit?
Infection appears to occur via flowers and wounds under certain unknown environmental conditions, which are likely to be high temperatures combined with rainfall (Serrano 1928, 1935).

Does *Pantoea ananatis* exhibits latent/asymptomatic traits?
There are no recorded asymptomatic infections in pineapple. This is likely due to the causative bacteria being present as epiphytes on the surface of the fruit (Rohrbach 1989). Epiphytes would not be detected in fresh produce.

More recent reports of *Pantoea ananatis* causing marbling disease in pineapple include *Acetobacter* spp. and *A. peroxydans* as causative agents (Rohrbach and Johnson 2003a; Ploetz 2018). It is possible that marbling disease in pineapples is an emergent disease from the interaction of *Acetobacter* spp. and *P. ananatis*.

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5 Pest risk assessments: Fungi

5.1 Fusarium oxysporum

Fusarium oxysporum is a very widespread soilborne fungus that is often saprophytic (lives on dead plant material) in the soil. Many *F. oxysporum* strains can colonise the root system and/or the vascular system of living plants with or without disease symptoms. *Fusarium oxysporum* is a common cause of root rots, seedling decays, vascular wilts, post-harvest fruit rots and other plant diseases but individual strains may be non-pathogenic, pathogenic to only one host or have a broad host range. In pineapple, *F. oxysporum* has been reported as the cause of pineapple plantation dieback disease, a vascular wilt and as a cause of internal and external fruit rots.

Context of this PRA:

Preliminary hazard identification indicated that *F. oxysporum* was associated with fresh pineapple and present in markets in scope of the Import Risk Analysis. This PRA aimed to answer the question of whether there are strains of *F. oxysporum* that are not present in New Zealand, can be associated with pineapple and would cause impacts in New Zealand on hosts other than pineapple. Pests and diseases only documented to affect pineapples are unlikely to be exposed to a new host and establish in New Zealand due to limited host availability and cause environmental, cultural or social impacts to New Zealand (see Annex 2.4.2 Potential impacts in New Zealand).

To determine whether *F. oxysporum* required assessment on the pineapple pathway, the project leads asked the MPI Plant Health and Environment Laboratory (PHEL) for additional information about strains of *F. oxysporum* found on pineapple. In general, the available sequences of *F. oxysporum* strains from pineapple do not match sequences of known New Zealand isolates (Katharina Hofer, PHEL, pers. comm. 2022). Searches of sequences in GenBank provided no information about whether strains of *F. oxysporum* from pineapple were associated with other hosts or pathogenic in other hosts (Katharina Hofer, PHEL, pers. comm. 2022). According to Edel-Hermann and Lecomte (2019), "Molecular identification of *F. oxysporum* formae speciales would ideally target pathogenicity-related genes". Whole genome sequencing, in order to identify virulence markers, would be necessary to determine host-specificity and/or identify *F. oxysporum* to the formae speciales level via molecular methods in the future (Katharina Hofer, PHEL, pers. comm. 2022). Unfortunately, this is not feasible with the methods currently available to PHEL and there is no reference material available for the known pineapple isolates (Katharina Hofer, PHEL, pers. comm. 2022). Details of the advice from PHEL are provided in the appendix (Annex 5.1.5) to this PRA.

Given that
- *Fusarium oxysporum* strains from pineapple are not recorded in New Zealand; and
- initial information from hazard identification provided no insight into whether *F. oxysporum* from pineapple can be associated with other hosts or is pathogenic in other hosts

the decision was made to assess *F. oxysporum* on the pineapple fresh produce pathway, taking into account general information on the biology and host specificity of the wider *F. oxysporum* species complex.

5.1.1 *Taxonomic description*

Scientific name: *Fusarium oxysporum* Schltdl. 1824
Order: Hypocreales **Family:** Nectriaceae
Other names: *Fusarium bulbigenum* Cooke & Massee; *Fusarium bulbigenum* var. batatas Wollenw; *Fusarium orthoceras* Appel & Wollenw.

In addition, some of the subspecific taxa currently referred to as formae speciales (see below; singular forma specialis, abbreviated to f. sp.) were formerly described as separate *Fusarium* species, e.g. *F. cepae* for *F. oxysporum* f. sp. *cepae,* or as varieties of *F. oxysporum, F. bulbigenum* or *F. orthoceras.*

Taxonomic notes:
Fusarium oxysporum is now recognised as a species complex, with cryptic species (i.e. hard to separate on the basis of morphology alone) that can be plant pathogens or non-pathogenic. Some individual species have been recently named within the complex.

Plant pathologists often classify *F. oxysporum* into subspecific taxa called 'formae speciales' (special forms), which are named according to the plant species on which they were reported to cause symptoms. Although *F. oxysporum* has been reported from pineapple (*Ananas comosus*) in several countries, searches[39] found only one record in a Costa Rican publication that referred to the strain or strains causing pineapple cultivation dieback in Costa Rica and Peru as *F. oxysporum* f. sp. *ananas* (Blanco-Menéses et al. 2022) and no other named strains on pineapples. However, there is evidence suggesting that other strains of *F. oxysporum* are associated with fruitlet core rot and fruit rot in pineapple and records of *F. oxysporum* from asymptomatic pineapple fruit or commercially purchased fruit where symptoms are not described (Stępień et al. 2013; Ibrahim et al. 2015; Souza et al. 2018; Barral et al. 2020; Vignassa et al. 2021).

There is high morphological similarity between certain *Fusarium* species. Some *Fusarium* isolates/pathogens from culture collections may have been misidentified as *F. oxysporum* in the past. For example, a study by Silva et al. (2014) identified two isolates as *F. solani,* although they had originally been identified as *F. oxysporum* f. sp. *phaseoli* and *F. oxysporum* f. sp *vasinfectum.* This PRA includes some records of *F. oxysporum* from pineapple that did not include molecular identification, so there may be uncertainty about whether the information relates to *F. oxysporum* or another *Fusarium* species.

5.1.2 *Hazard identification*

Fusarium oxysporum is now considered to be a species complex (the FOSC). Although *F. oxysporum* and other taxa within this complex are reported to be present in New Zealand, there are *F. oxysporum* strains from pineapple that are different from the recorded New Zealand strains:

- *Fusarium oxysporum* is recorded in NZOR (2022).
- *Fusarium oxysporum* is recorded in New Zealand in BiotaNZ (2022), PPIN (2022), both of which record collections from many different plant hosts throughout New Zealand.

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[39] Search terms in Google Scholar: with Fusarium oxysporum" and "Ananas comosus" or "pineapple", first 50 records checked, then search limited with -banana* -plantain and - -cubense; Search terms in CAB abstracts "Fusarium oxysporum" and "Ananas comosus" or "pineapple"; Farr and Rossman (2022), Mycobank (2022) and Species fungorum (2022).

- Most available sequences of *F. oxysporum* isolates from pineapple (from the Philippines, Brazil, Costa Rica, Cameroon, and Dominican Republic) do not match sequences available from any New Zealand isolates (Katharina Hofer, PHEL, pers. comm. 2022, see appendix for additional details).
- Many subspecies or strains of *F. oxysporum* have previously been assessed as an increased risk to New Zealand compared with those already present.
    - ONZPR (2022) records the regulatory status of *F. oxysporum* as not assessed, with an action upon interception on fresh fruit and vegetables of "Request technical advice from Plant Imports".
    - ONZPR (2022) records the following named strains as regulated: *F. oxysporum* f. sp. *aechmeae*; *F. oxysporum* var. *nicotianae*; and *F. oxysporum* formae speciales *albedinis, batatas, canariensis, capsici, cattleyae, chrysanthemi, ciceris, coriandrii, cubense, fragariae, garlic, hebes, lactucae, lagenariae, lilii, melongenae, nicotianae, passiflorae, pini, radicis-lycopersici, ranunculi, sesami, tracheiphilum, trifolii, tuberosi, vasinfectum* and *zingiberi.*

Strains/species in the *F. oxysporum* species complex (not present in New Zealand) have the potential to establish and spread in New Zealand:

- *Fusarium oxysporum* can survive as a saprotroph on plant debris in the soil, and the rhizosphere (around plant roots) and by colonising the vascular system of host plants (Pietro et al. 2003; Gordon 2017).
- Many other strains of *F. oxysporum* are already present in New Zealand (BiotaNZ 2022; PPIN 2022), so the climate is likely to be suitable for some new *F. oxysporum* strains.

Strains/species in the *F. oxysporum* species complex (not present in New Zealand) have the potential to cause harm to New Zealand.

- *Fusarium oxysporum* has the potential for economic impacts
    - it is considered one of the 'Top 10' fungal pathogens in terms of economic and scientific importance (Dean et al. 2012)
    - it is commonly reported as a cause of root and storage tuber rots and vascular wilts of many crops that are economically important to New Zealand, including onion, tomato, legumes and cucurbits (van Dam et al. 2016; Gordon 2017; Edel-Hermann and Lecomte 2019).
    - new strains of *F. oxysporum* have the potential to harm host plants of economic importance that are currently unaffected or to cause more severe impacts than the strains that are already in New Zealand.
    - *Fusarium oxysporum* was assessed further because comparison of available sequences from pineapple isolates with other records in GenBank provided no insight into whether *F. oxysporum* from pineapple can be associated with other hosts or are pathogenic in other hosts (Katharina Hofer, PHEL, pers. comm. 2022, see appendix (Annex 5.1.5) for additional details).

Fusarium oxysporum is associated with pineapple fruit.

- *Fusarium oxysporum* has been recorded from pineapple plants and pineapple fruit in commercial production areas (Jiménez and Granados 2014; Ibrahim et al. 2015; Souza et al. 2018; Vignassa et al. 2021) and from commercially purchased pineapple fruit (Stępień et al. 2013; Manthou et al. 2021)

Given the arguments and evidence above, strains/species in the *F. oxysporum* species complex (not present in New Zealand) associated with decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand are considered to be a hazard.

5.1.3 *Risk assessment*

5.1.3.1 Biology

Geographical distribution of *F. oxysporum*

Fusarium oxysporum senso latu is recorded in all markets in scope. Farr and Rossman (2022) record *F. oxysporum* sensu lato as present in Australia, Cook Islands, Costa Rica, Ecuador, Indonesia, Malaysia, Panama, Papua New Guinea, The Philippines, Samoa, Sri Lanka, Taiwan, Thailand and Tonga. The Pacific Islands Pest List Database (2022) records *F. oxysporum* in Cook Islands, New Caledonia, Fiji, Tonga and Vanuatu. However, it is not known whether new strains/species in the *F. oxysporum* species complex (not present in New Zealand) are associated with pineapple in all of these markets. *Fusarium oxysporum* has been reported from pineapple fruit from Costa Rica, Ecuador and Malaysia and from pineapple plants (no plant part specified) in the Philippines, but searches found no reports from pineapple in the other markets. Table 1 (see appendix) gives further details of searches[40] of literature, fungal collections, or the GenBank nucleotide sequence database for records of *F. oxysporum* from pineapple in these markets.

Reproduction and spread

Fusarium oxysporum produces conidia (asexual spores) in and on live plant tissue, on dead plant tissue and on plant debris in the soil (Pietro et al. 2003; Gordon 2017; Edel-Hermann and Lecomte 2019). The main way of *F. oxysporum* spreading is via conidia produced on plant debris in contaminated soil (Pietro et al. 2003; Gordon 2017; Edel-Hermann and Lecomte 2019). Airborne spread of conidia has also been reported. For example, *F. oxysporum* f. sp. *basilici* produced large numbers of conidia in lesions on the stems of basil plants and viable airborne conidia were collected in spore traps (Gamliel et al. 1996).

Fusarium oxysporum forms durable chlamydospores (resting spores) that can persist in soil and later germinate in the presence of root exudates to infect the roots of host plants (Gordon 2017). Conidia can be converted to chlamydospores (resting spores that survive harsh conditions) when no host material is available and/or environmental conditions are unsuitable for germination (e.g. drought) (Smith and Snyder 1972; Pietro et al. 2003; Gordon 2017). Chlamydospores of some formae speciales of *F. oxysporum* have been reported to survive for six to eight years in soil (Jiménez-Díaz et al. 2015; EFSA Panel on Plant Health et al. 2018).

Symptoms of *F. oxysporum* in pineapple

Fusarium oxysporum has been reported cause pineapple plantation dieback disease, fruit rot fruitlet core rot, post-harvest fruit rot and channelled rot of pineapple fruit (mancha con galerías) in pineapple.

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[40] GenBank (Clark et al. 2016); Google Scholar; CAB abstracts; USDA Fungal Database (Farr and Rossman 2022), HerbIMI (2022) and the Pacific Islands Pest List Database (2022) were searched with the term “Fusarium oxysporum”. Search terms for Google Scholar; CAB abstracts were "Fusarium oxysporum" and “Ananas comosus" or “pineapple” and the country name. Google scholar searches were limited where appropriate with -banana -plantain -Panama (not when searching for records in Panama) -cubense

In Costa Rica, Brazil and Peru, *F. oxysporum* is reported to cause pineapple cultivation dieback disease (Jiménez and Granados 2014; Rojas 2020; Blanco-Menéses et al. 2022), a vascular wilt disease. In farms in Venecia, San Carlos, affected by "pineapple cultivation dieback", patches of pineapple plants (cultivar MD-2) showed dieback symptoms caused by fungal obstruction of the vascular symptom of the stems (Jiménez and Granados 2014; Blanco-Menéses et al. 2022). Jiménez and Granados (2014) identified a fungus isolated from infected pineapple stems as *F. oxysporum* based on morphological symptoms, PCR-Restriction Fragment Length Polymorphisms, and elongation factor 1 (EF-1) gene sequences, but did not confirm its pathogenicity with tests. Blanco-Menéses et al. (2022) also identified fungal isolates from stems, stem-bases, roots and leaves of pineapples in Costa Rica as *F. oxysporum* based on TEF1-α sequences. Symptoms of infected plants included yellowing, wilting and eventually complete dessication of the top 15 cm of the leaves, slow plant growth, and death of the root system (Jiménez and Granados 2014; Blanco-Menéses et al. 2022). Fruit from plants infected with *F. oxysporum* were asymptomatic (Blanco-Menéses et al. 2022) and did not show external symptoms such as gummosis or staining (Jiménez and Granados 2014). In affected plantations, yield losses due to underweight fruit were between 2000 to 4000 boxes/hectare (Jiménez and Granados 2014). None of the studies of pineapple cultivation dieback reported isolating *F. oxysporum* from fruit. However, given that *F. oxysporum* was isolated from pineapple stems and the core of the pineapple fruit is a modified stem, it is highly likely it can be present in the core of pineapples grown on infected plants.

Fruitlet core rot of pineapple causes brown rot of the flesh in individual fruitlets under the bract of the mature fruit. (Barral et al. 2020; Vignassa et al. 2021). Fruitlet core rot of pineapple occurs as a result of *Penicillium* and *Fusarium* spp. invading pineapple flowers at a very early stage of development before the fruit forms (Fournier et al. 2015). Fruitlet core rot pathogens remain latent during fruit development, but when the fruit begin to ripen, the individual fruitlets develop disease symptoms (Fournier et al. 2015). The first symptoms of fruitlet core rot occur inside mature fruit, when the flesh under the bract begins to turn brown. As symptoms develop, the rotten area can spread as far as the core, but does not spread into the core or other fruitlets (Barral et al. 2020). On ripe fruit, the eyes (bracts) may appear necrotic, with brown soft rot symptoms (Fournier et al. 2015). Photographs of fruitlet core rot lesions included in the publications by Souza et al. (2018) and Vignassa et al. (2021) suggest that larger lesions would be externally visible as discoloured and/or squishy patches on the skin, but the fruit would need to be cut to observe smaller lesions in the flesh under the bract. *Fusarium oxysporum* is not the most prevalent cause of fruitlet core rot in pineapple in most countries. However, on Réunion Island, 8% of *Fusarium* isolates from mature pineapples (nine isolates from fruitlet core rot spots and one from a healthy fruitlet) were *F. oxysporum* (Barral et al. 2020) and in a study of fruitlet core rot in Brazil, *F. oxysporum* species complex isolates comprised one third of the *Fusarium* isolates from fruitlet core rot lesions (Souza et al. 2018). Fruitlet core rot in pineapple fruit has also been reported from Malaysia (Ng 2009), although the pathogens causing it were not identified.

In Malaysia, *F. oxysporum* and *F. solani* (syn. *Neocosmopora solani*) were isolated from rotten pineapple fruit with sunken skin and brown lesions (Ibrahim et al. 2015). In some cases fungal mycelia were observed in the lesions (Ibrahim et al. 2015). Ibrahim et al. (2015) did not report any molecular identification or characterisation of strains, but did carry out testing to confirm pathogenicity. The disease symptoms were observed on growing fruit, and the developmental stage of the plants/fruit was not reported. In pathogenicity tests, a toothpick colonised by fungal mycelia was inserted through the skin of detached fruit (Ibrahim et al.

2015). After two weeks (no storage/incubation conditions described), infected fruit were cut vertically to expose brown lesions with mycelia on the surface (Ibrahim et al. 2015). The authors do not comment on whether symptoms were visible on the outside of the pineapple before they were cut.

In Peru, *F. oxysporum* is one of the fungi reported to cause channelled rot of pineapple fruit (mancha con galerías), a rot associated with attack by Pineapple Fruit Fly (*Melanoloma canopilosum*) (Bello Amez and Julca Otiniano 2005). *Fusarium oxysporum* has also been isolated from pineapple fruit from Vietnam (Stępień et al. 2013) and pineapple fruit with post-harvest rot in India (Biswal et al. 2007).

Conditions favouring *F. oxysporum* symptom development in pineapple

Fruitlet core rot symptoms, detected in cut fruit, developed in pineapples ripened in storage at 19 °C from the C1 stage (when approximately a quarter of the skin was yellow) to fully ripe (Vignassa et al. 2021), although the authors do not record how long it took for the fruit to ripen or whether they checked for internal symptoms at the earlier stage. In pathogenicity tests with *F. oxysporum*, isolates from pineapples on Réunion Island, a solution of conidia was injected into ripe pineapple fruit (described by Vignassa et al. (2021) as “a blossom cup of fruitlets”). Rot symptoms (black spots in the flesh under the bracts) were observed when the fruitlets were cut open after seven days at 19 °C. In pathogenicity testing with isolates in the *F. oxysporum* complex from Brazilian pineapples with fruitlet core rot, 0.5 mm discs of mycelia were inoculated into wounds in fruit made with a sterile needle (Souza et al. 2018). All but two of the isolates caused internal rotten lesions in fruit in cut fruit after 7 days stored at 25 °C (Souza et al. 2018).

Host-specificity of *F. oxysporum*

Searches of Google Scholar and CAB Abstracts using the terms “Fusarium oxysporum” and “pineapple” or “Ananas” found no studies that considered the pathogenicity of isolates from pineapple to other hosts. However, there are many reports of strains of *F. oxysporum* that are pathogenic on one host colonising the roots or vascular systems of numerous other ‘non-susceptible’ species such as weeds or other crops growing nearby (for example, Abawi and Lorbeer 1972; Helbig and Carroll 1984; Gordon et al. 1989; Altinok 2013; Imazaki and Kadota 2015; Pegg et al. 2019).This suggests that imported plant products such as pineapple might sometimes carry strains pathogenic to other plant species, with no visible symptoms of infection on the pineapple fruit.

A recent review of the literature on formae speciales and races of pathogenic *F. oxysporum* reported that many formae speciales have several hosts within the same genus or family. For example, f. sp. gladioli is reported from gladiolus (*Gladiolus* spp.), but also from other flowers such as crocuses (*Crocus* sp.), irises (*Iris* spp.) and freesias (*Freesia* sp.) (Edel-Hermann and Lecomte 2019). Some formae speciales of *F. oxysporum* have a broader reported host range, including plants from several different families, e.g. forma specialis *apii* is reported from hosts in the Apiaceae (*Apium graveolens*, celery), Fabaceae (*Pisum sativum*, pea), Asteraceae (*Tithonia rotundifoli*, Mexican sunflower), Asparagaceae (*Asparagus officinalis;* asparagus), Malvaceae (*Gossypium* spp.), Solanaceae (*Solanum melongena*, eggplant) (Edel-Hermann and Lecomte 2019). It is uncertain whether strains of *F. oxysporum* entering New Zealand on pineapple fruit will be pathogenic only to pineapple, particularly if pineapple crops had been alternated with a different crop or planted in areas near other crops.

There is recent evidence that chromosomes or regions of chromosomes with pathogenicity factors can be transferred from *F. oxysporum* strain to another without sexual reproduction (i.e. horizontal transfer) (Ma et al. 2010; Mehrabi et al. 2011; Ma et al. 2013; Lombard et al. 2019). Non-pathogenic strains *F. oxysporum* became pathogenic to tomato due to horizontal transfer of an *F. oxysporum* f. sp. *lycopersici* chromosome carrying genes for pathogenicity factors (Ma et al. 2010; Vlaardingerbroek et al. 2016). Recent genomic studies have found evidence that suggests there has been recent horizontal transfer of genes for the ‘secreted in xylem’ (*SIX*) pathogenicity/virulence factors in other *F. oxysporum* formae speciales (for example, van Dam et al. 2016; Czislowski et al. 2018; Deltour et al. 2018). This suggests the possibility that local lineages that are well adapted to thrive in the New Zealand environment can acquire new pathogenicity/virulence factors via horizontal transfer from imported strains/formae speciales.

Pineapple variety susceptibility
There are reports of *F. oxysporum* associated with most varieties of pineapples and several different pineapple diseases. *Fusarium oxysporum* has been reported from the MD-2 cultivar in Réunion Island (fruit with fruitlet core rot) (Barral et al. 2020; Vignassa et al. 2021) and Costa Rica (pineapple plants with cultivation dieback symptoms). *Fusarium oxysporum* was also isolated from fruit of the Queen Victoria cultivar in Réunion Island (Barral et al. 2020; Vignassa et al. 2021) and the Pérola cultivar in Brazil. In Malaysia, *F. oxysporum* was isolated from fruit of the Moris, Josapine, and Gandul varieties with rot symptoms. In Peru, the Smooth Cayenne cultivar is susceptible to channelled rot of pineapple fruit (mancha con galerías), caused by *F. oxysporum* and other fungi (Bello Amez and Julca Otiniano 2005).

In information on diseases of pineapple from the Kerala Agricultural University website, Joy and Sindhu (2012) report that Smooth Cayenne pineapples in Kerala usually show no external symptoms of fruitlet core rot (attributed to *F. guttiforme* and *P. funiculosum*), whereas in the Mauritius cultivar (in the Queen cultivar group) infected fruitlets fail to ripen, remaining green (known as “green eye”). Assuming that this is a characteristic of the disease and does not reflect the particular *Fusarium* species, fruitlet core rot may be easier to detect in ripe Queen pineapples than in the Smooth Cayenne cultivar.

5.1.3.2 Likelihood of entry

Fusarium oxysporum has been reported to cause pineapple plantation dieback disease, fruit rot, fruitlet core rot, post-harvest fruit rot and channelled rot of pineapple fruit (mancha con galerías) in pineapple.

It is likely that symptoms of *F oxysporum* will sometimes, but not always, be detected on pineapple fruit during production, preparation for export using visual inspection. For example, *F. oxysporum* was recorded on pineapple fruit in Malaysia, causing rotten lesions that sometimes contained visible mycelia (Ibrahim et al. 2015). External lesions on fruit such as the ones described in this study are likely to be detected during production and/or removed during preparation for export. The “pineapple cultivation dieback” strain of *F. oxysporum* reported from Costa Rica was isolated from stems and it is likely that it can be systemic in the vascular system of the fruit core, which is a modified stem (Jiménez and Granados 2014; Blanco-Menéses et al. 2022). Fruit from plants infected with this strain do not have visible lesions. However, fruit from infected plants is often undersized (Jiménez and Granados 2014; Blanco-Menéses et al. 2022) and undersized fruit is likely to be rejected during preparation for export. *Fusarium oxysporum* is also reported as a cause of fruitlet core rot. Fruitlet core rot pathogens are thought to infect the flowers and enter the fruit as it forms, but symptoms remain latent until the fruit is mature (Fournier et al. 2015). In pathogenicity tests, rot symptoms were observed in cut fruitlets after seven days at 19 °C. This suggests that fruitlet core rot symptoms caused by *F. oxysporum* will develop quickly once fruit ripens if it is stored at (or returned to) ambient temperatures (Vignassa et al. (2021). However, pineapples exported to New Zealand may be at the mature green stage and symptoms are unlikely to develop while the fruit is kept cool. Fruitlet core rot symptoms are often confined to an individual fruitlet and internal (see above), although symptoms may sometimes be visible on the skin as a brown rot (Fournier et al. 2015) or a bract that has remained green when the fruit ripened (Joy and Sindhu 2012). Symptoms of fruitlet core rot can be entirely internal (see above) and in this case they would not be detected in a visual inspection unless the fruit was cut on an axis that exposed the infected fruitlet. *Fusarium oxysporum* has not specifically been recorded as associated with fruitlet core rot in markets in scope of the PRA.

Pineapples are usually shipped at 7–13 ° C under 85–90% moisture for 14–28 days (see Annex.Appendix 3). *Fusarium oxysporum* may not be growing actively at this temperature, as growth tends to slow or stop at low temperatures (for example, mycelium of *F. oxysporum f. sp. ciceris* (Fusarium wilt of chickpeas) grew at temperatures between 7.5–35 °C (Jiménez-Díaz et al. 2015). In pineapple ripened at 19 °C, some fruitlets developed core rot symptoms, (Vignassa et al. 2021), suggesting the fungus remained viable and was capable of growth at this temperature. *Fusarium oxysporum* in ready-to-eat commercial pineapple stored at 4 °C also remained viable and subsequently grew in culture (Manthou et al. 2021). Therefore, it is considered highly likely that most strains of *F. oxysporum* can remain viable through sea freight transit times and that transit conditions are likely to allow survival but unlikely to promote development of *F. oxysporum* symptoms.

There are no border interceptions of any *Fusarium* species, only two fungi and no other pathogens identified by the MPI diagnostic laboratories from border interceptions on imported fresh pineapples between 2000–2020 (LIMS 2022). This could be interpreted as evidence that fungi are not frequently associated with the fresh pineapple pathways. However, given the evidence presented above, it is likely that *F. oxysporum* can be associated with asymptomatic pineapple fruit or remain latent in fruit stored at cold temperatures so that fruit does not show symptoms until it is returned to a temperature that allows the fungus to grow (as described above for fruitlet core rot caused by *F. oxysporum*).

Given the high volume of fresh pineapples imported to New Zealand, and the high likelihood that some *F. oxysporum* infections of pineapple fruit will remain undetected because symptoms are internal or the fruit is asymptomatic, even a low prevalence of infection would equate to a high likelihood of entry (one–two infected fruit entering New Zealand undetected/year)

Uncertainty

There is low uncertainty (strong evidence from several studies) that *F. oxysporum* can be associated with commercially produced pineapple fruit, for example Stępień et al. (2013), Ibrahim et al. (2015), Souza et al. (2018), Jiménez and Granados (2014), Barral et al. (2020), Vignassa et al. (2021). There is also low uncertainty (strong evidence from several studies) that *F. oxysporum* can sometimes be present in pineapple fruit without showing symptoms, for example Souza et al. (2018), Barral et al. (2020) and Vignassa et al. (2021). Overall, there is low uncertainty that *F. oxysporum* can enter New Zealand associated with commercial pineapple fruit.

Given that

- *Fusarium oxysporum* is recorded from all markets in scope of the IRA although it is not known whether new strains/species in the *F. oxysporum* species complex (not present in New Zealand) are associated with pineapple in all of them;
- *Fusarium oxysporum* has been recorded as associated with pineapple fruit from Ecuador, Malaysia and Costa Rica, countries in scope of the IRA;
- *Fusarium oxysporum* sometimes causes external fruit rot symptoms in pineapple, and sometimes causes internal fruitlet rot or no symptoms;
- *Fusarium oxysporum* can be associated with mature commercially produced pineapple fruit at the time of export, but visually detectable symptoms are unlikely to develop in fruit stored at cool temperatures;
- Internal symptoms caused by *F. oxysporum* will only be detected if the fruit is cut along an axis that exposes the infected parts of the fruit. Asymptomatic infections cannot be detected in a visual inspection;

MPI considers the likelihood of new strains/species in the *F. oxysporum* species complex (not present in New Zealand) entering New Zealand associated with pineapple fruit is HIGH with LOW uncertainty.

5.1.3.3 Likelihood of exposure

This assessment is made on the basis that new strains/species in the F. oxysporum species complex (not present in New Zealand) have entered New Zealand undetected in/on fresh pineapple.

Exposure is considered to be the transfer of a pest or disease from an imported commodity or inanimate object, to a host or environment suitable for the completion of development or production of offspring.

Imported fresh pineapple fruit is intended for human consumption, therefore, when the fruit arrives in New Zealand it will be distributed throughout New Zealand for wholesale or retail sale. Fresh pineapple fruit generates substantial amounts of unavoidable waste; the thick rind is always removed and disposed of, and the fruit is also sometimes cored (see waste analysis Annex 2.3.1). Pineapple dieback strains of *F. oxysporum* are likely to be associated with the core of the pineapple. Fruitlet core rot produces internal brown rot of fruitlets (the flesh under an individual bract) and rotten parts of the pineapple are also more likely to be discarded by consumers. The disposal of whole fruit (e.g., culled/unsold fruit, uneaten fruit remains) is not uncommon during wholesale, retail and by consumers. This suggests that *F. oxysporum* may have a higher likelihood of exposure when associated with fresh pineapple fruit than when it is associated with other kinds of fresh produce that are generally eaten whole.

In New Zealand the most common method of disposal of organic waste is bagged into landfill (Askarany and Franklin-Smith 2014); this is unlikely to be a risk. However, there are other disposal methods that could increase the exposure likelihood of the fungus, such as feeding out to animals, home composting and direct disposal into the environment. Fruit waste may be collected from unpacking areas (e.g., supermarket preparation rooms) and taken to rural areas where it is placed on the ground for eventual consumption by pigs or other farm animals (MPI 2014). The waste materials may also be used in worm farming. Using the waste materials to feed animals may inadvertently expose *F. oxysporum* to the soil and waterways before it eventually finds a suitable host. Many reviews and studies suggest that most or all strains of *F. oxysporum* can live in the soil as saprophytes on dead plant debris (e.g. crop residues and probably pineapple waste) (for examples, see Gordon et al. 1989; Olivain and Alabouvette 1997; Imazaki and Kadota 2015; Gordon 2017; Deltour et al. 2018).

Commercial composting can suppress many plant pathogens because the internal temperature of the compost can exceed 55°C (Hoitink et al. 1997; Mehta et al. 2014) and *F. oxysporum* is unlikely to survive in such conditions. However, the fungus is likely to thrive in home composts since their temperatures mostly range between 15°C and 30°C (Mensah 2017). If pineapple waste infected with *F. oxysporum* is disposed of in domestic compost, fed to animals or discarded directly into the environment, the fungus is highly likely to persist on the pineapple waste itself and on other plant debris in compost or soil. Due to its saprophytic lifestyle, *F. oxysporum* would not require a live plant host for exposure to occur.

Uncertainty
There is moderate uncertainty in these conclusions because assumptions about survival of *F. oxysporum* strains from pineapple in the soil and rhizosphere are based on reviews of the whole species complex and specific research on other formae speciales.

Given that:

- pineapple is a high waste commodity and rinds and sometimes cores are removed and discarded; and
- if pineapple waste infected with *F. oxysporum* is disposed of in domestic compost or directly into the environment, the fungus can survive and reproduce on pineapple waste and other plant debris. It does not require a live plant host.

MPI considers the likelihood of exposure of new strains/species in the *F. oxysporum* species complex (not present in New Zealand) in New Zealand from pineapple fruit is HIGH, with MODERATE uncertainty.

5.1.3.4 Likelihood of establishment

This assessment is made on the basis that strains/species in the F. oxysporum species complex (not currently present in New Zealand) entering New Zealand on pineapples have been successfully exposed to suitable host material in the New Zealand environment.

The reported host range of *F. oxysporum* strains isolated from pineapple is pineapple (*Ananas comosus*) and it is not known whether these strains can colonise other live plant hosts. However, a partial review of the extensive literature on *F. oxysporum* suggests that most or all strains are able to live as saprophytes on plant debris, on nutrients in the rhizosphere (around the root systems) and many strains can colonise the roots and vascular systems of nearby plants to some extent (for example, Abawi and Lorbeer 1972; Helbig and Carroll 1984; Gordon et al. 1989; Altinok 2013; Imazaki and Kadota 2015; Pegg et al. 2019). Therefore, although pineapple is not widespread in New Zealand, it is highly likely that *F. oxysporum* strains entering New Zealand on pineapple would be able to live in the soil even if no suitable live host plants were available (see section above), assuming other environmental conditions favoured their survival.

Fusarium oxysporum sensu lato is widespread in New Zealand; BiotaNZ (2022) and PPIN (2022) record collections of *F. oxysporum* (sometimes identified as a particular forma speciales) from a large range of hosts throughout New Zealand. Therefore, it is assumed that the climate in New Zealand will not limit the establishment of new strains of *F. oxysporum.* Although imported pineapples originate in tropical areas and it is possible that some strains entering New Zealand in pineapple will not adapt well to New Zealand climate conditions, *F. oxysporum* can produce chlamydospores (resting spores) to survive when environmental conditions become limiting (Jiménez-Díaz et al. 2015; Gordon 2017; EFSA Panel on Plant Health et al. 2018). *Fusarium oxysporum* chlamydospores have been reported to survive in soil for several years until suitable host material is available and the environment favours development of the fungus (Jiménez-Díaz et al. 2015; Gordon 2017; EFSA Panel on Plant Health et al. 2018).

Uncertainty

There is moderate uncertainty in this conclusion because assumptions about survival of *F. oxysporum* strains from pineapple in the soil and the rhizosphere are based on reviews of the whole species complex and specific research on other formae speciales.

Imported pineapples originate in tropical areas. The areas where *F. oxysporum* has been reported from cultivated pineapple are mostly tropical areas. For example, in Malaysia, *F. oxysporum* was isolated from plants in Kedah, Penang, Perak, Selangor, Negeri Sembilan, and Johor (Ibrahim et al. 2015). These areas have a climate match index of 0.5, indicating that the climate is not very similar to any part of New Zealand (Phillips et al. 2018). The pineapple cultivation dieback strain of *F. oxysporum* is reported from Venecia, San Carlos, Costa Rica (Jiménez-Díaz et al. 2015), which has a very different climate from New Zealand (Phillips et al. 2018). Therefore, there is also moderate uncertainty about whether these strains will survive in New Zealand’s sub-tropical-temperate climates or compete successfully with microorganisms (including *F. oxysporum* strains present in New Zealand) that are already well adapted to thrive in New Zealand. However, *F. oxysporum* in pineapple stored at 19 °C remained viable and the fruit developed symptoms (Vignassa et al. 2021), suggesting the fungus was capable of growth at this temperature. *Fusarium oxysporum* in ready-to-eat commercial pineapple stored at 4 °C remained viable and subsequently grew in culture (Manthou et al. 2021).

Given that:

- many strains of *F. oxysporum* are able to live as saprophytes on plant debris and in the rhizosphere (around the root systems), so it is likely that *F. oxysporum* entering New Zealand on pineapple would be able to live in the soil even in the absence of particular live host plants;
- many strains can colonise the root and vascular systems of nearby plants to some extent;
- *Fusarium oxysporum* can produce chlamydospores (resting spores) and these spores can survive for several years and germinate when conditions favour development of the fungus;
- *Fusarium oxysporum* sensu lato is widespread in New Zealand and reported from many different host plants, so the New Zealand environment is known to be suitable for many strains of *F. oxysporum*;

MPI considers the likelihood of new strains/species in the *F. oxysporum* species complex (not currently present in New Zealand) from pineapple establishing in New Zealand is HIGH, with MODERATE uncertainty.

5.1.3.5 Impacts in New Zealand

This assessment is made on the assumption that strains/species in the F. oxysporum *species complex (not currently present in New Zealand) entering New Zealand on pineapples has successfully established in the New Zealand environment.*

It is likely that some *F. oxysporum* strains from pineapple will be able to establish local populations in the soil (see above). New strains of *F. oxysporum* can be carried to new areas by human movement of soil and infected plant material. Although the only reported host of *F. oxysporum* strains that affect pineapple is pineapple, some *Fusarium oxysporum* strains are reported to cause disease in more than one host e.g. forma specialis *apii* is reported from hosts in the Apiaceae (*Apium graveolens*, celery), Fabaceae (*Pisum sativum*, pea); the Asteraceae (*Tithonia rotundifolia;* Mexican sunflower), Asparagaceae (*Asparagus officinalis;* asparagus), Malvaceae (*Gossypium* spp.), Solanaceae (*Solanum melongena*; eggplant) (Edel-Hermann and Lecomte 2019). However, without additional molecular data, there is no way of knowing whether any isolates from other hosts are the same as pineapple strains.

Fusarium oxysporum is widespread in New Zealand on many hosts, including hosts of economic importance to New Zealand. Any assessment of impacts would be purely speculative because there is no specific evidence that regulated/unwanted named species, or formae speciales, or as yet undescribed species/strains in the *F. oxysporum* complex, are associated with pineapple or that *F. oxysporum* strains recorded from pineapple are pathogenic on other plant species. The biosecurity risks associated with *F. oxysporum* on pineapple are similar to the biosecurity risks associated with *F. oxysporum* on other fresh produce pathways that are not known to be host regulated or unwanted *F. oxysporum* strains. For a newly introduced strain/species in the *F. oxysporum* species complex to have impacts on hosts other than pineapple beyond the existing impacts from *F. oxysporum* already present in New Zealand, it would need to be able to colonise and cause disease symptoms in plant hosts of economic importance or environmental significance to New Zealand, and out-compete local *Fusarium* strains in the soil and/or in plant hosts. The likelihood of this sequence of events is assessed as negligible. Even if *F. oxysporum* strains from imported pineapple occasionally cause disease symptoms on plant hosts in New Zealand, it is unlikely that the impacts will be greater than the impact of *F. oxysporum* strains that are already present. Overall, it is most likely that *F. oxysporum* strains entering New Zealand associated with pineapple will be pathogenic only to pineapple, or opportunistic post-harvest pathogens, or non-pathogenic strains and the economic or environmental impact of such strains to New Zealand is considered to be negligible. There is low uncertainty in these conclusions.

Economic impacts

The only reported host of *F. oxysporum* strains that affect pineapple is pineapple. The New Zealand pineapple industry is currently very small and localised to a single production site in Northland. For an imported strain of *F. oxysporum* to have impacts on pineapple in New Zealand, it would have to establish close to where pineapples are grown or be spread there by movement of contaminated soil or plant material.

Reports on the climate/weather conditions that lead to *F. oxysporum* causing severe disease in pineapples (see above) suggest that the weather in Northland (or elsewhere in New Zealand if pineapple production expanded) would seldom be consistently warm and wet enough for these strains to have an impact on pineapple production. Weather conditions that are reported to favour symptom development in pineapple plants infected with the Costa Rican “pineapple cultivation dieback” *F. oxysporum* strain (>80% humidity and daytime temperatures from

28–35 °C for a prolonged period (Jiménez and Granados 2014)) are extremely unlikely to occur in New Zealand, even in a changing climate. In contrast, development of fruitlet core rot symptoms on Réunion Island, is favoured by high rainfall and temperatures between 16–21 °C at the time of flowering (Fournier et al. 2015), conditions that may sometimes occur in Northland. However, *F. oxysporum* is not often reported as a prevalent cause of fruitlet core rot in pineapple, apart from a single study in Brazil by Souza et al. (2018).

Uncertainty
There is low uncertainty in this conclusion because there is very limited evidence that *F. oxysporum* strains from pineapple can be pathogenic to other hosts, and because it is considered highly unlikely that pineapple strains imported from tropical areas will out-compete local *F. oxysporum* strains.

Given that

- the only reported host of *F. oxysporum* strains from pineapple is pineapple;
- the New Zealand pineapple industry is currently very small and localised to a single production site in Northland;
- weather conditions (prolonged periods of high temperature and humidity) that promote symptom development in *F. oxysporum*-infected pineapple plants are extremely unlikely to occur in New Zealand, even in a changing climate;
- for a newly introduced strain of *F. oxysporum* to have economic impacts on other plant hosts it would need to spread to production areas, out-compete local *Fusarium* strains in the soil or plant hosts and be pathogenic (or acquire pathogenicity) to economic hosts other than pineapple, and the likelihood of this sequence of events is considered negligible;
- even if *F. oxysporum* strains from imported pineapple occasionally cause disease symptoms on other plant hosts in New Zealand, it is unlikely that the impacts will be greater than the impact of *F. oxysporum* strains that are already present;

MPI considers the economic impact of new strains/species in the F. oxysporum species complex (not currently present in New Zealand) from pineapple in New Zealand is NEGLIGIBLE, with LOW uncertainty.

Environmental impacts
Given that it is likely that *F. oxysporum* strains entering New Zealand associated with pineapple will be pathogenic only to pineapple, or opportunistic post-harvest pathogens, or non-pathogenic strains (see above), MPI considers the environmental impact of new strains/species in the *F. oxysporum* species complex (not currently present in New Zealand) from pineapple in New Zealand is negligible, with low uncertainty.

Human health impacts
Searches (see above) found no specific evidence that *F. oxysporum* strains from pineapple cause human disease, but two studies reported that *F. oxysporum* strains from pineapple could produce harmful mycotoxins in culture.

Numerous studies record *F. oxysporum* as a human pathogen in immunocompromised people and infections are sometimes reported in immunocompetent people (Lombard et al. 2019), and *F. oxysporum* has been reported to cause approximately 20% of cases of fusariosis (Guarro 2013). Systemic *Fusarium* infections in humans are often difficult to treat because they are resistant to commonly used antifungal treatments (Guarro 2013). Although pineapple strains of *F. oxysporum* have not been recorded as human pathogens, it is likely that they can sometimes cause opportunistic infections in humans, particularly if they are immunocompromised. However, given that such opportunistic infections are rare, and many strains of *F. oxysporum* are already present in New Zealand (BiotaNZ 2022), the likelihood of additional impacts from new strains is considered to be negligible.

Fusarium oxysporum can produce toxins in food that are harmful to human health when eaten. For example, *F. oxysporum* isolates from pineapple contain the gene for producing the mycotoxin beauvericin (Stępień and Waśkiewicz 2013; Waśkiewicz and Stępień 2013). Barral et al. (2020) reported that *F. oxysporum* culture from pineapple produced beauvericin. Eating a diet contaminated with beauvericin and enniatins (another class of mycotoxins) caused liver and gut lesions, changes in liver function, decreased diversity of the gut microbiome and reduced growth in recently weaned piglets (Novak et al. 2021). *Fusarium oxysporum* has also been reported to produce fumosinin analogs which may also be harmful to human health (Rheeder et al. 2002) and fusaric acid (López-Díaz et al. 2018) in culture. However, for new *F. oxysporum* strains to produce mycotoxins in New Zealand grown pineapples, they would first have to establish in New Zealand in this host, which is highly unlikely. Therefore, the health impacts for consumers from mycotoxins produced by *F. oxysporum* in New Zealand grown pineapples are negligible. Although there is potential for human health impacts from mycotoxins produced by *F. oxysporum* in imported pineapples, this is out of scope of this PRA.

Given that:

- the risk of harmful mycotoxins contaminating New Zealand grown pineapples as a result of new *F. oxysporum* strains from imported pineapples is negligible;
- opportunistic *F. oxysporum* infections in humans are rare, many strains of *F. oxysporum* are already present in New Zealand and the likelihood of additional infections from new strains is considered to be negligible;

MPI considers the human health impact of new strains/species in the *F. oxysporum* species complex (not currently present in New Zealand) from pineapple in New Zealand is NEGLIGIBLE, with LOW uncertainty.

Sociocultural impacts

The only reported host of *F. oxysporum* strains that affect pineapple is pineapple, which is only occasionally grown in home gardens in New Zealand. It is unlikely that *F. oxysporum* strains from pineapple are pathogenic to hosts unrelated to pineapple (see above). Therefore, MPI considers the sociocultural impact of *F. oxysporum* strains from pineapple in New Zealand is NEGLIGIBLE, with LOW uncertainty.

5.1.3.6 Overall impact to New Zealand

MPI considers the overall impact of strains/species in the *F. oxysporum* species complex (not present in New Zealand) on the New Zealand economy, environment, health and society is NEGLIGIBLE, with low UNCERTAINTY.

5.1.3.7 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is HIGH,

- assuming entry, the likelihood of exposure is HIGH,
- assuming successful exposure, the likelihood of establishment is HIGH, and
- the overall impact on the New Zealand economy, environment, human health, and society is considered to be NEGLIGIBLE,

MPI considers the overall level of assessed risk to New Zealand from strains/species in the *F. oxysporum* species complex (not present in New Zealand) on pineapple fruit is NEGLIGIBLE with LOW uncertainty.

5.1.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *F. oxysporum* association with pineapple fruit been observed?

There are reports of *F. oxysporum* associated with most varieties of pineapples and several different pineapple diseases. *Fusarium oxysporum* has been reported from the MD-2 cultivar in Réunion Island (fruit with fruitlet core rot) (Barral et al. 2020; Vignassa et al. 2021) and Costa Rica (pineapple plants with cultivation dieback symptoms). *Fusarium oxysporum* was also isolated from fruit of the Queen Victoria cultivar in Réunion Island (Barral et al. 2020; Vignassa et al. 2021) and the Pérola cultivar in Brazil. In Malaysia, *F. oxysporum* was isolated from fruit of the Moris, Josapine, and Gandul varieties with rot symptoms. In Peru, the Smooth Cayenne cultivar is susceptible to channelled rot of pineapple fruit (mancha con galerías), caused by *F. oxysporum* and other fungi (Bello Amez and Julca Otiniano 2005). Jiménez and Granados (2014) also mention that a strain of *F. oxysporum* was isolated from plants of the Smooth Cayenne and Spanish cultivars with dieback symptoms in Venezuela, but the original reference to this was not sourced.

In information on diseases of pineapple from the Kerala Agricultural University website, Joy and Sindhu (2012) report that Smooth Cayenne pineapples in Kerala usually show no external symptoms of fruitlet core rot (attributed to *F. guttiforme* and *P. funiculosum*), whereas in the Mauritius cultivar (in the Queen cultivar group) infected fruitlets fail to ripen, remaining green (known as “green eye”). Assuming that this is a characteristic of the disease and does not reflect the particular *Fusarium* species, fruitlet core rot may be easier to detect in ripe Queen pineapples than in the Smooth Cayenne cultivar.

Fusarium oxysporum can be isolated from fruit at all stages of development. In fruitlet core rots, *Fusarium* spp. are reported to enter the flower associated with mites, so the fungi are present from the earliest stages of fruitlet development, although the fungus remains latent until fruit is ripe (Fournier et al. 2015). There are reports of *F. oxysporum:*

- on developing fruit at production sites (Ibrahim et al. 2015),
- sampled from fully ripe fruit with completely yellow skin (C4 stage). Partially ripe fruit was harvested when ¼ of the skin was yellow (C1 stage) and ripened at 19 °C (Vignassa et al. 2021),
- isolated from mature fruit at the time of harvest (Barral et al. 2020),
- isolated from commercially available ripe fruit (Stępień et al. 2013) and from samples of ready to eat pineapple (fresh-cut pineapple packed in PVC trays) supplied by a manufacturer in Athens, Greece (Manthou et al. 2021).

Which part(s) of the pineapple fruit is *Fusarium oxysporum* associated with (e.g. fruit, bract, stem or crown remnant) and is it detectable by visual detection?

Fusarium oxysporum is reported as the cause of pineapple plantation dieback disease, a vascular wilt, in Costa Rica (Jiménez and Granados 2014; Blanco-Menéses et al. 2022), and possibly the Philippines, based on the descriptions of accessions MZ604650.1, MZ604651.1, and MZ604652.1 in GenBank. Pineapple plantation dieback disease strains of *F. oxysporum* are most likely to be associated with the core (which is a modified stem), and crown or stem remnants without visible symptoms. These strains would not be detected by visual inspection.

Fusarium oxysporum can also be associated with individual fruitlets under the bracts of the pineapple, although it is not the most frequently reported cause of fruitlet core rots (Souza et al. 2018; Barral et al. 2020; Vignassa et al. 2021). Fruitlet core rot symptoms develop sometimes as soft brown spots of visible rot on the bracts or skin (Fournier et al. 2015; Souza et al. 2018). However, photos of cut sections of diseased fruitlets in Souza et al. (2018) and Vignassa et al. (2021), suggest that fruitlet core rots can sometimes be entirely internal and these would escape detection during post-harvest processing and visual inspection. Both these authors also reported isolating *F. oxysporum* from asymptomatic fruit. In the Mauritius cultivar (in the Queen cultivar group) fruitlets with fruitlet core rot may fail to ripen, remaining green (known as “green eye”) (Joy and Sindhu 2012). In many cases fruitlet core rot would only be detected if the fruit was cut along an axis that exposed the infected fruitlets.

In an outbreak in Malaysia, rotten lesions containing fungal mycelium were reported on the outside of the fruit (Ibrahim et al. 2015), and a rot such as this would be easily detected during production or preparation for export.

Are different life stages of *F. oxysporum* associated with different parts of the pineapple fruit?
No sexual stages of *F. oxysporum* have been observed (Gordon 2017), so only the asexual stage is associated with pineapple.

Under what environmental conditions (temperature, season etc) are *F. oxysporum* symptoms expressed on pineapple fruit?
On Réunion Island, where *F. oxysporum* was sometimes associated with fruitlet core rot (Barral et al. 2020; Vignassa et al. 2021), disease development is favoured by high rainfall and temperatures between 16–21 °C at the time that pineapple flowers, although symptoms do not develop until the fruit ripen (Fournier et al. 2015). Rot symptoms (black spots in the flesh under the bracts) developed in pathogenicity tests on mature fruit after seven days at 19 °C. Harvested fruit developed symptoms after ripening fully at 19 °C, but these were observed by cutting the fruit and symptoms may remain internal. In pathogenicity tests with *F. oxysporum* isolates from pineapple in Brazil, the fungus caused internal rotten lesions in fruit after 7 days stored at 25 °C (Souza et al. 2018).

Does *F. oxysporum* exhibit latent/asymptomatic traits?
Asymptomatic colonisation of the vascular system of above ground parts of host plants by *F. oxysporum* is reported (for example, Imazaki and Kadota 2015, see section above).

In pineapple, *F oxysporum* has been isolated from fruitlet core rots, in which infection occurs at the time of flowering, but symptoms remain latent (do not develop) until the fruit begins to ripen (Fournier et al. 2015). It is highly likely that pineapple cultivation dieback strains of Although the only visible symptom of pineapple cultivation dieback in fruit is reduced size in severe infections (Jiménez and Granados 2014; Blanco-Menéses et al. 2022), it is highly likely that *F. oxysporum* can be systemic in the vascular system of the plant, including the core of the fruit and stem or crown remnants (see above).

5.1.5 *Appendix to risk assessment of Fusarium oxysporum*

Information from MPI Plant Health and Environment Laboratory
The project leads asked the MPI Plant Health and Environment Laboratory (PHEL) for additional information about whether strains of *F. oxysporum* found on pineapple fruits are present in NZ and whether these strains are specific to pineapple. Answers to these questions are detailed in the appendix.

Most available sequences of *F. oxysporum* strains found from pineapple do not match sequences of known New Zealand isolates:

- Of the 316,360 *Fusarium oxysporum* sequences in GenBank, 23 were recorded as associated with pineapple (Katharina Hofer, PHEL, pers. comm. 2022). None of these records derived from New Zealand isolates, but from isolates obtained from the Philippines, Brazil, Costa Rica, Cameroon, and Dominican Republic (Katharina Hofer, PHEL, pers. comm. 2022).
- There is no evidence that any of the pineapple-associated *F. oxysporum* strains with sequences in GenBank are present in New Zealand. BLAST analysis showed that most of these pineapple-associated sequences did not match sequences from known New Zealand isolates (Katharina Hofer, PHEL, pers. comm. 2022).
- The ITS region sequence from one isolate matched the sequence of a New Zealand isolate (Katharina Hofer, PHEL, pers. comm. 2022). However an ITS sequence alone is not sufficient to identify Fusarium species or subspecies (Katharina Hofer, PHEL, pers. comm. 2022). Another gene region (e.g. TEF or RPB2) would need to be analysed to determine if this isolate is identical to the New Zealand isolate (Katharina Hofer, PHEL, pers. comm. 2022). Note that this only one of the 23 isolates, so even if this strain were present, the others are not.

Searches of *F. oxysporum* sequences in GenBank provided no information about whether strains of *F. oxysporum* from pineapple were associated with other hosts or pathogenic in other hosts.

- Although many of the 23 pineapple-associated *F. oxysporum* sequences found in GenBank searches matched with other publicly available records, each of these matches was based on a single gene region (ITS, TEF, or RPB2) from a pineapple-associated *F. oxysporum* isolate (Katharina Hofer, PHEL, pers. comm. 2022). Matches across more than one would be necessary to draw conclusions whether a certain isolate is identical to another one (Katharina Hofer, PHEL, pers. comm. 2022).
- Many of the matching records in GenBank do not state the host they were isolated from and/or have not been published in scientific papers, so do not provide any insight into host-specificity or pathogenicity of the pineapple isolates (Katharina Hofer, PHEL, pers. comm. 2022). Therefore, there is no specific information about whether strains of *F. oxysporum* from pineapple can cause disease in other hosts.
- According to Edel-Hermann and Lecomte (2019), “Molecular identification of F. oxysporum formae speciales would ideally target pathogenicity-related genes”. Whole

genome sequencing, in order to identify virulence markers, would be necessary to determine host-specificity and/or identify *F. oxysporum* to the formae speciales level via molecular methods in the future (Katharina Hofer, PHEL, pers. comm. 2022). Unfortunately, this is not feasible with the methods currently available to PHEL, and there is no reference material available for the known pineapple isolates (Katharina Hofer, PHEL, pers. comm. 2022).

Geographical distribution of *F. oxysporum* from pineapple

Table 5.1 shows the reports of *F. oxysporum* from pineapple in markets in scope of the IRA found in literature and database searches[41].

Table 5.1. Records of *Fusarium oxysporum*, from pineapple, in markets in scope of this IRA.

Market	Record of *F. oxysporum* from pineapple
Costa Rica	Isolated from commercially available Costa Rican pineapple fruit with fungal symptoms (sometimes in coinfection with other *Fusarium* species) (Stępień et al. 2013). Identified based on translation elongation factor tef-1α sequence alignment. Isolated from stalks of plants (MD-2 cultivar) with symptoms of the disease "pineapple cultivation dieback" (see below) collected from farms in Venecia, San Carlos. Identified by morphological characteristics, PCR-Restriction Fragment Length Polymorphisms and comparison of TEF gene sequences with accessions in GenBank. (Stępień et al. 2013; Jiménez and Granados 2014; Umaña-Castro 2018; Blanco-Menéses et al. 2022)
Ecuador	Isolated from commercially available pineapple fruit from Ecuador with fungal symptoms (sometimes in coinfection with other *Fusarium* species) (Stępień et al. 2013). Identified based on translation elongation factor tef-1α sequence alignment (Stępień et al. 2013); No other information found in searches of literature, fungal collections or the GenBank nucleotide sequence database.
Malaysia	Isolated from pineapple fruit (varieties Moris, Josapine, and Gandul) with disease symptoms (rotten lesions and visible mycelia) in Kedah, Penang, Perak, Selangor, Negeri Sembilan, and Johor (Ibrahim et al. 2015) and this record is cited in the USDA Fungal Database (Farr and Rossman 2022) Collections from Sabah and Peninsular Malaysia in HerbIMI (2022). No further evidence found in searches of literature, fungal collections.
The Philippines	Three translation elongation factor 1-alpha (tef1-α) sequences in GenBank (Clark et al. 2016) identified as *F. oxysporum* from *Ananas comosus* leaf from an unpublished study of pineapple cultivation dieback in the Philippines (GenBank: MZ604650.1, MZ604651.1, MZ604652.1).

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[41] GenBank (Clark et al. 2016); Google Scholar; CAB abstracts; USDA Fungal Database (Farr and Rossman 2022), HerbIMI (2022) and the Pacific Islands Pest List Database (2022) were searched with the term “Fusarium oxysporum”. Search terms for Google Scholar; CAB abstracts were "Fusarium oxysporum" and “Ananas comosus" or “pineapple” and the country name. Google scholar searches were limited where appropriate with -banana -plantain -Panama (not when searching for records in Panama) -cubense

Australia	No record of *F. oxysporum* from pineapple found in searches of literature, fungal collections or the GenBank nucleotide sequence database. No record of *F. oxysporum* on pineapple in a report by Summerell et al. (2010) cataloguing *Fusarium* species associated with plants in Australia.
Indonesia, Panama, Sri Lanka, Taiwan, Thailand	No record of *F. oxysporum* from pineapple found in literature searches, fungal collections or sequence databases.
Pacific countries: Cook Islands, Fiji, New Caledonia, Papua New Guinea, Samoa, Tonga Vanuatu	No record of *F. oxysporum* from pineapple found in searches of literature, fungal collections or the GenBank nucleotide sequence database. No record of *F. oxysporum* from pineapple in the Pacific Islands Pest List Database (2022)

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5.2 Fusarium verticillioides

Fusarium verticillioides is a fungal pathogen that often colonises its hosts systemically as an endophyte and causes disease symptoms when the plant is stressed or injured. It causes economically significant yield losses due to stalk, ear and kernel rots in some grain crops, especially maize, and causes occasional outbreaks of seedling, stem and root rots, vascular wilts or post-harvest fruit rots in many other plant crops. It is probably an opportunistic pathogen of pineapple and can be associated with either asymptomatic fruit or fruit with rot symptoms.

5.2.1 *Taxonomic description*

Scientific name: *Fusarium verticillioides* (Sacc.) Nirenberg 1976
Order: Hypocreales **Family:** Nectriaceae
Other names: *Gibberella fujikuroi* mating population A; *Oospora verticillioides* Sacc. 1881; *Alysidium verticillioides* (Sacc.) Kuntze 1898; *Fusarium moniliforme* J. Sheld. 1904; *Gibberella moniliformis* Wineland 1924; Fusarium ear rot (of maize).

Taxonomic notes:
Fusarium verticillioides was part of the historic species named as *F. moniliforme,* but they are not exact synonyms. *Fusarium moniliforme*-included six or more reproductively isolated mating populations from the *Fusarium fujikuroi* species complex (some of which have since been described as separate species), and Seifert et al. (2003) designated one of these mating populations as *F. verticillioides.* The name *F. moniliforme* should not be considered to be equivalent to *F. verticillioides,* particularly when dealing with older literature (Seifert et al. 2003; Yilmaz et al. 2021). However, this PRA has referred some older studies describing the biology of *F. moniliforme* in maize (a well-studied host of economic importance to New Zealand), since this probably relates to *F. verticillioides* or a closely related species with similar biology.

5.2.2 *Hazard Identification*

Fusarium verticillioides is not known to be present in New Zealand.

- *Fusarium verticillioides* is recorded as “not present in NZ” BiotaNZ (2022).
- There is no entry of *Fusarium verticillioides* in PPIN (2022). Although *F. moniliforme* is recorded in New Zealand, BiotaNZ (2022) says that the record of *F. moniliforme* by Fullerton (1978) is unlikely to be *F. fujikuroi* Mating Population A (that is *F. verticillioides*), and PPIN does not record any collections of *F. verticillioides.*
  Fusarium verticillioides is a regulated pest for New Zealand (ONZPR 2022).

Fusarium verticillioides has the potential to establish and spread in New Zealand.

- *Fusarium verticillioides* has a broad geographical distribution and is widespread in many areas with a similar climate to the whole of New Zealand (based on a climate match index of ≥0.7 using the CLIMEX tool of (Phillips et al. 2018)).
- *Fusarium verticillioides* has a broad host range including commonly grown New Zealand plants and many weed species (Postic et al. 2012; Farr and Rossman 2022), and suitable hosts are likely to be available throughout New Zealand.

- *Fusarium verticillioides* produces spores on infected tissues and plant debris, which can be spread by water and insects (Parsons and Munkvold 2012; Drakulic et al. 2017) and are adapted for air (wind) dispersal (Ooka and Kommedahl 1977).

Fusarium verticillioides has the potential to cause harm to New Zealand.

- *Fusarium verticillioides* is reported to cause disease symptoms in many horticultural hosts that are important to New Zealand, such as stem and ear rots of maize (*Zea mays*) (Goertz et al. 2010; Parsons and Munkvold 2012).
- *Fusarium verticillioides* can cause disease in humans and other animals (Nucci and Anaissie 2007; Benedict et al. 2017; Oldenburg et al. 2017; Blacutt et al. 2018).

Fusarium verticillioides has been isolated from commercially produced pineapple fruit, with and without disease symptoms (Stępień et al. 2013; Ibrahim et al. 2017; Vilaplana et al. 2018; Valencia-Chamorro et al. 2021; Vignassa et al. 2021).

Given the arguments and evidence above, *F. verticillioides* is considered to be a hazard on decrowned pineapple (*Ananas comosus*) fruit (as described in the commodity description) imported to New Zealand.

5.2.3 *Risk Assessment*

5.2.3.1 Biology

Hosts and geographical distribution

Fusarium verticillioides has a widespread distribution in tropical, sub-tropical and temperate areas, including many areas with a similar climate to New Zealand. For example, *F. verticillioides* has been reported in Spain (Aguín et al. 2014), Serbia (Krnjaja et al. 2018), Germany (Pfordt et al. 2020), Kansas, Iowa, Georgia, Tennessee California and North Carolina, USA (Bush et al. 2004; Parsons and Munkvold 2012), Italy (Cao et al. 2013), Poland (Czembor et al. 2019), Germany (Goertz et al. 2010), Serbia (Krnjaja et al. 2018), Croatia (Postic et al. 2012), Slovakia (Srobarova et al. 2002), eastern China (Anhui and Jiangsu) (Qiu et al. 2015), and Australia (New South Wales) (Watson et al. 2014), all areas with a climate similar to the whole of New Zealand (based on a climate match index values of ≥0.7 using the CLIMEX model of Phillips et al. (2018)).

Fusarium verticillioides is reported from pineapple (*Ananas comosus*) fruit (Stępień et al. 2013; Ibrahim et al. 2017; Vilaplana et al. 2018; Vignassa et al. 2021, discussed in detail in the next section). There are specific reports of *F. verticillioides* on pineapple in Costa Rica, Malaysia and Ecuador (markets in scope of this import risk analysis). However, searches using the terms “Fusarium verticillioides” and “pineapple” or “Ananas comosus” found no evidence that *F. verticillioides* isolates would be specific to pineapples, so this assessment has assumed that the fungus can be associated with pineapple anywhere that it is present. Table (appendix) shows evidence from literature and database searches[42] that *F. verticillioides* is present in most markets in the scope of this import risk analysis.

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[42] GenBank (Clark et al. 2016); Google Scholar; CAB abstracts; USDA Fungal Database (Farr and Rossman 2022), HerbIMI (2022) and the Pacific Islands Pest List Database (2022) were searched with the term “Fusarium verticillioides”. Search terms for Google Scholar; CAB abstracts were " Fusarium verticillioides " and the country name. An additional search on the terms “Fusarium moniliforme” and the country name. was included in Google scholar and CAB abstract searches if no records were found in the initial search, but country presence records based on this synonym have high uncertainty (see taxonomic notes).

Fusarium verticillioides has a broad host range across many plant families (Farr and Rossman 2022), and yield losses are commonly reported in grains and grasses (Poaceae), especially maize (Parsons and Munkvold 2012; Watson et al. 2014; Li et al. 2019; Pfordt et al. 2020) Although the major economic host of importance to New Zealand of *F. verticillioides* is maize, it has also sometimes been reported to cause disease symptoms in other crops of economic importance to New Zealand, e.g. head rot affecting Chinese flowering cabbage (*Brassica rapa* L. *parachinensis*) plants (Akram et al. 2020), post-harvest fruit rot of grapes (*Vitis vinifera*) (Lorenzini and Zapparoli 2015), root rot of asparagus (*Asparagus officinale*) (Ismail et al. 2017), vascular wilt of tomato (Chehri 2016; Murad et al. 2016; Chang et al. 2018) and spring onion (Dissanayake et al. 2009) and bulb rot of garlic (Delgado-Ortiz et al. 2016).

Fusarium verticillioides has also been isolated from soil and crop debris and weed species in some areas (Postic et al. 2012; Martínez et al. 2021). *Fusarium verticillioides* is reported to cause economic impacts in some other hosts of less importance to New Zealand, such as sugarcane (*Saccharum officinarum*), rice (Oryza sativa), sorghum (*Sorghum bicolor*) and cotton (*Gossypium hirsutum*) (not discussed in detail in this PRA but see references in the entry for *F. verticillioides* in Farr and Rossman 2022 if more information about impacts in these crops is required)

In addition to causing disease in plant hosts, *F. verticillioides* has been reported as pathogenic to insects and mites (Pelizza et al. 2011; Abdel Galil et al. 2019; Patel and Ghetiya 2019; Sain et al. 2021; Ni et al. 2022). For example, blue winged grasshoppers (*Tropidacris collaris* (Stoll); Orthoptera: Acridoidea: Romaleidae) were collected, and kept in conditions that favour fungal development of entomopathogenic fungi (30 °C, 14:10 light-dark photoperiod, 60% relative humidity) (Pelizza et al. 2011). *Fusarium verticillioides* was isolated from grasshoppers that died within 10 days of collection. In pathogenicity tests, a spur-throated grasshopper species (*Ronderosia bergii* (Stål); Orthoptera: Acridoidea: Acrididae: Melanoplinae) were infected with *F. verticillioides* and approximately 60% of the insects were dead by 10 days after inoculation.

Symptoms of *F. verticillioides* in pineapple

There are several recent records confirming that *F. verticillioides* can be present in pineapple fruit as an asymptomatic endophyte or in disease lesions alone or with other pathogens (Stępień et al. 2013; Ibrahim et al. 2017; Vilaplana et al. 2018; Vignassa et al. 2021). *Fusarium verticillioides* can be associated with all parts of the pineapple fruit. *Fusarium verticillioides* has been isolated from the cores (Stępień et al. 2013), internal fruitlets (Vignassa et al. 2021) and external lesions of the skin and flesh (e.g. brown discolouration, dry rot and sunken patches, fungal mycelium, brownish ooze) (Ibrahim et al. 2017; Vilaplana et al. 2018). Infected pineapple plants also showed symptoms including gum exudation, rotten or sunken stems, dry rot of leaves and leaf chlorosis and necrosis (Ibrahim et al. 2017).

Fusarium verticillioides can be asymptomatic or cause only internal symptoms in pineapple fruit. The fungus was isolated from healthy pineapple fruitlets and from fruitlets with core rot symptoms in pineapples harvested partially green and ripened in storage at 19 °C (Vignassa et al. 2021). Vignassa et al. (2021) did not carry out pathogenicity tests to confirm that *F. verticillioides* isolates could cause fruitlet core rot symptoms. Fruitlet core rot is rot of individual fruitlets under the bracts which can develop into soft brown spots of visible rot on the bracts or skin (Fournier et al. 2015), but photos of cut sections of diseased fruitlets in

Vignassa et al. (2021) suggest that symptoms can sometimes be entirely internal and would escape detection unless the fruit was cut along an axis that exposed the infected fruitlets. Internal rot of pineapple caused by *F. verticillioides* was observed during cold storage (Valencia-Chamorro et al. 2021).

The evidence summarised above suggests that *F. verticillioides* is usually a mild (probably opportunistic) pathogen in pineapple fruit and may be present as an asymptomatic endophyte or in disease lesions along with other pathogens. Whether symptoms of *F. verticillioides* are external and can be detected by visual inspection in pineapple fruit probably depends on the interaction of many factors including time and route of infection, environmental conditions, coinfection with other pathogens, whether the pineapple plant or fruit is damaged or injured, packhouse fungicide treatments, fruit ripeness and the strain of the fungus.

Conditions favouring *F. verticillioides* symptom development in pineapple

In pathogenicity tests in puncture-inoculated pineapple fruit (MD2 variety), lesions of *F. verticillioides* developed in cold storage at 8 °C (relative humidity = 80%), reaching approximately 25 mm in diameter after 21 days (Vilaplana et al. 2018). These lesions expanded to 35 mm diameter when the fruit was returned to an ambient temperature of 20 °C (relative humidity = 85%) for seven days (Vilaplana et al. 2018). Vilaplana et al. (2018) do not record cutting the fruit, so it is assumed that the rot lesions were externally visible. *Fusarium verticillioides* lesions developed much more slowly in pineapple fruit treated with the fungicide prochloraz (to a final size of approximately 10 mm diameter), and Vilaplana et al. (2018) report that this fungicide treatment is a standard packhouse treatment for fruit from Ecuador.

Mild fruit rot symptoms (brown lesions) were observed in cut pineapple fruit, two weeks after wound inoculation with *F. verticillioides* isolates from pineapple (fruit incubated at 27 ± 1°C with 75%–80% humidity)(Ibrahim et al. 2017). Ibrahim et al. (2017) do not state the stage of development, but the fruit shown in the figure illustrating symptoms on pineapple fruit in the field appears yellow and detached mature fruit were used for pathogenicity tests.

Pineapple variety susceptibility

In pathogenicity tests on ripe pineapples (Gandul, Josapine and Morris varieties) with *F. verticilliodes* isolates from Malaysia, Josapine showed the most severe rot symptoms (Ibrahim et al. 2017). *Fusarium verticilliodes* was associated with fruit of MD2 variety with rot symptoms (Vilaplana et al. 2018). *Fusarium verticilliodes* was isolated from fruitlets of ripe pineapples of the ‘Queen Victoria’ cultivar with and without symptoms (Vignassa et al. 2021).

Life cycle, reproduction and transmission

Spread: *Fusarium verticillioides* is a seed and soilborne pathogen and microconidia, or small asexual spores, are the main form of inoculum and are spread by wind (up to 400km), water splash and insects (Ooka and Kommedahl 1977; Munkvold et al. 1997; Munkvold 2003; Presello et al. 2007; Wilke et al. 2007; Ortiz et al. 2015; Blacutt et al. 2018). Although *F. verticillioides* can produce spores through sexual reproduction (for example Gomes et al. (2020)), different mating types would not be required for *F. verticillioides* to establish in New Zealand. *Fusarium verticillioides* can systemically colonise maize plants via the soil (Oren et al. 2003; Gai et al. 2018). Western flower thrips (*Frankliniella occidentalis*) are associated with the spread of *F. verticillioides* in maize (Parsons and Munkvold 2010, 2012; Drakulic et al. 2017) and are present in New Zealand (BiotaNZ 2022). Lepidopteran ear borers such as

Helicoverpa armigera, *Conogethes punctiferalis, Ostrinia nubilalis* and *O. furnacalis* are also reported to spread *F. verticillioides* in maize (Darvas et al. 2011; Mazzoni et al. 2011; Niculina et al. 2019; Li 2021), but of these species, only *H. armigera* is reported in New Zealand (BiotaNZ 2022). Sap beetles, rootworm beetles and picnic beetles have also been reported to carry spores of *F. verticillioides* (Gilbertson et al. 1986; Sobek and Munkvold 1999; Drakulic et al. 2017).

Growth and reproduction of *F. verticillioides*: In culture, the optimum temperature for growth of *F. verticilliodes* was between 28 –30°C and the fungus grew at temperatures between 4–36 °C (Wilke et al. 2007), although Reid et al. (1999) reported 5 °C as the minimum temperature for growth.

In culture, production of conidia (asexual spores) of *F. verticillioides* isolates from maize in Italy increased progressively from 5 °C to the optimum temperature of approximately 27–30°C (Rossi et al. 2009). Sporulation declined rapidly above this temperature, with only at low levels at 40°C and no spore production at 45°C (Rossi et al. 2009). Conidia of *F. verticillioides* germinated between 5–37 °C in culture, with an optimum of 25°C (Marin et al. 2004)

Environmental reservoirs of *F. verticillioides*

Fusarium verticillioides survives in crop residues in the soil and this serves as a reservoir and primary source of fungal inoculum to infect hosts systemically via the roots, or via water splash or wind dispersal of spores) (Leslie et al. 1990; Wilke et al. 2007; Murillo-Williams and Munkvold 2008). *Fusarium verticillioides* does not produce chlamydospores (resting spores) but overwinters on crop residues as sclerotia (quiescent thickened hyphae) which resume growth when environmental conditions become favourable again (Munkvold 2003; Parsons and Munkvold 2012). *Fusarium verticillioides* (as *F. moniliforme*) was recovered from corn, sorghum, and soybean crop residues (Leslie et al. 1990). *Fusarium verticillioides* remained viable in maize stalk residue on the soil surface or buried for at least 630 days and on wheat stalks on the soil surface for 180 days (when the experiment ended) (Palazzini et al. 2013).*Fusarium verticillioides* can survive in soil and potting mix (Karim et al. 2016; Mohammadian et al. 2017; Puértolas et al. 2018).

Weed species from diverse monocot and dicot families can act as environmental reservoirs of *F. verticillioides* including *Agrostemma githago* (Caryophyllaceae), *Amaranthus retroflexus* and *Chenopodium album* (Amaranthaceae), *Avena fatua, Hordeum* sp. and *Sorghum halepense* (Poaceae), *Capsella bursa-pastoris* (Brassicaceae), *Papaver rhoeas* (Papaveraceae), *Helianthus* sp., *Portulaca oleracea* (Portulacaceae) and *Xanthium strumarium* (Asteraceae) and *Datura ferox* (Solanaceae) (Postic et al. 2012; Martínez et al. 2021).

5.2.3.2 Likelihood of entry

Fusarium verticillioides has been reported from the fruitlets of pineapple fruit (Vignassa et al. 2021) and the flesh and skin. Although systemic endophytic infections have not specifically been reported from pineapple, they are common in many other monocot hosts (e.g. maize, wheat) and it is likely that *F. verticillioides* from the soil can systemically colonise the stems of pineapple, and be present in the core (a modified stem) and stem and crown remnants of fruit.

Fusarium verticillioides can be asymptomatic, or disease symptoms may be entirely internal in pineapple fruit (Vignassa et al. 2021), see description of fruitlet core rot (section 4.1.3.1). It is likely that internal fruitlet core rot symptoms would escape detection in the packhouse or visual inspection.

Fusarium verticillioides sometimes produces external rot symptoms on pineapple fruit. For example, Vilaplana et al. (2018) describe symptoms of *F. verticillioides* as light to dark brown discoloured sunken patches on fruit, covered with fungal mycelium and a brownish exudate. *Fusarium verticillioides* was one of the *Fusarium* species recorded on pineapple fruit in Malaysia, causing brown discolouration of fruit, dry rot and sunken fruit skin and internal fruitlet rot (Ibrahim et al. 2017). External lesions on fruit such as the ones described in these studies are likely to be detected during production and/or removed during preparation for export.

In pathogenicity tests with isolates from fruit with external rot symptoms, mild rot symptoms were observed in detached mature fruit by cutting the fruit vertically after 2 weeks incubation (27 ± 1°C with 75%–80% humidity) (Ibrahim et al. 2017). In pathogenicity tests, an isolate of *F. verticillioides* caused external rot symptoms in ripe pineapples even at 8 °C (Vilaplana et al. 2018). Fruitlet core rot symptoms in fruit infected with *Fusarium* spp. early in development do not usually develop until fruit is ripe (Fournier et al. 2015). This suggests that rot symptoms caused by *F. verticillioides* may develop once fruit ripens. However, pineapples exported to New Zealand may be at the mature green stage and rot symptoms do not seem to be reported in unripe fruit. In addition, pineapple fruit for export may be treated with fungicides to slow development of post-harvest rots. For example, Vilaplana et al. (2018) note that in Ecuador, pineapples are usually treated in the packhouse with the fungicide prochloraz and in their study rotten lesions of *F. verticillioides* developed more slowly in fruit sprayed with prochloraz. This suggests that symptoms of *F. verticillioides* on pineapple fruit will often be mild and difficult to detect, or still internal at the time of arrival in New Zealand.

Pineapples are usually shipped at 7–13 ° C under 85–90% moisture for 14–28 days (see Annex.Appendix 3). Studies have shown that isolates of *F. verticillioides* can grow in culture (Reid et al. 1999; Marin et al. 2004; Wilke et al. 2007) and even produce conidia (Rossi et al. 2009) at temperatures as low as 5 °C (although this temperature is far below the optimum, see 4.1.3.1). *Fusarium verticillioides* can overwinter as sclerotia on plant debris (Munkvold 2003b; Parsons and Munkvold 2012). *Fusarium verticillioides* is widespread in areas such as Poland (Czembor et al. 2019), Germany (Goertz et al. 2010), Serbia (Krnjaja et al. 2018), Croatia (Postic et al. 2012), Slovakia (Srobarova et al. 2002) and corn-growing regions of mainland USA (Parsons and Munkvold 2012) where winter temperatures are regularly below freezing point. Therefore, it is considered highly likely that *F. verticillioides* can remain viable through sea freight transit times and that transit conditions are likely to allow survival of *F. verticillioides* but unlikely to promote rapid development of symptoms, especially in less ripe fruit.

There are no border interceptions of any *Fusarium* species on imported fresh pineapples between 2000–2020 (LIMS 2022), only two fungi and no other pathogens identified by the MPI diagnostic laboratories. This could be interpreted as evidence that fungi are not frequently associated with the fresh pineapple pathways. However, given the evidence presented above, it is likely that *F. verticillioides* can be associated with asymptomatic pineapple fruit and remain latent in fruit stored at cold temperatures. Pineapple fruit may not show symptoms until it is returned to a temperature that allows the fruit to ripen and the fungus to grow more rapidly (as described above for fruitlet core rot caused by *F. verticillioides*).

Given the high volume of fresh pineapples imported to New Zealand, and the high likelihood that some *F. verticillioides* infections of pineapple fruit will remain undetected because symptoms are internal or the fruit is asymptomatic, even a low prevalence of infection would equate to a high likelihood of entry (one–two infected fruit entering New Zealand undetected/year)

Uncertainty

There is low uncertainty (evidence from several studies) that *F. verticillioides* can be associated with commercially produced pineapple fruit (Stępień et al. 2013; Ibrahim et al. 2017; Vilaplana et al. 2018; Vignassa et al. 2021). There is evidence that *F. verticillioides* can sometimes be present in pineapple fruit without showing symptoms (Vignassa et al. 2021) or causes only small lesions in fungicide-treated fruit (a common packhouse treatment in Ecuador) (Vilaplana et al. 2018) that might be missed in a visual inspection because of the complex architecture of the fruit.

Given that:

- *Fusarium verticillioides* is recorded from most markets in scope of the IRA;
- *Fusarium verticillioides* can be associated with pineapple fruit at all developmental stages;
- *Fusarium verticillioides* can survive transit conditions;
- *Fusarium verticillioides* is sometimes associated with internal fruitlet rots;
- *Fusarium verticillioides* is sometimes asymptomatic in pineapple fruit so cannot always be detected in a visual inspection even if fruit is cut in half;

the likelihood of *F. verticillioides* entering New Zealand associated with pineapple fruit is considered to be high, with low uncertainty.

5.2.3.3 Likelihood of exposure

This assessment is made on the basis that F. verticillioides has entered New Zealand undetected.

Exposure is considered to be the transfer of a pest or disease from an imported commodity or inanimate object, to a host or environment suitable for the completion of development or production of offspring.

Imported fresh pineapple fruit is intended for human consumption, therefore, when the fruit arrives in New Zealand it will be distributed throughout New Zealand for wholesale or retail sale. Fresh pineapple fruit generates substantial amounts of unavoidable waste; the thick rind is always removed and disposed of, and the fruit is also sometimes cored (see waste analysis Annex 2.3.1). Given that *F. verticillioides* often colonises plants via the vascular system (the water and nutrient transport system that runs through the roots and stems), it is likely that it can be present in the cores of pineapple fruit with internal infections. *Fusarium verticillioides* is also an occasional fruitlet core rot pathogen – infected skin and localised areas of rotten flesh are likely to be discarded by consumers. The disposal of whole fruit (e.g. culled/unsold fruit, uneaten fruit remains) is not uncommon during wholesale, retail and by consumers. This suggests that *F. verticillioides* may have a higher likelihood of exposure when associated with fresh pineapple fruit than when it is associated with other kinds of fresh produce that are generally eaten whole.

In New Zealand the most common method of disposal of organic waste is bagged into landfill (Askarany and Franklin-Smith 2014); this is unlikely to be a risk. However, there are other disposal methods that could increase the exposure likelihood of the fungus, such as feeding out to animals, home composting and direct disposal into the environment. Fruit waste may be collected from unpacking areas (e.g., supermarket preparation rooms) and taken to rural areas where it is placed on the ground for eventual consumption by pigs or other farm animals (MPI 2014). The waste materials may also be used in worm farming. Using the waste materials to feed animals may inadvertently expose *F. verticillioides* to the soil and waterways before it eventually finds a suitable host. *Fusarium verticillioides* can persist in host residue (e.g. crop residues and probably pineapple waste) on or in the soil (Leslie et al. 1990; Postic et al. 2012) for almost two years (Cotten and Munkvold 1998). Fusarium verticillioides can overwinter as sclerotia (Munkvold 2003; Parsons and Munkvold 2012). Viable *F. verticillioides* was recovered commercial potting mix at 17 months after inoculation (when sampling ended) (Puértolas et al. 2018). Fusarium verticillioides has been isolated from soil samples, although it was less prevalent than other Fusarium species (Karim et al. 2016; Mohammadian et al. 2017).

Commercial composting can suppress many plant pathogens because the internal temperature of the compost can exceed 55°C (Hoitink et al. 1997; Mehta et al. 2014) and *F. verticillioides* is unlikely to survive in such conditions. However, the fungus is likely to thrive in home composts since their temperatures mostly range between 15°C and 30°C (Mensah 2017). This suggests that F. verticillioides can survive on pineapple waste in domestic compost and be transferred into the environment when the compost is spread in the garden.

Fusarium verticillioides spores can be spread by water splash, wind and insects (Ooka and Kommedahl 1977; Munkvold et al. 1997; Munkvold 2003; Presello et al. 2007; Wilke et al. 2007; Ortiz et al. 2015; Blacutt et al. 2018), so it is likely that *F. verticillioides* spores produced on pineapple waste in the compost can spread to nearby plants (rodents and invertebrates visiting the compost bin or pile could also contribute to this). Suitable hosts are highly likely to be growing near anywhere that pineapple waste is discarded into home compost, if it is fed to animals outside, and in garden areas where domestic compost is likely to be spread. *Fusarium verticillioides* can colonise many plant species that commonly grow in home gardens, including tomatoes (Chehri 2016; Chang et al. 2018; Mwangi et al. 2021), garlic (Delgado-Ortiz et al. 2016), corn (Parsons and Munkvold 2012), rhododendron (Ares 2020), several species of pine (Salerno and Lori 2007; Martín-Pinto et al. 2008; Maciel et al. 2017), and sunflowers, poppies and common weed species including sorghum and amaranth (Postic et al. 2012)

Uncertainty

There is moderate uncertainty in these conclusions, because it is uncertain what proportion of domestic fruit and vegetable waste is discarded into domestic compost or into the environment (see waste analysis Annex 2.3.1). However, given that pineapple is a high waste commodity, and a high volume of pineapple is imported, it is assumed that some infected waste will be discarded in home compost.

Given that:

- Pineapple is a high waste commodity and rinds and sometimes cores are removed and discarded; and
- If pineapple waste infected with *F. verticillioides* is disposed of in domestic compost or directly into the environment, the fungus can survive on pineapple waste and other plant debris.
- The fungus can be spread by movement of soil and plant material (including compost) and can colonise/infect host plants via the roots or via microconidia (asexual spores) which are carried by water, insects, or wind.
- Suitable hosts are widespread in New Zealand.
- The environment throughout New Zealand is likely to be suitable for *F. verticillioides*

the likelihood of exposure of *F. verticillioides* in New Zealand from pineapple fruit is considered to be high with moderate uncertainty.

5.2.3.4 Likelihood of establishment

This assessment is made on the basis that F. verticillioides has been successfully exposed to a suitable host plant in the New Zealand environment.

The climate in New Zealand is highly unlikely to limit the establishment of *F. verticillioides.* The fungus is reported to have a worldwide distribution and is widespread in areas with a similar climate to the whole of New Zealand, that is areas with a climate match index ≥7 according to the CLIMEX model of Phillips et al. (2018) (for examples see section 4.1.3.1). In cooler climates, *F. verticillioides* can overwinter as sclerotia (thickened hyphae).

Microconidia (small asexual spores) can be wind, water and insect-borne and are the main form of inoculum for spread of *F. verticillioides* (Ooka and Kommedahl 1977; Munkvold 2003; Drakulic et al. 2017; Blacutt et al. 2018). Given that asexual spores are the main form of inoculum for spread of *F. verticillioides* (Ooka and Kommedahl 1977), different mating types would not be required for *F. verticillioides* to establish in New Zealand, although *F. verticillioides* can also produce spores through sexual reproduction (Gomes et al. 2020).

Hosts of *F. verticillioides* are ubiquitous in the New Zealand environment and include tomatoes (Chehri 2016; Chang et al. 2018; Mwangi et al. 2021), garlic (Delgado-Ortiz et al. 2016), maize/corn (Parsons and Munkvold 2012), rhododendron (Ares 2020), several species of pine (Salerno and Lori 2007; Martín-Pinto et al. 2008; Maciel et al. 2017), and sunflowers, poppies and common weed species including sorghum and amaranth (Postic et al. 2012).

Competition with *F. graminearum, F. proliferatum, F. oxysporum* and other *Fusarium* species common in New Zealand is unlikely to limit establishment of *F. verticillioides. Fusarium verticillioides* co-occurs with these species throughout its range (for examples see Windels et al. 1976; Presello et al. 2007; Petrovic et al. 2009; Goertz et al. 2010; Ilić et al. 2012; Li et al. 2019; Jabłońska et al. 2020; Pfordt et al. 2020).

There is low uncertainty in these conclusions.

Given that:
- The climate of New Zealand is likely to be very suitable for *F. verticillioides*
- Suitable hosts of *F. verticillioides* are ubiquitous in New Zealand

- *Fusarium verticillioides* can reproduce asexually, so does not require two different mating types
- Microconidia of *Fusarium verticillioides* are spread by wind, water splash and insects (some species of which are present in New Zealand)
- Competition with *Fusarium* species already present in New Zealand is unlikely to limit establishment of *F. verticillioides*.

the likelihood of *F. verticillioides* establishing in New Zealand is considered to be high, with low uncertainty.

5.2.3.5 Impacts in New Zealand

This assessment is made on the assumption that F. verticillioides *has successfully established in the New Zealand environment.*

It is highly likely that *F. verticillioides* can spread throughout New Zealand, given that the climate is likely to be suitable and microconidia can be spread over long distances (up to 400 km) by wind (Ooka and Kommedahl 1977), as well as by movement of plant material and soil (see 4.1.3.1). Insects have also been reported to spread *F. verticillioides* and increase its impacts in maize, including Western flower thrips (*Frankliniella occidentalis*) (Parsons and Munkvold 2010, 2012) and *Helicoverpa armigera*, (Darvas et al. 2011; Niculina et al. 2019). These species are reported in New Zealand (BiotaNZ 2022).

Economic impacts

Fusarium verticillioides has the potential to cause harm to New Zealand, primarily by causing ear rots and reduced yield in maize. *Fusarium verticillioides* has also sometimes been reported to colonise and/or cause disease symptoms in other crops of economic importance to New Zealand, but this is not expected to result in economic losses (discussed below). *Fusarium verticillioides* is reported to cause economic impacts in some other hosts of less importance to New Zealand, such as sugarcane (*Saccharum officinarum*), rice (Oryza sativa), sorghum (*Sorghum bicolor*) and cotton (*Gossypium hirsutum*) (not discussed further in this PRA but see references in the entry for *F. verticillioides* in Farr and Rossman 2022 if more information about impacts in these crops is required).

Maize is likely to be the main economic host of *F. verticillioides* in New Zealand. Mould symptoms and reduced kernel weight due to *F. verticillioides* infection can cause reductions to maize grain yields and consequently economic losses in areas with a similar climate to New Zealand[43], for example Argentina (Presello et al. 2007), maize-growing regions of USA (Parsons and Munkvold 2012) Chongqing, China (Zhou et al. 2018) and New South Wales, Australia (Watson et al. 2014). The proportion of kernels with mould or starburst[44] symptoms attributed to *F. verticillioides* typically ranges from 0% to 10%, depending on the susceptibility of hybrid and seasonal growing conditions (Presello et al. 2007; Parsons and Munkvold 2012). However, symptoms and yield losses can be more severe when environmental conditions favour disease development. For example, in maize grain grown in Kauai county (Hawaii) and Yolo county (California), the proportion of mouldy kernels attributed to *F. verticillioides* was greater than 70% in some samples (Parsons and Munkvold 2012). (Parsons and Munkvold 2012). Parsons and Munkvold (2012) reported that mould symptoms were highly correlated with thrips populations Outbreaks of cob rot in sweetcorn

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[43] areas where maize was grown in these studies have a similar climate to the whole of New Zealand based on a climate match index of 0.7–0.8 according to the CLIMEX model of Phillips et al. (2018).

[44] white or pink streaks radiating from the base of the kernel which reduce kernel weight and quality

and maize attributed to *F. verticillioides* caused processors and stockfeed suppliers to reject several crops in New South Wales Australia because local regulations do not allow mould kernels (Watson et al. 2014).

There is strong evidence suggesting that *F. verticillioides* will cause additional impacts on maize, greater than the impact of the *Fusarium* species that are already present in New Zealand, particularly in hotter dryer growing seasons. *Fusarium verticillioides* is often the most prevalent *Fusarium* pathogen colonising maize, although it often coexists with other pathogens, including *F. graminearum*, *F. temperatum*,, *F. proliferatum* and *F. oxysporum* (Munkvold 2003; Goertz et al. 2010; Krnjaja et al. 2018; Zhou et al. 2018; Li et al. 2019; Liu et al. 2019; Pfordt et al. 2020). Prior infection of maize with *F. graminearum* (which is present in New Zealand) can lead to increased rates of *F. verticillioides* infection (Picot et al. 2012)) *Fusarium verticillioides* reached higher levels in maize ears than *F graminearum* when maize plants had been co-inoculated with both species (Picot et al. 2012). This suggests that the presence of *F. graminearum* in New Zealand may contribute to the spread and impacts of *F. verticillioides*. Some in-field management measures such as ploughing that are used to control *F. graminearum* in maize may favour *F. verticillioides* infection (Pfordt et al. 2020), These species are also favoured by different climatic conditions. Moderate temperatures and frequent rainfall during the growing season promote infection by *F. graminearum* and *F. temperatum,* whereas hotter drier (drought) seasons favour *F. verticillioides* (Goertz et al. 2010). This suggests that the impacts of *F. verticillioides* are likely to be highest in hotter, drier regions and at times of drought when crops and stock are already experiencing the effects of water and heat stress.

MPI has estimated that that impacts of *F. verticillioides* in New Zealand over a 20-year period would be moderate, based on yield losses to the $389 million/year maize industry and the following assumptions:

- *Fusarium verticillioides* is likely to cause approximately 3% losses annually to maize production, based on a scenario in which between 1–8% of the crop develops fungal symptoms (usually at the lower end), depending on hybrids and growing conditions in a given year. This is based on the assumption that *F. verticillioides* widely colonises maize plants as it has in other areas with similar climates to New Zealand and that mould symptoms are scattered and mild in most cultivars and growing seasons.
- The fungus was assumed to take 5 years to achieve its maximum spread across maize production areas of New Zealand.
- Management measures for *Fusarium* species are not completely effective (and different, and sometimes incompatible controls are useful for *F. verticillioides* from other maize-infecting *Fusarium* species in New Zealand, see above), so we have assumed that the maize industry will never fully recover (>100 years).
- In addition, we have assumed that there will be at least one growing season in the 20-year period where *F. verticillioides* has higher impacts (yield losses of approximately 10%) across one or more maize production areas due to weather conditions favouring development of disease symptoms (hot and dry years).

There are likely to be downstream impacts of yield losses from *F. verticillioides* (see Robertson and Hurren (2022), which estimates the total economic impact of maize, including downstream industries such as animal production and food manufacture as $843 million/year), but these are difficult to quantify as downstream industries would presumably source grain from elsewhere if New Zealand maize yields were lower in one season. This PRA has not estimated the economic impacts of animal illness or mortality due to high mycotoxin levels, nor impacts of mycotoxin contamination on sales of maize here or in overseas markets. However, in areas with a similar climate to New Zealand and high prevalence of *F. verticillioides*, fumonisin levels in maize grain are sometimes above regulatory limits. For example, in Umbria (Italy), mean fumonisin levels were above 4 mg/g (the maximum limit set by the European Union) in both 2006 and 2007 and this was attributed primarily to *F. verticillioides* (Covarelli et al. 2011). In a survey in China between 2016–2018, 8.2% of maize kernel samples had fumonisin levels above 4.0 mg/kg, and 20.4% had fumonisin levels above 2.0 mg/kg (the maximum limit set by the United States Food and Drug Administration) (Li et al. 2019). Shipments of grain with fumonisin levels above maximum limits might be rejected for export causing losses for the producer. Fumonisins caused heart inflammation and intestinal lesions (atrophy and fusion of the villi in the jejunum) in piglets fed on feed contaminated with 3.7 mg/kg fumonisins, below the European Union (EU) recommended maximum of level of 5 mg/kg of total fumonisins in swine (Terciolo et al. 2019). Equine leukoencephalomalacia disease caused by fumonisins has occurred several times in Australia, resulting in the death of several thoroughbred horses (Summerell et al. 2010). This suggests that outbreaks of *F. verticillioides* in maize have the potential for flow-on effects on animal health and productivity

Wheat (*Triticum* spp.) and barley (*Hordeum vulgare*) are frequently reported as hosts of *F. verticillioides* and the fungus can cause stalk rot and kernel symptoms (rot or black point) in these species (Cosic et al. 2007; Busman et al. 2012; Gagkaeva and Yli-Mattila 2020) and reduce germination rates (Duan et al. 2007) However, infection rates of *F. verticilliodes* in wheat and barley samples were low compared with other *Fusarium* species such as *F. graminearum, F. proliferatum F. avenaceum and F. poae* (Loiveke 2006; Cosic et al. 2007; Duan et al. 2007; Busman et al. 2012; Ji et al. 2019), which BiotaNZ (2022) records as present in New Zealand). Isolates of *F. graminearum* from Croatian wheat and barley had a higher kernel infection rate in pathogenicity tests in wheat and barley and caused much larger reductions in seed germination and total kernel weight (that is grain yield) than isolates of *F. verticilliodes* (Cosic et al. 2007). Therefore, it is considered unlikely that *Fusarium verticillioides* will cause yield losses in wheat and barley beyond those already caused by *Fusarium* species present in New Zealand.

Before the recent arrival of pitch pine canker (*Fusarium circinatum*) in Europe, *F. verticillioides*, along with *F. oxysporum* and *F. proliferatum*, was among the main causes of damping-off of *Pinus* spp. in European nurseries (Elvira-Recuenco et al. 2020). Isolates of *F. verticillioides* from pine seeds of several species have been shown to reduce seedling emergence cause damping-off symptoms such as wilting, low, seedling-survival rate, reduced root development and root rot and leaf chlorosis in pathogenicity tests (Salerno and Lori 2007; Maciel et al. 2017). *Fusarium verticillioides* was isolated from symptomatic *P. radiata* nursery plants in Portugal, although the authors did not specify the exact symptoms or confirm pathogenicity with testing (Ares 2020). Damping-off associated with *F. oxysporum* is infrequent in Australasian nurseries in normal growing conditions (Dick and Simpson 2003) and there is no evidence that *F. verticillioides* will have higher impacts on plantation pine species than *F. oxysporum* and other *Fusarium* species that are present in New Zealand. Therefore, impacts on pine were not assessed in detail.

There are isolated reports of *F. verticillioides* causing post-harvest fruit rots, vascular wilts, leaf spots and defoliation and root rots (usually confirmed by pathogenicity testing) at isolated production sites or at low prevalence in disease surveys in other crop plants that are economically important to New Zealand, for example, grapes (*Vitis vinifera*), avocado

(*Persea Americanum*), tomato (*Solanum lycopersicum*), cabbages (*Brassica* spp.), beets (*Beta vulgaris*), garlic (*Allium sativum*), sweet potato (*Ipomoea* batatas), Welsh onion (*Allium fistulosum*) and asparagus (*Asparagus officinale*) (Zhang et al. 2008; Dissanayake et al. 2009; Lorenzini and Zapparoli 2015; Chehri 2016; Delgado-Ortiz et al. 2016; Ismail et al. 2017; Cao et al. 2018; Chang et al. 2018; Akram et al. 2020; Ekhuemelo and Nsobundu 2020; Jitjak and Sanoamuang 2021; Mwangi et al. 2021). Several of these reports are from an area very different climate from New Zealand,[45] such as Guangdong, China (Akram et al. 2020), Thailand (Jitjak and Sanoamuang 2021), Malaysia (Ismail et al. 2017) or Benue, Nigeria (Ekhuemelo and Nsobundu 2020). Due to the scattered nature of these reports, it appears that infections of *F. verticillioides* in crops other than grains are sporadic. Impacts in these crops were not modelled because we have assumed that it is unlikely that the fungus will cause disease outbreaks in these crops with impacts greater than the *Fusarium* species already present in New Zealand, such as *F. proliferatum, F. solani* or *F. oxysporum* which were found in coinfection with *F. verticillioides* in these hosts (for examples, see Zhang et al. 2008; Dissanayake et al. 2009; Lorenzini and Zapparoli 2015; Chehri 2016; Delgado-Ortiz et al. 2016; Cao et al. 2018; Chang et al. 2018).

Uncertainty

This conclusion is based on the assumption that *F. verticillioides* will have negligible impacts on hosts that are economically important in New Zealand, other than maize. There is good information from several studies available for barley and wheat that although *F. verticillioides* can be quite prevalent in these crops, it usually occurs in coinfection with other *Fusarium* species, particularly *F. graminearum* which was more pathogenic to these hosts in tests (Cosic et al. 2007) and is present in New Zealand (BiotaNZ 2022). For most of the other hosts described above, searches (of Google Scholar and CAB abstracts, using the terms “Fusarium verticillioides” and “host species name” or “host common name”) found zero, one or very few reports of symptomatic infections with *F. verticillioides*. Disease outbreaks were often localised to a single production site and *F. verticillioides* was usually a minor component of the *Fusarium* community isolated from infected plants. Although this PRA has assumed that *F. verticillioides* is rarely a major cause of disease in hosts other than maize, there is moderate uncertainty in this conclusion because there is limited information available for each of these hosts, diseases caused by *Fusarium* species are common, and the agents are not always identified.

Given that:

- estimates of economic impacts to New Zealand based on a single severe outbreak of ear rot in maize caused by *F. verticillioides* causing yield losses of approximately 20% of the crop in that season, and ongoing yield losses of 0–5% depending on growing conditions in that season.
- There are rare reports of outbreaks of symptomatic disease associated with *F. verticillioides* in other plants of economic importance to New Zealand.
- Impacts in crops other than maize are assumed to be unlikely given that impacts will not be greater than the *Fusarium* species already present in New Zealand.

the economic impact of *F. verticillioides* in New Zealand is considered to be moderate, with moderate uncertainty.

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[45] Based on a climate match index of ≤6 using the Climex model of (Phillips et al. 2018) indicating the climate is not similar to the whole of New Zealand

Environmental impacts

Fusarium verticillioides has the potential to cause harm to indigenous plant species. *Fusarium verticillioides* has an extremely broad host range, but disease symptoms are commonly reported in grain species in the Poaceae family such as sorghum (Kelly et al. 2017; Félix-Gastélum et al. 2022), wild and cultivated rice (*Oryza sativa, O. australiensis*) (Pak et al. 2017) and maize (Parsons and Munkvold 2012; Watson et al. 2014). The New Zealand Plant Conservation Network lists 101 native or endemic plants in the Poaceae family, all of which are considered ‘at risk’ or ‘threatened’ (NZPCN 2022). *Fusarium verticillioides* was also associated with disease symptoms in an exotic *Pittosporum* species (*P. tobira*) in a Portuguese nursery but no pathogenicity testing was reported, and other *Fusarium* species associated with these plants may have been responsible for the symptoms. The New Zealand Plant Conservation Network lists 23 native or endemic *Pittosporum* species or varieties, of which 13 have a conservation status of ‘threatened’ or ‘at risk’ (NZPCN 2022).

Fusarium verticillioides has the potential to cause harm to indigenous arthropod species. *Fusarium verticillioides* has been reported to cause disease and death in insects and mites and is sometimes used for biocontrol (Pelizza et al. 2011; Abdel Galil et al. 2019; Patel and Ghetiya 2019; Sain et al. 2021; Ni et al. 2022). New Zealand has indigenous species in the Acrididae and has endemic species in Orthoptera with ‘at risk’ or ‘threatened’ conservation status (NZTCS 2022). *Fusarium verticillioides* caused high mortality in naturally infected blue winged grasshoppers (*Tropidacris collaris* Orthoptera: Romaleidae) in the wild and approximately a spur-throated grasshopper species (*Ronderosia bergii,* Orthoptera: Acrididae) (Pelizza et al. 2011). Orthopterans tend to aggregate, especially to mate, so it is likely that the pathogen would have the opportunity to spread if it infected endemic communities in New Zealand. However, the insects in this study were kept in captivity in conditions that favour symptom development of fungal pathogens of insects (30 °C, 14:10 light-dark photoperiod, 60% relative humidity) (Pelizza et al. 2011), so there is high uncertainty about whether insects would develop symptoms of fungal infection under natural conditions

Overall, there is high uncertainty about whether *F. verticillioides* will cause disease in indigenous species in the natural environment because there is no direct evidence that *F. verticillioides* causes disease symptoms in particular indigenous plant or insect species. Grains in commercial production and nursery plants are grown at high density and are likely to be subject to different stresses from plants growing in the natural environment in New Zealand. *Fusarium verticillioides* is unlikely to pose a significant threat to species that are abundant or distributed widely across New Zealand, but even localised disease symptoms that reduce the fitness of a few plants or insects might impact a rare or threatened species.

Given that:

- *Fusarium verticillioides* is reported to cause disease in plant and insect genera and families that include indigenous species with “at risk” or “threatened” conservation status, but there is no direct evidence that *F. verticillioides* causes disease symptoms in particular indigenous plant or insect species

the environmental impact of *F. verticillioides* in New Zealand is considered to be very low with high uncertainty.

Human health impacts

Fusarium verticillioides can cause disease in humans (Nucci and Anaissie 2007; Benedict et al. 2017). *Fusarium verticillioides* is one of the fungi that causes superficial keratitis, especially in soft contact lens users or cases of eye trauma (Kamle et al. 2019). It can occasionally cause deep infections, systemic infections or even death, although usually in immunocompromised patients (Nucci and Anaissie 2007; Tortorano et al. 2008; Benedict et al. 2017). A cluster of severe *F. verticillioides* infections in seven hospitalised internal medicine patients (not immunocompromised) as a result of a hospital reconstruction in Greece resulted in the deaths of four patients (Benedict et al. 2017). Infections caused by species in the *Fusarium solani* complex (e.g. *F. petroliphilum*) and *F. oxysporum* species complex cause approximately 80 % of human clinical cases and infections by *F. verticillioides* are comparatively rare and more often susceptible to antifungal drugs (Guarro 2013).

Fusarium verticillioides can also produce mycotoxins (fumonisins) in food crops, especially maize grain, that are associated with liver or kidney disease, cancer and birth defects in humans (Ortiz et al. 2015; Oldenburg et al. 2017). Fumonisin levels are sometimes over the European Union and United States limits in maize grain from areas with a similar climate to New Zealand (see 0 Economic impacts)

There is low uncertainty in this conclusion.

Given that:

- *Fusarium verticillioides* can cause minor localised skin or eye infections but can occasionally cause systemic or fatal infections.
- In maize and other food crops, *F. verticillioides* can produce fumonisin and other mycotoxins that are associated with liver or kidney disease, cancer and birth defects.
- However, fumonisin levels are usually below the European Union and United States limits in maize grain areas with a similar climate to New Zealand

the human health impact of *F. verticillioides* in New Zealand is considered to be very low, with low uncertainty.

Sociocultural impacts

Fusarium verticillioides has the potential to cause harm to some taonga species. *Fusarium verticillioides* was one of the fungi isolated from leaf spot lesions on sweet potato (*Ipomoea batatas*) plants growing in Makurdi, Benue State, Nigeria (Ekhuemelo and Nsobundu 2020). The climate match index of this area is 0.4 indicating that the climate is not similar to all of New Zealand (based on the CLIMEX model of Phillips et al. (2018)). *Ipomoea batatas* is the sweet potato species that includes the taonga plant kumara. In pathogenicity tests in which the plants were inoculated by spraying with an *F. verticillioides* spore suspension, dark brown necrotic lesions developed on the leaves and approximately 37% of leaves were lost by four weeks after inoculation (Ekhuemelo and Nsobundu 2020). There is some uncertainty about the reliability of the identification because Ekhuemelo and Nsobundu (2020) identified *F. verticillioides* based on morphological features only. Given that there is only a single report of *F. verticillioides* causing disease in sweet potato (along with other fungi), overall impacts on kumara are likely to be negligible, although there may be localised instances of *F. verticillioides* causing disease symptoms in kumara plants.

Searches of Google Scholar using the terms "Fusarium verticillioides" and each genus of the taonga species listed in Table 5.3 found host records relating to three of these genera, *Phormium*, *Pittosporum* and *Solanum*. *Fusarium verticillioides* was associated with disease symptoms in nursery plants of the endemic taonga species harakeke (New Zealand Flax; *Phormium tenax*) in nursery plants in Portugal, along with other *Fusarium* species (*F. oxysporum, F. subglutinans, F. graminearum*) (Ares 2020), all of which are present in New Zealand (BiotaNZ 2022). *Wharariki* (mountain flax, *Phormium cookianum*), another endemic species is also in this genus. *Fusarium verticillioides* was also associated with an exotic *Pittosporum* species (*P. tobira*) (Ares 2020), and tarata (lemonwood; *P eugenioides*) and Kahurangi pittosporum (*P. dallii*) are in the genus *Pittosporum.* The taonga poroporo (*Solanum laciniatum* and *S aviculare*) is in the genus *Solanum* and *F verticillioides* can cause vascular wilt in tomato (*S. lycopersicum*; confirmed by pathogenicity tests) (Chehri 2016; Chang et al. 2018) and was isolated from potatoes (*S. tuberosum*) with storage rot (Loiveke 2006).

Given that isolates of *F. verticillioides* caused disease and death in species of two different families in the Orthoptera (Pelizza et al. 2011; discussed in detail above), the fungus might be capable of infecting wētā in some conditions.

Overall, there is high uncertainty about whether *F. verticillioides* will cause disease in taonga species in the natural environment because there is no direct evidence that *F. verticillioides* causes disease symptoms in particular indigenous plant or insect species. Given that *F. verticillioides* is commonly isolated from diverse weed species it may be able to colonise taonga plants growing in the wild, and environmental conditions may occasionally favour development of disease symptoms in some plants in a localised area, but impacts are likely to be low.

Given that:

- There is a single report of *F. verticillioides* causing leaf spot disease in *Ipomoea batatas* (the sweet potato species that includes New Zealand kumara cultivars), but only in an area of Nigeria with very different climate to New Zealand, so *F. verticillioides* is unlikely to pose a threat to kumara.
- *Fusarium verticillioides* is reported to cause disease in plant and insect genera and families that include indigenous taonga species, including species with "at risk" or "threatened" conservation status, but there is no direct evidence that *F. verticillioides* causes disease symptoms in particular indigenous plant or insect species.

the sociocultural impact of *F. verticillioides* in New Zealand is considered to be very low with high uncertainty.

5.2.3.6 Overall impact to New Zealand

MPI considers the overall impact of *F. verticillioides* on the New Zealand economy, environment, health and society is MODERATE with HIGH uncertainty.

5.2.3.7 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is HIGH

- assuming entry, the likelihood of exposure is HIGH
- assuming successful exposure, the likelihood of establishment is HIGH
- the overall impact on the New Zealand economy, environment, human health, and society is considered to be MODERATE

MPI considers the overall level of assessed risk to New Zealand from *F. verticillioides* on pineapple fruit is MODERATE with HIGH uncertainty.

5.2.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *Fusarium verticillioides* association with pineapple fruit been observed?

It is likely that *F. verticillioides* can be associated with most or all pineapple varieties and pineapple fruit at all stages of development. *Fusarium verticilliodes* was isolated from fruitlets of ripe pineapples of the 'Queen Victoria' cultivar with and without symptoms – the pineapples were harvested when still partially green and ripened in storage (Vignassa et al. 2021), and fruitlet infection usually occurs at an early stage of development before the bracts close (Fournier et al. 2015). *Fusarium verticilliodes* was isolated from symptomatic pineapples at production sites in Malaysia, but the authors do not say what stage the fruit was at when symptoms appeared (Ibrahim et al. 2017). In pathogenicity tests on ripe pineapples (Gandul, Josapine and Morris varieties) with *F. verticilliodes* isolates from Malaysia, Josapine showed the most severe rot symptoms (Ibrahim et al. 2017). Ripe pineapples of the MD2 variety showed fusariosis symptoms (Vilaplana et al. 2018).

Which part(s) of the pineapple fruit is *F. verticilliodes* associated with (e.g. fruit, bract, stem or crown remnant) and is it detectable by visual detection?
Fusarium verticillioides has been isolated from fruitlets (i.e. internal flesh) (Vignassa et al. 2021) and the core (Stępień et al. 2013), and was visible on the skin (i.e. bracts) of pineapple fruit with fusariosis (Vilaplana et al. 2018). It is a systemic vascular endophyte/pathogen in many other hosts so may also be associated with crown and stem remnants.

Are different lifestages of *F. verticillioides* associated with different parts of the pineapple fruit?
Not applicable

Under what environmental conditions (temperature, season etc) are *F. verticillioides* symptoms expressed on pineapple fruit?
Symptoms of *F. verticillioides* (fusariosis or fruitlet core rot) are likely to develop faster at higher temperatures (although the fungus can grow slowly at temperatures as low as 5°C). In pathogenicity tests, fusariosis (external rot) symptoms developed in pineapple fruit in cold storage at 8 °C (Vilaplana et al. 2018). Mild rot symptoms (brown lesions) were observed in cut fruit of three cultivars (Gandul. Josapine, Moris), two weeks after wound inoculation with *F. verticillioides* in ripe pineapple fruit incubated at 27 ± 1°C with 75%–80% humidity (Ibrahim et al. 2017). Fruitlet core rot symptoms in fruit with early natural infections of *F. verticillioides* developed in fruit stored at 19 °C, although the authors did not confirm that *F. verticillioides* caused symptoms with pathogenicity tests (Vignassa et al. 2021).

Does *F. verticillioides* exhibit latent/asymptomatic traits in pineapple fruit?

Yes. *Fusarium verticillioides* was isolated from asymptomatic fruitlets in ripe pineapples, as well as fruitlets with core rot symptoms (Vignassa et al. 2021).

5.2.5 *Appendix to risk assessment of Fusarium verticillioides*

Table 5.2 Evidence for *Fusarium verticillioides* in markets in scope of this IRA

Market	Recorded in market	Uncertainty
Asia		
Indonesia	Yes (for example, Nugroho et al. 2013; Pakki 2016; Dhanti et al. 2017; Maryani et al. 2019; Widiastuti et al. 2020; Mirsam et al. 2021; Farr and Rossman 2022).	Low. Strong evidence based on many reports
Malaysia	Yes (Hsuan et al. 2011; Ibrahim et al. 2017; Ismail et al. 2017; Najihah et al. 2017; Ibrahim et al. 2020; Yazid et al. 2021; Farr and Rossman 2022)	Low. Strong evidence based on many reports.
Philippines	Yes (for example,Cumagun et al. 2009; Alvindia and Acda 2010; Magculia and Cumagun 2011; Van Hove et al. 2011; Singh et al. 2014; Hussien et al. 2017; Farr and Rossman 2022)	Low. Strong evidence based on many reports.
Sri Lanka	Yes, but record of *F. verticillioides* from maize is unreliable. Adikaram and Yakandawala (2020) records as present in maize based on Senevirathna and Aoki (2008), but the maize samples in that study were from a Japanese collection (but published in a Sri Lankan journal). Seneviratne and Jeyanandarajah (2004) record *F. moniliforme,* syn. *F. verticillioides* as a cause of Bakanae disease in rice. *Fusarium moniliforme* is recorded as an important pathogen in rice (Fernando et al. 2022, conference abstract only). No record in Farr and Rossman (2022) and no records found in CAB abstracts searches.	High, because there are no reliable reports of *F. verticillioides,* only *F. moniliforme.* However, *F. verticillioides* is reported in many neighbouring countries, including India and is highly likely to be present in Sri Lanka. .
Taiwan	Yes (for example, Hsieh et al. 2020; Sun et al. 2020; Farr and Rossman 2022) In addition, GBIF records *F. verticillioides* from Taiwan (Tianliao's Moon World, Taiwan, Taiwan; Chiayi, Taiwan). No records found in searches of CAB abstracts and Google Scholar.46	Low. Strong evidence based on several reports.
Thailand	Yes (for example, Boonyapranai et al. 2008; Van Hove et al. 2011; Mohamed Nor et al. 2019; Srihom et al. 2021; Farr and Rossman 2022),	Low. Strong evidence based on many reports.
Oceania		
Australia	(Summerell et al. 2010; Watson et al. 2014; Liew et al. 2016; Kelly et al. 2017; Farr and Rossman 2022) GBIF has records from Queensland, New South Wales and Western Australia.	Low. Strong evidence based on many reports.
Fiji, New Caledonia, Papua New Guinea, Samoa, Tonga	No record in Pacific Islands Pest List Database (2022), nor Farr and Rossman (2022). No records in other searches. [3]	High. There is no record of either presence or absence (i.e. no survey data), so given the broad geographical distribution of *F. verticillioides*, its presence in these countries cannot be ruled out.
Cook Islands	Yes, collected from Musa sp. in Aitutaki in 1982 (preserved specimen in Landcare collection PDD 44561)	High. Presence inferred based on single historic record in reliable database, but with no molecular data.
Vanuatu	Yes. Collected from maize stem in Efate, Teoumu Gardens in 1996, Vanuatu, redetermined in 2014 based on EF1a DNA sequence (a record in GBIF is derived from this record) (BiotaNZ 2022). No other records found in searches.[3]	Moderate, based on a single (reliable) record.
Central and South America		

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46 GenBank (Clark et al. 2016); Google Scholar; CAB abstracts; USDA Fungal Database (Farr and Rossman 2022), HerbIMI (2022) and the Pacific Islands Pest List Database (2022) were searched with the term “Fusarium verticillioides”. Search terms for Google Scholar; CAB abstracts were " Fusarium verticillioides " and the country name. An additional search on the terms “Fusarium moniliforme” and the country name. was included in Google scholar and CAB abstract searches if no records were found in the initial search, but country presence records based on this synonym have high uncertainty (see taxonomic notes).

Costa Rica	(Danielsen and Jensen 1998; Danielsen et al. 1998; Stępień et al. 2013; Guido-Mora et al. 2021)	Low, several references, including molecular identification.
Ecuador	Yes (Pacin et al. 2003; Moretti et al. 2004; Patiño et al. 2006; Silva et al. 2007; Vilaplana et al. 2018; Valencia-Chamorro et al. 2021)	Low, several references, including molecular identification.
Panama	Yes (Moretti et al. 2004; Patiño et al. 2006).	Moderate, *F. verticillioides* is recorded from nearby countries including Costa Rica. Note (Van Hove et al. 2011) record isolates of *F. musae* (a close relative of *F. verticillioides* lacking the fumonisin gene cluster) from Panama that may have originally been recorded as *F. verticillioides* – (Patiño et al. 2006) recorded non- fumonisin producing isolates of *F. verticillioides* from banana (*M. sapientum*) Patiño et al. (2006) recorded non-fumonisin producing isolates of *F. verticillioides* from banana (*M. sapientum*) which may be the closely related *F. musae* (which lacks the fumonisin gene cluster)

Table 5.3 List of some taonga species (EPA 2018) checked for association with *F. verticillioides* (Search of Google Scholar with search terms “Fusarium verticillioides” and the genus name)

Metrosideros fulgens, Metrosideros perforata, Metrosideros colensoi, Metrosideros diffusa, Dodonaea viscosa, Geniostoma rupestre var. ligustrifolium, Phormium tenax, Elaeocarpus dentatus, Pseudopanax crassifolius, Pseudowintera colorata, Pseudowintera axillaris, Hoheria sexstylosa var. *ovata, Dacrycarpus dacrydioides, Pennantia corymbose, Coprosma grandifolia, Kunzea ericoides, Kunzea arenaria, Corynocarpus laevigatus, Aciphylla glaucescens, Aciphylla ferox, Coprosma robusta, Coprosma lucida, Ripogonum scandens, Porphyra columbina, Hierochloe redolens, Libocedrus plumosa, Macropiper excelsum* ssp. *excelsum, Freycinettia banksia, Dysoxylum spectabile, Tetragonia implexicoma, Tetragonia tetragonioides, Anisotome aromatic, Hebe salicifolia, Hebe leiophylla, Peraxilla colensoi, Fuchsia excorticata, Sophora microphylla, Sophora longicarinata, Elaeocharis sphacelate, Melicytus ramiflorus, Aristotelia serrata, Asplenium bulbiferum, Cyathea medullaris, Manoao colensoi, Lepidothamnus intermedius, Leptospermum scoparium, Prumnopitys taxifolia, Rorippa divaricate, Leucopogon fasciclatus, Prumnopitys ferruginea, Lepidium banksii, Lepidium oleraceum, Gingidia haematitica, Dracophyllum elegantissimum, Dracophyllum traversii, Dracophyllum townsonii, Dracophyllum latifolium, Myoporum laetum, Rhopalostylis sapida, Schefflera digitata, Polystichum richardii, Pimelea prostrata, Pimelea carnosa, Ficinia spiralis, Acaena anserinifolia, Peraxilla tetrapetala, Peraxilla colensoi, Cyathea dealbata, Solanum laciniatum, Solanum aviculare, Passiflora tetrandra Laurelia novae-zelandiae, Pteridium esculentum, Brachyglottis repanda, Metrosideros umbellata, Metrosideros robusta, Raukaua edgerleyi, Typha orientalis, Arthropodium cirrhatum, Dacrydium cupressinum, Lophomyrtus obcordate, Phyllocladus trichomanoides, Cyperus ustulatus, Pittosporum eugenioides, Pittosporum dallii, Rubus australis, Rubus schmidelioides, Cordyline australis, Alectryon excelsus ssp. excelsus, Austroderia richardii, Cordyline indivisa, Podocarpus totara, Podocarpus hallii, Leptecophylla juniperina, Coriaria arborea, Phormium cookianum, Entelea arborescens, Pseudopanax arboreus, Dicksonia squarrosa, Dicksonia fibrosa, Juncus pallidus, Agathis australis,*

5.2.6 *References*

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5.3 Pestalotiopsis microspora

Pestalotiopsis microspora is an endophytic pathogen of over 90 plant species from 48 different families and these include pineapple, kiwifruit, blueberry, and pine trees. The pathogen often expresses disease symptoms on fruits, leaves and twigs of its hosts. Notable disease symptoms caused by *P. microspora* include black spots, scab disease, root rot and post-harvest fruit rot fruits.

5.3.1 *Taxonomic description*

Scientific name: *Pestalotiopsis microspora* (Speg.) G.C. Zhao & N. Li 1995
Order: Amphisphaeriales **Family:** Sporocadaceae
Other names: *Pestalotia microspora* Spegazzini 1880; *Pestalotiopsis microspora* var. *philippinensis* (Saccardo & P. Sydow) Batista & Peres 1966; *Pestalotia dichaeta* Spegazzini 1911; *Pestalotia royenae* Guba 1932; *Pestalotiopsis royenae* (Guba) Steyaert 1949; *Pestalotia microspora* var. *philippinensis* Saccardo & P. Sydow 1913

Taxonomic notes:
Pestalotiopsis was first recognised as a distinct genus in a taxonomic revision of the genus *Pestalotia* and genus *Monochaetia* (Steyaert 1949), thus *Pestalotia microspora* became known as *Pestalotiopsis microspora* (Batista et al. 1966). Recognition of the genus *Pestalotiopsis* was further supported by molecular and taxonomic evidence (Jeewon et al. 2002). However, some research articles published before 2000 still used *Pestalotia microspora* instead of *Pestalotiopsis microspora*.

Metz et al. (2000) proposed that *Pestalosphaeria hansenii* is the teleomorph (sexual form) of *P. microspora,* which would mean that it would now be considered to be the same species. Although *Pestalosphaeria hansenii* is present in New Zealand, it is not recognised as the teleomorph of *Pestalotiopsis microspora* because there is insufficient evidence to assert that the two species are synonymous (Bevan Weir[47,] pers. comm.). The 18S rDNA sequences used in the Metz et al. (2000) study have poor species resolution and there is no sequence data confirming the synonymy of the two species in the ICMP[48] cultures (Bevan Weir[1], pers.com). *Pestalosphaeria hansenii* is not given as a synonyn of *Pestalotiopsis microspora* in the major fungal taxonomy databases (BiotaNZ 2022; Farr and Rossman 2022; Index Fungorum 2022; Mycobank 2022).

Cultural and genetic characteristics of *Pestalotiopsis microspora* are very diverse such that multiple distinct isolates can occur in an individual plant (Li et al. 1996). The genetic variability in the different isolates of *P. microspora* may determine the kind of chemical compounds they can produce (Li et al. 1996), and possibly their pathogenic effects on plant hosts (Maharachchikumbura et al. 2011).

5.3.2 *Hazard identification*

Pestalotiopsis microspora is not known to be present in New Zealand.

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[47] Bevan Weir, Research Leader, Biological Collections and Databases, Manaaki Whenua – Landcare Research
[48] International Collection of Microorganisms from Plants (ICMP)

- *Pestalotiopsis microspora* is recorded as "absent" in New Zealand (BiotaNZ 2022; NZOR 2022).
- There is no entry of *Pestalotiopsis microspora* in PPIN (2022).
- *Pestalotiopsis microspora* (syn *Pestalotia microspora*) is a regulated pest for New Zealand and has an unwanted status in ONZPR (2022).

Pestalotiopsis microspora has the potential to establish and spread in New Zealand.

- The geographic distribution of *P. microspora* includes many countries (Farr and Rossman 2022) and some of these countries have a similar climate with New Zealand.
- *Pestalotiopsis microspora* has a wide host range (Farr and Rossman 2022) and some of the hosts (e.g. kiwifruit, blueberries and monterey pines) are commonly grown in many areas of New Zealand.
- The common ivy and monterey pine are known hosts of *P. microspora* (Farr and Rossman 2022) and these species are also widely distributed invasive species in New Zealand.

Pestalotiopsis microspora has the potential to cause harm to New Zealand.

- *Pestalotiopsis microspora* has the potential to harm economically important plants (e.g. kiwifruit) in New Zealand by damaging their fruits or leaves.
- *Pestalotiopsis microspora* has the potential to expand its host range to include some native plants because it has host species in the same genera in its realised geographic range.
- *Pestalotiopsis microspora* has the potential to affect ornamental trees which are commonly planted in parks and recreational areas.

Pestalotiopsis microspora is associated with pineapple fruit.

- Pineapple is a reported host of *P. microspora* (Rao and Mhaskar 1973; Maharachchikumbura et al. 2011) and the fungus is known to cause post-harvest fruit rot in pineapples (Yaouba et al. 2021).

Given the arguments and evidence above, *Pestalotiopsis microspora* is considered to be a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

5.3.3 *Risk assessment*

5.3.3.1 Biology

Fungi in the genus *Pestalotiopsis* are mostly identified by their conidia (Wei et al. 2005) and they may occur in plants, soil and water (Guba 1961; Maharachchikumbura et al. 2011). They commonly occur as endophytes of many plant species (Strobel 2002) and are also known to occur as saprobes (Guba 1961; Osono and Takeda 1999). *Pestalotiopsis* spp. may inhabit tree bark and leaves without causing symptoms but symptoms can develop when host plants are stressed or wounded (Maharachchikumbura et al. 2011). They are frequently not host specific but opportunistic pathogens (Hopkins and McQuilken 2000). *Pestalotiopsis* spp. are able to infect a wide range of host plants, usually requiring openings caused by mechanical or insect injuries (Hopkins and McQuilken 2000; Elliott 2006).

Pestalotiopsis spp. are common in both tropical and subtropical ecosystems (Strobel 2002; Wei et al. 2007). Some species in this genus which includes *P. microspora* have received attention from scientists because they produce compounds which are useful in pharmaceutical science (Strobel et al. 1996; Strobel et al. 2002). A very interesting aspect of *Pestalotiopsis microspora* is that they are very diverse in their morphological and genetic characteristics (Strobel 2002). For example, Li et al. (1996) found that each of the 16 *P. microspora* isolates sampled from seven twigs in a bald cypress tree had distinctive cultural features except for two isolates. In addition, only nine of the 6 isolates were capable of producing a medically important compound known as Taxol, and the degree of Taxol production among the nine isolates varied significantly (Li et al. 1996).

As pathogens, *P. microspora* cause a variety of diseases depending on host species. For example, *P. microspora* is known to cause leaf blight in rubber trees (Ngobisa et al. 2018), leaf spot in blueberry (Yi-Lan et al. 2021), root rot in loquat (Lu et al. 2016), postharvest fruit rot in kiwifruit (Li et al. 2016; Li et al. 2017), scab disease in guava (Keith et al. 2006) and twig disease in bayberry (Ren et al. 2013). Although *P. microspora* has not been established as the causative agent of some diseases like mango tree decline (Dianda et al. 2018) and cacao leaf spot (Villavicencio et al. 2020), its association with such diseases indicates that it may likely foster their prevalence.

Hosts and geographical distribution

Pestalotiopsis microspora is known to associate with a wide range of plant species (Farr and Rossman 2022). Although *P. microspora* has been recorded in about 90 plant species from over 45 families (Annex 5.3.6), the list is not exhaustive because the fungus may only occur as an endophyte in some plant species without causing any disease. For example, *P. microspora* is not known to cause any disease in *Camellia sinensis* (Wei et al. 2005; Wei et al. 2007), *Terminalia arjuna* (Tejesvi et al. 2007) and *Artocarpus heterophyllus* (Riga et al. 2019). *Pestalotiopsis microspora* has also been reported from soil and fresh water (EBI 2022). The distribution record of *P. microspora* spans across all continents including Antarctica (Table 5.4).

Table 5.4 Geographic distribution of *Pestalotiopsis microspora* (CMI: 0.3 – 0.9) mostly based on Farr and Rossman (2022). Markets in the scope of this IRA are recorded in bold while distributions with cited references are not recorded in Farr and Rossman (2022).

Continent/Region	Country/Area/Market
Africa	Burkina Faso (Dianda et al. 2018), Cameroon (Yaouba et al. 2021), Egypt (El-Argawy 2016), Ghana (iBOL 2022), Kenya, Morocco (EBI 2022), Réunion Islands (EBI 2022), Tanzania (Telenius 2016).
Asia	Bangladesh, China, Hong Kong, India, **Indonesia** (Suwandi et al. 2012), Iraq (EBI 2022), Japan, Lebanon (Verkleij 2020), **Malaysia** (EBI 2022), Myanmar, Nepal, Singapore, South Korea, **Sri Lanka** (EBI 2022), **Thailand** (Tibpromma et al. 2018).
Europe	Netherlands (Verkleij 2020), UK (BMS 2022), Spain (Berbegal et al. 2010).
North America and the Caribbean Islands	Cuba, Mexico, USA (Oregon, New Jersey, Hawaii, Florida) Bermuda, West indies, Canada (EBI 2022), **Costa Rica** (Gall 2022)
Oceania and Antarctica	Antarctica (Gonçalves et al. 2015), **Australia**, **Papua New Guinea** (Strobel et al. 2002)
South America	Argentina, Brazil, Colombia (Chaves et al. 2022), **Ecuador** (Villavicencio et al. 2020), Venezuela, Uruguay

Symptoms

Pestalotiopsis microspora is predominantly known to be a leaf pathogen in pineapple, but one study recently reported rot symptoms in pineapple fruit in the field and demonstrated that the fungus was the cause of these symptoms. Postharvest fruit-rot of pineapples caused by *P. microspora* has been reported on the ‘smooth Cayenne’ variety (Yaouba et al. 2021) but it is not certain whether all other pineapple varieties can equally be infected. Infected pineapple fruits with rot symptoms were collected from different farms after harvest (Yaouba et al. 2021) indicating that the infection was naturally occurring on mature pineapple fruits in the fields. Diseased fruits show dark coloured necrotic lesions which expand from the point of infection and these lesions often appear darker in the grooves surrounding the bracts (Yaouba et al. 2021). Because *P. microspora* was reported to cause rot symptoms in pineapple fruit for the first time just recently, it is unclear whether the rot symptoms were common in pineapple fruit but the fungus has only been identified as the causative agent, or whether there is a newly emerged strain that affects fruit as well as causing leaf blotch.

Disease symptoms on pineapple plants, while not part of the commodity description, may appear as leaf blotch (Rao and Mhaskar 1973) or on dead leaves (Guba 1961). Infected plants show pale brown circular or irregular necrotic lesions on the tips or central parts of the leaves and these lesions produce dark fruiting bodies (sporodachia) from which the conidia may be dispersed (Rao and Mhaskar 1973).

Separate pathogenicity tests for *P. microspora* on pineapple fruit (Yaouba et al. 2021) and leaves (Rao and Mhaskar 1973) in the laboratory showed that infected samples may express symptoms between 8–10 days at room temperature (25°C) but it is not clear if the same time is required in natural environments. Cultured specimens isolated from fruit and leaves thrived well at a temperatures close to 25°C (Rao and Mhaskar 1973; Yaouba et al. 2021). The fungus is also known to survive well at a pH range of 6–7 and a temperature range of 24–26°C (Chen et al. 2016). Rao and Mhaskar (1973) also noted that sporulation of *P. microspora* cultures may continue for up to 15 days while Yaouba et al. (2021) noted that the cultures produce abundant white mycelia at the top while the base remains brownish black in colour.

Transmission

Pestalotiopsis spp. are typically transmitted to uninfected hosts by rain or water splashes (Hopkins 1996). Pathogenicity tests on pineapple fruits (Yaouba et al. 2021) and leaves (Rao and Mhaskar 1973) using spray inoculation techniques provides evidence that *P. microspora* can be transmitted via water droplets. However, the experimental inoculation on pineapple fruits and leaves required open wounds (Rao and Mhaskar 1973; Yaouba et al. 2021). *Pestalotiopsis microspora* may occur as an endophyte (Wei et al. 2007) but it is unclear whether pineapple fruits are principally infected via the vascular tissues of or via secondary transmission from other inoculum sources. Given that *P. microspora* spores can develop on the exterior parts of pineapple fruits, it is possible that direct contact between wounded fruits and infected fruits may further transmit the disease.

Pestalotiopsis spp. may also be transmitted mechanically (Hopkins and McQuilken 2000). Although no evidence was found to assert that *P. microspora* can be transmitted mechanically on pineapples, it is still possible that equipment used to harvest or decrown pineapples may aid transmission where infected plants or fruits occur.

5.3.3.2 Likelihood of entry

Pestalotiopsis microspora is globally distributed (Table 5.4) and has a wide range of hosts. It is reported from some markets within the scope of this IRA project, including Australia, Costa Rica, Ecuador, Indonesia, Malaysia, Papua New Guinea, Sri Lanka, and Thailand (Table 1). While *P. microspora* is known to be associated with pineapple (Rao and Mhaskar 1973; Yaouba et al. 2021), most records have been associated with other plant hosts. *Pestalotiopsis microspora* has been observed on pineapple fruits in Cameroon (Yaouba et al. 2021). Although Rao and Mhaskar (1973) demonstrated that *P. microspora* is associated with pineapple leaves in India, it was not certain if the pineapple fruits there were also infected.

No interception record of *P. microspora* has been found on pineapple fruits in Europe (EPPO 2022) or New Zealand (LIMS 2022). However, there are over 100 interceptions of the genus *Pestalotiopsis* on other hosts in the LIMS 2000–2020 database (LIMS 2022) and about half of these interceptions have not been identified to species level. Records from Quancargo database (QuanCargo 2021) shows that pineapple fruits have been imported from countries where *P. microspora* occur (i.e. Australia, Ecuador and Thailand) since 2001 but there was no interception record of *P. microspora* on the commodity (LIMS 2022).

Pineapple fruits infected by *P. microspora* are likely to be intercepted during border inspection because the symptoms are obvious – these include rotting patches and dark necrotic lesions (Yaouba et al. 2021; refer to Symptom in Annex 5.3.3.1). However, the expression of symptoms within eight days or more after infection (Yaouba et al. 2021) suggests that infected pineapple fruits could enter undetected. Given that *P. microspora* primarily depends on open wounds to infect its hosts, the process of harvesting and decrowning of pineapples may increase the chances of infection and thus infected fruits may enter undetected if they arrive New Zealand less than a week after harvest. In addition, the temperature which was suitable for the development of symptoms on fruits within eight days in the pathogenicity test was 25 °C. The temperature required for transit (7–13 °C) is lower than the temperature in the pathogenicity test and may not be suitable for symptom development during transit.

Uncertainty

There is high uncertainty that *P. microspora* could arrive on the commodity because it has not been recorded on pineapples in any of the export markets within the scope of this IRA. Strobel (2002) explained that *P. microspora* isolates occurring in one location are often highly diverse in their genetics and biology which may be reflected by their different chemical by-products. Therefore, the pathogenic strain associated with pineapples in Cameroon (Yaouba et al. 2021) may be further different from the ones occurring in markets within the scope of this IRA.

Symptom development of *P. microspora* on pineapple fruits may be favoured by temperatures close to 25 °C (Yaouba et al. 2021). Therefore, it is uncertain if symptoms will take longer to be expressed in the colder conditions (7–13 °C) required for transit, this might increase the likelihood of entry.

Given that:
- it is associated with pineapple fruit;
- it can be undetected in pineapple fruits if symptoms are yet to be produced.
- it has the potential to remain viable on pineapple fruit during transit;

but considering that:

- Association with pineapple fruit is indicated from a single record in a country which is not one of the pineapple exporting markets in this IRA.
- It is uncertain whether it is local to this country (such as new strain of the fungus or a vector capable of moving it from the leave to the fruit) or whether fruit rot is commonly caused by the fungus but has not been diagnosed previously.

MPI considers the likelihood of *P. microspora* entering New Zealand associated with pineapple fruit is LOW, with HIGH uncertainty.

5.3.3.3 Likelihood of exposure

This assessment is made on the assumption that Pestalotiopsis microspora *has entered New Zealand undetected. Exposure is considered to be the transfer of a pest or disease from an imported commodity or inanimate object, to a host or environment suitable for the completion of development or production of offspring.*

Imported fresh pineapple fruit is intended for human consumption, therefore, when the fruit arrives in New Zealand it will be distributed throughout New Zealand for wholesale or retail sale. Fresh pineapple fruit generates substantial amounts of unavoidable waste; the thick rind is always removed and disposed of, and the fruit is also sometimes cored (see waste analysis Annex 2.3.1). The disposal of whole fruit (e.g. culled/unsold fruit, uneaten fruit remains) is not uncommon during wholesale, retail and by consumers. This suggests that *P. microspora* may have a higher likelihood of exposure when associated with fresh pineapple fruit than when it is associated with other kinds of fresh produce that are generally eaten whole. Given that *Pestalotiopsis* spp. are typically transmitted by rain or water splashes (Hopkins 1996), *P. microspora* from pineapple waste can be easily exposed to uninfected hosts or soil.

In New Zealand the most common method of disposal of organic waste is bagged into landfill (Askarany and Franklin-Smith 2014); this is unlikely to be a risk. However, there are other disposal methods that could increase the exposure likelihood of the fungus, such as feeding out to animals, home composting and direct disposal into the environment. Fruit waste may be collected from unpacking areas (e.g., supermarket preparation rooms) and taken to rural areas where it is placed on the ground for eventual consumption by pigs or other farm animals (MPI 2014). The waste materials may also be used in worm farming. Using the waste materials to feed animals may inadvertently expose *P. microspora* to the soil and waterways before it eventually finds a suitable host. *Pestalotiopsis microspora* has been reported to occur in the soil (Thiruvengadam et al. 2020; EBI 2022) and water (Nor et al. 2018; ENA 2022).

Commercial composting can suppress many plant pathogens because the internal temperature of the compost ranges between 45-65°C and NZS 4454 stipulates it must be held at 55°C for at least three days for pasteurisation (Hoitink et al. 1997; WasteMINZ 2009; Mehta et al. 2014) While the reported upper lethal temperature for *P. microspora* is 56 °C for 20 minutes (Chen et al. 2016), the fungus is unlikely to survive exposure to the mandatory 72 hours at 55°C required for pasteurisation of commerical compost. However, the fungus is likely to thrive in home composts since their temperatures mostly range between 15°C and 30°C (Mensah 2017). *Pestalotiopsis* spp. may occur in the soil (Thiruvengadam et al. 2020) or used growing media (McQuilken and Hopkins 2004) and are known to withstand harsh environmental conditions such as cold weather and dryness (Maharachchikumbura et al. 2011). Given that some hosts of *P. microspora* occur widely in New Zealand, the chances of encountering a host is relatively high. Home composting methods may likely increase the likelihood of exposure of the fungus to immediate hosts that are commonly found in New Zealand gardens and backyards (e.g., common ivy, lemon, red alder and monterey pine trees). In addition, environmental temperature is unlikely to limit the exposure of *P. microspora* to its hosts because the fungus occurs in both tropical and temperate regions (Table 5.4).

Uncertainty

Information regarding food waste in New Zealand is based on general data and there is no specific information on pineapple waste. Therefore, it is assumed that the quantity of pineapple fruit skin which are not disposed in the landfill in New Zealand will be much lower than the volume disposed in the landfill.

It is uncertain if the heat in commercial composts may be sufficient to render *P. microspora* spores non-viable. Since *P. microspora* often invade their hosts through open wounds, it is not clear if it will survive for long time before finding an opening in a suitable host.

Given that:

- the fungus has a wide range of hosts available in New Zealand including some invasive plants,
- the fungus can survive in the soil and water,
- climate is unlikely to limit exposure of *P. microspora*,

but considering:

- the uncertainty surrounding its survival in commercial composts,the requirement for open wounds on host plants limits the opportunities of *P. microspora* to invade uninfected hosts

the likelihood of exposure of *P. microspora* in New Zealand from pineapple fruit is MODERATE, with MODERATE uncertainty.

5.3.3.4 Likelihood of establishment

This assessment is made on the basis that Pestalotiopsis microspora *has been successfully exposed to a suitable host plant in the New Zealand environment.*

Pestalotiopis microspora has a wide range of hosts (Farr and Rossman 2022). Some of the known hosts occur in New Zealand as commercially cultivated crops (e.g. kiwifruit, blueberry and lemon) and/or forest timber trees (e.g. Monterey pine and red alder). *Pestalotiopis microspora* is often pathogenic on many of its hosts but its symptom expression may depend on the host species (Maharachchikumbura et al. 2011). Alternatively, the fungus may occur as an endophyte in some species e.g. jackfruit (Riga et al. 2019) where it is not known to cause any symptom. Common ivy is a known host of the fungus (Guba 1961; Farr and Rossman 2022) and this plant is an invasive plant which occurs widely in New Zealand (Froude 2002). The unusually wide range of host plants strongly suggests that *P. microspora* will find new hosts in New Zealand. Availability of hosts and variability of disease symptom expression will likely favour the establishment of *P. microspora* because infected plant parts may increase spread and propagule pressure.

Pestalotiopis microspora is distributed across a wide geographical range (Table 1). However, most of the countries where *P. microspora* exist have either tropical or subtropical climates. Some parts of New Zealand's North Island have a slightly warmer climate, which is typical of countries where *P. microspora* occurs. Following the observation by Chen et al. (2016)

that the optimum conditions for *P. microspora* include a temperature range of 24–26°C and a pH range of 6–7, these conditions may frequently be achieved in many parts of the North Island. Climatic similarity between New Zealand and other parts of the world can be assessed using the composite match index (Phillips 2018). The CMI values range from 0.2 to 1. If a location has a CMI of ≥ 0.7, its climate is similar to the climate of all of New Zealand. While the ranges of CMI values in most of the countries where *P. microspora* occurs are less than 0.6, it also occurs in other countries like China (0.5–0.9), Japan (0.6–0.8), Uruguay (0.5–0.8), USA (0.5–0.8), and Spain (0.7–0.9), which demonstrates its potential to establish a population in New Zealand. The isolation of *P. microspora* from rhizosphere soil of the Antarctic hair grass (*Deschampsia antarctica*) in Antarctica (Gonçalves et al. 2015) strongly suggests that the cold climate in New Zealand is unlikely to be a limiting factor for its establishment.

The existence of *P. microspora* in the soil (Thiruvengadam et al. 2020), fresh water (ENA 2022) or aquaculture biofloc water (Nor et al. 2018) increases its likelihood of establishment if exposed in the New Zealand environment. Consequently, the fungus can potentially spread to new areas through flowing water and movement of infected plants with the soil surrounding their roots. The detection of *P. microspora* in pine seeds (Cleary et al. 2019) suggests that it could be spread through seed trade. Conidia of *P. microspora* from the pycnidia of infected leaves are a common source of inoculum (Maharachchikumbura et al. 2011) and these may spread further to new areas when the infected plant parts are blown off their trees by strong winds.

Uncertainty
Evidence for the existence of *P. microspora* in water mostly come from studies in the tropics (Indonesia and Malaysia). Additionally, the detection of *P. microspora* in fresh water (ENA 2022) was based on a molecular evidence and it is not clear if it was viable. Therefore, it is uncertain whether the fungus can remain viable in water under the cold climate in New Zealand. Although spores of *Pestalotiopsis* spp. can often survive harsh conditions(Maharachchikumbura et al. 2011) like intense cold and dryness, it is not clear if they can survive in cold water for a long time.

Given that:

- hosts are widely available for the establishment of *P. microspora*,
- climate is unlikely to limit the establishment of *P. microspora*,
- the fungus can occur in water and soil

but considering:

- the uncertainty of the fungus’ viability and possible growth after long exposures in water,

the likelihood of *Pestalotiopis microspora* establishing in New Zealand is HIGH, with MODERATE uncertainty.

5.3.3.5 Impacts in New Zealand

This assessment is made on the assumption that P. microspora has successfully established in the New Zealand environment.

Economic impacts

Pestalotiopsis microspora occurs in a wide variety of hosts (Farr and Rossman 2022) as either a pathogenic fungus or non-pathogenic endophyte (Strobel 2002; Maharachchikumbura et al. 2011). Some of its known hosts which are important for New Zealand's economy include pines, kiwifruits, grapes, blueberries and avocados but it is not pathogenic on all these hosts.

The negative impact of *P. microspora* depends on the host species. The fungus is known to cause post-harvest rot in kiwifruit (Li et al. 2016) and represents up to 11% of the causative agents of the rot in China (Li et al. 2017). Liu et al. (2020) indicated that the incidence of post-harvest rot in kiwifruit could be up to 20% and this means that in worst case scenario, *P. microspora* alone can account for 2% of the disease in China.

Similarly, *P. microspora* is a known causative agent of anthracnose disease on avocado where it accounts for up to 43% of fungal isolates associated with the disease in Kenya (Kimaru et al. 2018). In Kenya, anthracnose disease causes up to 60% loss in avocado fruit production (Wasilwa et al. 2004) and this means 26% of this loss could be attributed to *P. microspora* infection.

The fungus is also associated with blueberry leaf lesions in Hawaii (Keith et al. 2006). Although Yi-Lan et al. (2021) argued that blueberry leaf spot caused by *P. microspora* can affect the quality and quantity of fruits, they provided no data to support their assertion. The fungus has also been isolated from healthy blueberry twigs and a pathogenicity test revealed that it is not pathogenic on the shoots (Sessa et al. 2018).

In 2021, the cumulative value of kiwifruit, avocado and blueberry produced in New Zealand was NZ$2.9 billion. The export value of kiwifruit alone is about NZD 2.7 billion which accounts for about 40% of New Zealand's horticultural revenue. Based on the available impact data on only kiwifruit (2%) and avocado (26%), an inhouse model predicted a moderate economic impact over 20 years as the worst case scenario.

- This is based on the estimated combined annual impact on kiwifruit and avocado which amounts to NZD 83 million.
- The fungus is assumed to take 2 years to achieve its greatest impact because even when it spreads, it requires wound openings to infect its hosts.
- The time taken to full recovery was assumed to be 2 years because *Pestalotiopsis* spp. are susceptible to fungicides (Hopkins 1996; El-Argawy 2016) and they can be controlled by managing water regime (Elliott 2006).

However, it is highly unlikely that *P. microspora* can have a significant impact on kiwifruit as postharvest fruit-rot pathogen because Li et al. (2017) showed that naturally infected fruits require temperatures in range of 15–20 °C for two weeks in order for symptoms to be expressed – this is enough time and condition for the fruits to naturally deteriorate. Furthermore, successful inoculation of *P. microspora* was only achieved in wounded kiwifruits (Li et al. 2017) which suggests that potential to affect healthy and well packed kiwifruit may likely be negligible. Similarly, the avocado damage caused by *P. microspora* in Kenya is not likely to occur in a similar magnitude in New Zealand because of the environmental differences between Kenya and New Zealand.

Although grapes (*Vitis* spp) and pines (*Pinus radiata*) are significant for New Zealand's economy, no evidence was found to indicate that they can be negatively affected by *P. microspora*. The fungus was isolated from healthy fruits of grape (Ma et al. 2009). It was also recorded as an endophyte of pine (Nattrass 1961; Cleary et al. 2019) and tea (Wei et al. 2005; Wei et al. 2007). The occurrence of *P. microspora* in both heathy and yellow leaves of lemon at a low rate (<1% of all fungal isolates) (Douanla-Meli et al. 2013), suggests that it may not be pathogenic on the plant.

Uncertainty

Potential for *P. microspora* to harm other crops important to New Zealand's economy, such as avocado, may be linked with physiological and environmental factors. It is possible that climate change may increase the impacts of this fungus in some sectors. Lee et al. (1995) demonstrated that *P. microspora* may not cause disease as an endophyte in *Torreya taxifolia* but may become pathogenic when there is a significant physiological or environmental change. The biological and genetic diversity of the fungus (Strobel 2002) may be another source of uncertainty as It is unclear form the available information whether the strains of *P. microspora* associated with pineapple fruit will be pathogenic on hosts of economic importance to New Zealand or whether pathogenicity is host specific. Furthermore, the evidence that infected fruits would develop symptoms under appropriate fruit storage conditions is lacking – this implies that fruit rot caused by *P. microspora* may be largely linked with natural fruit senescence.

Given that:

- some known hosts of *P. microspora* are considered as economic plants in New Zealand, and
- the fungus is known to cause significant economic damage to hosts such as avocado in the tropics.

but considering:

- the lack of evidence for disease expression under suitable fruit storage conditions,
- diversity of *P. microspora* strains may determine severity of impact

the economic impact of *Pestalotiopsis microspora* in New Zealand is considered to be LOW, with HIGH uncertainty.

Environmental impacts

The known hosts of *Pestalotiopsis microspora* are mostly tropical, subtropical and temperate plants. No native New Zealand plants have been identified as hosts of *P. microspora*. However, it has the potential to expand its host range to include some native plant species because it has hosts in the same genera, for example *Fuchsia* and *Podocarpus*. Among the known podocarp-hosts of *P. microspora*, *Podocarpus* is the only known genus which has native species occuring in New Zealand and the fungus is not known to cause any disease on *Podocarpus* spp. *Pestalotiopsis* spp. can be managed with fungicides (Hopkins 1996) but soil invertebrates may be inadvertently affected in the process (Carniel et al. 2019).

Uncertainty

Uncertainty associated with the potential of *P. microspora* to cause environmental impacts includes the lack of information about its association with native plant species. There is no certainty that *P. microspora* will find suitable hosts among native plant species or cause any significant harm on such species even though some of its hosts' genera are present in New Zealand.

Given that:

- some of the fungus' host genera are present in New Zealand, and

- endemic invertebrates can be inadvertently killed when fungus is managed with fungicides

the environmental impact of *P. microspora* in New Zealand is considered to be VERY LOW, with HIGH uncertainty.

Human health impacts

There is no evidence to link *P. microspora* to any human health impact. However, unidentified species in the genus *Pestalotiopsis* have been isolated from eyes of patients with corneal abrasions (Sutton 1999). Unidentified *Pestalotiopsis* spp. have also been isolated from human sinuses, scalp, feet and fingernails (Sutton 1999). It is not clear if any of those *Pestalotiopsis* spp. are *P. microspora* or if they actually cause any human disease.

Given that there is no evidence of *P. microspora* causing any human disease, the human health impact of *P. microspora* in New Zealand is considered to be NEGLIGIBLE, with HIGH uncertainty.

Sociocultural impacts

Pestalotiopsis microspora affects a wide variety of plant species which include tea (*Camellia sinensis*) and *Podocarpus macrophyllus* (Farr and Rossman 2022). *Camellia* species are common in many public and private gardens in New Zealand hence there is a possibility that *P. microspora* may infect some of them if it establishes. This may potentially have a slight sociocultural impact on many people who are used to having *Camellia* plants around their homes and outdoor amenity spaces. *Pestalotiopsis microspora* has been isolated as an endophyte in *Podocarpus macrophyllus* in China. Nevertheless, *P. microspora* is unlikely to affect *Podocarpus totara* which is considered taonga by Māori because the fungus is not known to cause any disease *Podocarpus* hosts. No evidence was found to indicate that the fungus can have any sociocultural impact in New Zealand.

Given that there is no evidence that *P. microspora* may have a sociocultural impact, the sociocultural impact of *P. microspora* in New Zealand is considered to be VERY LOW with HIGH uncertainty.

5.3.3.6 Overall impact to New Zealand

MPI considers the overall impact of *Pestalotiopsis microspora* on the New Zealand economy, environment, health and the society is LOW with HIGH uncertainty.

5.3.3.7 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is LOW with HIGH uncertainty,
- assuming entry, the likelihood of exposure is MODERATE with MODERATE uncertainty,
- assuming successful exposure, the likelihood of establishment is HIGH with MODERATE uncertainty,
- the overall impact on the New Zealand economy, environment, human health, and society is considered to be is LOW with HIGH uncertainty

MPI considers the overall level of assessed risk to New Zealand from *Pestalotiopsis microspora* on pineapple fruit is LOW with HIGH uncertainty.

5.3.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *Pestalotiopsis microspora* association with pineapple fruit been observed?
The fungus is known to infect the 'smooth cayenne' variety of pineapple fruit (Yaouba et al. 2021). It is also known to infect pineapple leaves (Guba 1961; Rao and Mhaskar 1973) but those varieties were not specified and it is not clear if their fruits can also be infected.

Which part(s) of the pineapple fruit is *Pestalotiopsis microspora* associated with (e.g. fruit, bract, stem or crown remnant) and is it detectable by visual detection?
The fungus causes obvious dark-coloured necrotic lesions which continually expand around the bracts from the sites of infection on the fruit (Yaouba et al. 2021). Given that symptoms may take up to eight days to be expressed (Yaouba et al. 2021), infected fruits be not be detected if they reach New Zealand within a week from harvest.

Are different lifestages of *Pestalotiopsis microspora* associated with different parts of the pineapple fruit?
No information was found to indicate whether any specific life stage of the fungus is associated or not associated with pineapple fruit.

Under what environmental conditions (temperature, season etc) are *Pestalotiopsis microspora* symptoms expressed on pineapple fruit?
Cultures of the fungus and infections on pineapple fruits developed well at 25°C (Yaouba et al. 2021). The fungus is also known to thrive under high humidity at room temperature (Rao and Mhaskar 1973). Chen et al. (2016) also observed that the optimum conditions for *P. microspora* include a temperature range of 24–26°C and a pH range of 6–7.

Does *Pestalotiopsis microspora* exhibits latent/asymptomatic traits?
No evidence was found to indicate that the fungus exhibits latent or asymptomatic traits in pineapples. However, Yaouba et al. (2021) observed that infection only occurs in wounded fruits and it might take up to eight days for the pathogen to express symptoms.

5.3.5 *References*

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5.3.6 *Appendix to risk assessment of Pestalotiopsis microspora*

Known hosts of *Pestalotiopsis microspora*.

Family	Host species	Country recorded from	Database or reference
Actinidiaceae	*Actinidia chinensis*	China	(Farr and Rossman 2022)
	Actinidia sp.	China	(Farr and Rossman 2022)
Anacardiaceae	*Mangifera indica*	Burkina Faso	(Dianda et al. 2018)
	Spondias dulcis	Malaysia	(EBI 2022)
Apocynaceae	*Adenium obesum*	Brazil	(Farr and Rossman 2022)
Araceae	*Anthurium andraenum*	Thailand	(EBI 2022)
Araliaceae	*Aralia nudicaulis*	Canada	(EBI 2022)
	Hedera helix	Argentina, Italy	(Farr and Rossman 2022)
Araucariaceae	*Araucaria bidwillii*	China	(Farr and Rossman 2022)
	Araucaria sp.	Bermuda	(Farr and Rossman 2022)
	Araucaria sp.	Myanmar	(Farr and Rossman 2022)
Asparagaceae	*Reineckea carnea*	China	(Farr and Rossman 2022)
Berberidaceae	*Mahonia bealei* (Syn *Berberis bealei*)	China	(Farr and Rossman 2022)
	Mahonia confusa	China	(Farr and Rossman 2022)
	Nandina domestica	China	(Farr and Rossman 2022)
Betulaceae	*Alnus rubra*	USA (oregon),	(Farr and Rossman 2022)
	Corylus chinensis	China	(Farr and Rossman 2022)
Bromeliaceae	*Ananas comosus*	Bermuda, India	(Farr and Rossman 2022)
Boraginaceae	*Cordia dichotoma*	India	(Dhakshinamoorthy and Packiam 2021)
Burseraceae	*Canarium album*	China	(Chen et al. 2018)
Combretaceae	*Terminalia arjuna*	India	(Farr and Rossman 2022)
	Terminalia morobensis	Papua New Guinea	(Strobel et al. 2002)
	Terminalia chebula	India	(Farr and Rossman 2022)
Cupressaceae	*Biota orientalis* (syn *Platycladus orientalis*)	China	(Farr and Rossman 2022)
	Cunninghamia lanceolata	China	(Farr and Rossman 2022)
	Cupressus funebris	China	(Farr and Rossman 2022)
	Juniperus bermudiana	Bermuda	(Farr and Rossman 2022)
Cupressaceae	*Sabina chinensis* (syn *Juniperus chinensis*)	China	(Farr and Rossman 2022)
	Taxodium ascendens	China	(Farr and Rossman 2022)
	Taxodium distinchum	India	(Farr and Rossman 2022)
Dipterocarpaceae	*Shorea macrophylla*	Malaysia	(EBI 2022)
Ebenaceae	*Diospyros kaki*	Spain	(Berbegal et al. 2010) 2010
Ericaceae	*Vaccinium corymbosum*	Uruguay	(Farr and Rossman 2022)
Euphorbiaceae	*Hevea brasiliensis*	Cameroon	(Wilton 2022)
	Jatropha curcas	China	(Xiao et al. 2010)
Fabaceae	*Acacia mangium*	Malaysia	(EBI 2022)
	Copaifera sp.	Brazil	(Farr and Rossman 2022)
	Hymenaea sp.	Brazil	(Farr and Rossman 2022)
Fagaceae	*Lithocarpus glaber*	China	(Farr and Rossman 2022)

Family	Host species	Country recorded from	Database or reference
	Quercus acutissima	China	(Farr and Rossman 2022)
	Quercus coccinea	USA (New Jersey)	(Farr and Rossman 2022)
Graminae	*Oryza australiensis*	Australia	(Farr and Rossman 2022)
	Sorghum sp.	Nepal	(Farr and Rossman 2022)
Hypericaceae	*Hypericum androsaemum*	China	(Farr and Rossman 2022)
	Hypericum patulum	Japan	(Farr and Rossman 2022)
Juglandaceae	*Carya cathayensis*	China	(Farr and Rossman 2022)
	Carya illinoensis (Syn *Carya pecan*)	Brazil, China	(Farr and Rossman 2022)
Lauraceae	*Cinamomum verum*	Sri Lanka	(EBI 2022)
	Lindera obtusiloba	Korea	(Farr and Rossman 2022)
	Machilus nanmu	China	(Farr and Rossman 2022)
Lauraceae	*Persea americana*	Kenya	(Kimaru et al. 2018)
Lythraceae	*Lagerstroemia speciosa*	China	(Farr and Rossman 2022)
	Sonneratia sp.	Indonesia	(EBI 2022)
Malvaceae	*Theobroma cacao*	Ecuador	(Villavicencio et al. 2020)
Meliaceae	*Azadirachta indica*	India	(Farr and Rossman 2022)
Musaceae	*Musa* sp.	Bangladesh	(Farr and Rossman 2022)
Myricaceae	*Myrica rubra*	China	(Farr and Rossman 2022)
Myristicaceae	*Otoba gracilis*	Colombia	(Chaves et al. 2022)
Myrtaceae	*Campomanesia* sp.	Brazil	(Farr and Rossman 2022)
	Psidium guajava	USA (Hawaii)	(Farr and Rossman 2022)
Onagraceae	*Fuchsia hybrid cultivar*	ECUADOR	(EBI 2022)
Orchidaceae	*Stanhopea bucephalus*	Mexico	(Farr and Rossman 2022)
	Vanilla planifolia	Reunion	(EBI 2022)
Palmae (syn Arecaceae)	*Archontophoenix alexandrae*	China, Singapore	(Farr and Rossman 2022)
	Elaeis guineensis	China, Indonesia	(Farr and Rossman 2022)
Pandanaceae	*Pandanus sp.*	Thailand	(Tibpromma et al. 2018)
Phyllanthaceae	*Bridelia monoica*	China	(Farr and Rossman 2022)
	Bridelia stipularis	China	(Farr and Rossman 2022)
Pinaceae	*Abies beshanzuensis*	China	(Farr and Rossman 2022)
	Pinus radiata	Kenya	(Farr and Rossman 2022)
Platanaceae	*Platanus orientalis*	China	(Farr and Rossman 2022)
Podocarpaceae	*Podocarpus macrophyllus*	China	(Farr and Rossman 2022)
Primulaceae	*Aegiceras corniculatum*	Hong Kong	(Farr and Rossman 2022)
	Amomum tsao-ko (syn *Lanxangia tsao-ko*)	China	(Farr and Rossman 2022)
	Ardisia sp.	China	(Farr and Rossman 2022)
Rosaceae	*Eriobotrya japonica* (Syn *Rhaphiolepis bibas*)	China	(Farr and Rossman 2022)
	Fragaria virginiana	Canada	(EBI 2022)
	Malus halliana	China	(Farr and Rossman 2022)
	Photinia x Fraseri	China	Guan (Guan et al. 2013)
Rubiaceae	*Faramea capillipes*	Ecuador	(EBI 2022)
	Ixora chinensis	Malaysia	(EBI 2022)

Family	Host species	Country recorded from	Database or reference
Rutaceae	*Citrus limon*	Cameroon	(Farr and Rossman 2022)
Sapindaceae	*Acer palmatum*	China	(Farr and Rossman 2022)
Taxaceae	*Taxus wallichiana*	Nepal	(Farr and Rossman 2022)
	Taxus cuspidata	Korea	(Farr and Rossman 2022)
Taxaceae	*Torreya grandis*	China	(Farr and Rossman 2022)
	Torreya taxifolia	USA (Florida), North America	(Farr and Rossman 2022)
Theaceae	*Camellia oleifera*	China	(Li et al. 2011)
	Camellia sinensis	China	(Farr and Rossman 2022)
Vitaceae	*Vitis* sp.	Morocco	(EBI 2022)
Zingiberaceae	*Hedychium coronarium*	Cuba, Venezuela, West indies	(Farr and Rossman 2022)

5.4 *Thielaviopsis paradoxa* (pineapple black rot)

Thielaviopsis paradoxa is a soil-borne wound parasite, capable of infecting all parts of a plant. The fungus was first reported in 1886 from France, causing rot in pineapple fruits. The fungus has spread to other warm temperate and tropical regions of the world and the associated rot disease is recognised as an economically important problem for sugarcane, banana, and pineapple crops.

5.4.1 *Taxonomic description*

Scientific name: *Thielaviopsis paradoxa* (De Seynes) Höhn. 1904
Order: Microascales **Family:** Ceratocystidaceae
Other names: *Ceratocystis paradoxa* (Dade) C. Moreau 1952; *Chalara paradoxa* (De Seynes) Sacc. 1892; *Ceratostomella paradoxa* Dade, (1928); *Sporoschisma paradoxum* De Seynes 1886; *Endoconidiophora paradoxa* (De Seynes) R.W. Davidson, (1935); *Ophiostoma paradoxum* (Dade) Nannf., (1934); *Stilbochalara dimorpha* Ferd. & Winge 1910; Water blister of pineapple (soft rot); White leaf spot; Butt rot; Black rot of pineapple.

Taxonomic notes:
Thielaviopsis paradoxa was previously known as *Ceratocystis paradoxa* and some research articles continue to use this name. The fungus belongs to the filamentous ascomycetes group and forms thick walled spores along with infective asexual spores (conidia) (Hewajulige and Wijesundera 2014)

A 2016 Technical Paper was commissioned by MPI and completed by Manaaki Whenua Landcare Research to investigate whether fungal samples found in New Zealand were in fact *Thielaviopsis paradoxa* (Johnston and Park 2016). The report summarised that:

- *T. paradoxa* does not occur in New Zealand.
- After taxonomic analysis isolates in the International Collection of Microorganisms from Plants (ICMP) originally identified as *T. paradoxa,* were actually *T. musarum* (= *Ceratocystis musarum*) and *T. ethacetica* (often confused with *T. paradoxa*).

5.4.2 *Hazard identification*

Thielaviopsis paradoxa is not known to be present in New Zealand.

- *Thielaviopsis paradoxa* was recorded in error as present in New Zealand (Johnston and Park 2016; NZOR 2022).
- *Thielaviopsis paradoxa* is recorded as "recorded in error" in BiotaNZ (2022), and it is recorded that " Before April 2016 Thielaviopsis paradoxa was recorded as present in New Zealand as Ceratocystis paradoxa. However sequencing of ICMP cultures from NZ (ICMP 15221 and ICMP 13062) could not confirm its presence in NZ, thus is was considered to be recorded in error. [PRJ, April 2016; BSW, Aug 2021]"
- *Thielaviopsis paradoxa's* regulatory, quarantine and country freedom status has not been assessed, according to ONZPR (2022). However, its synonym *Ceratocystis paradoxa* is a regulated and quarantine pest in New Zealand.

Thielaviopsis paradoxa has the potential to establish and spread in New Zealand.

- *Thielaviopsis paradoxa* has a wide host and geographic range (Appendix Risk Assessment of *Thielaviopsis paradoxa*: Table 1) (Hewajulige and Wijesundera 2014).

- The fungus has spread to other warm temperate and tropical regions of the world (Elliott 2006).
- *Thielaviopsis paradoxa* has the potential to cause harm to plant species of economic importance in New Zealand (e.g. carrot, potato, kūmara , Eucalyptus and lettuce) (Farr and Rossman 2022).

Thielaviopsis paradoxa is associated with pineapple fruit.

- *Thielaviopsis paradoxa* has been reported from pineapple fruit and has been identified as the causal agent of pineapple fruit rot (Wisemer and Bailey 1990; Hewajulige and Wijesundera 2014).

Given the arguments and evidence above, MPI considers *Thielaviopsis paradoxa* is a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

5.4.3 *Risk assessment*

5.4.3.1 Biology

Hosts and geographical distribution

Thielaviopsis paradoxa has a wide host and geographic range (Appendix Risk Assessment of *Thielaviopsis paradoxa*: Table 1). The fungus was first reported in 1886 from France, causing rot in pineapple fruits (Wisemer and Bailey 1990; Hewajulige and Wijesundera 2014). The fungus has spread to other warm temperate and tropical regions of the world and the associated pineapple rot disease is recognised as an economically important problem (Wisemer and Bailey 1990).

Its preferred host range is mostly restricted to monocot plants grown in warmer climates (Elliott 2006; Hewajulige and Wijesundera 2014). It is associated with other host plants growing in both tropical and temperate regions (Appendix 1.1.9) such as *Ipomoea batatas* (kūmara), *Solanum tuberosum* (potato), *Lactuca sativa* (lettuce), *Cucurbita moschata* (pumpkin), *Daucus carrota* (carrots), *Cupressus macrocarpa* (macrocarpa trees) and *Eucalyptus* spp (Hewajulige and Wijesundera 2014).

While the fungus is found throughout the world it ceases growth and becomes almost inactive at temperatures above 52.3°C or below 10°C (Martínez et al. 1997) with optimum growing temperatures being between 21 – 22°C (Frossard 1978; Hassan et al. 2011; Hewajulige and Wijesundera 2014; Pongener et al. 2018). It was also noted by Frossard (1978) that *T. paradoxa* (identified as *Ceratocystis*) growth rate was considerably reduced at 12°C and stopped at 8°C, but the fungus has the ability to resume growth when returned to suitable temperatures.

Symptoms

Thielaviopsis paradoxa is a soil-borne wound parasite, capable of infecting all parts of a plant. Symptoms caused by *T. paradoxa* include soft, watery rot in the fruit flesh which can rapidly liquefy at 25°C, exuding a sweet odour. Following this, the infected tissue darkens and results in juice leaking from diseased tissue (Py et al. 1987).

The fungus can also infect pineapple fruit via broken fruit stalk (peduncle), which usually occurs soon after harvest. The infection results in cone-shape symptoms (circular sunken shaped rot) developing within the pineapple core (Hewajulige and Wijesundera 2014). The fungus can also invade through bruised or wounded fruit skin. Stored fruit for the export market has been associated with 20 – 80% losses in Asian countries (Hewajulige and Wijesundera 2014). On pineapple, watery rots occur inside the fruit with a brittle outer shell remaining. However, the skin, flesh and core breakdown with the fruit leaking watery substance through the shell (CABI 2022).

Symptoms in pineapples consist of leaf spot, basal rot of the asexual propagative part of plant and fruit rot (Hewajulige and Wijesundera 2014). Basal rot and fruit rot are more economically devastating than leaf spot symptoms as the latter is associated with low disease levels in commercial pineapple cultivars. Pineapple fruit rot is a serious and common disease of commercially produced pineapple fruits and is present in all pineapple producing countries, except Samoa, which are included within the scope of this project (Hewajulige and Wijesundera 2014).

Kowalska (2003) reported that *T. paradoxa* caused black sooty symptoms in carrots which appeared as black sooty patches that gradually covers the entire root. It was noted that temperatures of about 18°C were condusive for the spread of the disease. While it has been reported to be a pathogen that causes disease in important crops such as potato, kumara and corn (Hewajulige and Wijesundera 2014; Farr and Rossman 2022), symptoms caused on these crops species and impacts on yield were not clearly described.

Latency infection

Thielaviopsis paradoxa can be present in a latent phase on the bracts of pineapples without causing disease symptoms and eventually cause symptoms during the ripening process (Frossard 1978). The latent phase of *T. paradoxa* is reported to occur especially on crown, stem end and perianth of the spike region of pineapple fruits (Adisa 1983). Furthermore, While these references are dated, no recent evidence of latency of *T. paradoxa* in pineapple fruit could be found in the available literature.

Pineapple variety susceptibility

Thielaviopsis paradoxa is an economically significant pathogen affecting pineapples and found in most pineapple production areas (Wisemer and Bailey 1990; Hewajulige and Wijesundera 2014). As such, it is likely that the pathogen can infect most varieties of pineapples. However, in scientific literature it was specifically stated that the pathogen is known to infect pineapple varieties Md2 in Malaysia (Kuruppu et al. 2022), Mauritius in Sri Lanka (Hewajulige et al. 2006), Gold Honey in Columbia (Perez et al. 2014) and Perola in Brazil (Sales et al. 2016). No details regarding latency of *T. paradoxa* in the mentioned pineapple varieties were found.

Reproduction and transmission

Thielaviopsis paradoxa produce chlamydospores which can remain viable for up to 10 years in soil and plant debris (Frossard 1978; Kowalska 2003; MPI 2016). Asexual conidia can be spread by rain splash and increased humidity can enable the spread of conidia from infected to healthy pineapple fruits. Spores can also spread from tools used in harvesting. Infection occurs before harvest, by insect/rodent punctures or wounds sustained during handling of the fruit (Hewajulige and Wijesundera 2014). Wounded fruit can become infected via contaminated soil (Elliott 2006). Infection can occur eight to 12 hours after wounding, with disease development exacerbated by warm temperatures and high relative humidity. Furthermore, likelihood of infection is increased in washed fruits, when compared to unwashed fruit (Hewajulige and Wijesundera 2014) due to spores being disturbed. This can possibly strengthen transmission efficiency.

On pineapple fruits, *T. paradoxa* is a major postharvest disease causing leaf spots, fruit, and basal rots. Lack of refrigeration during transport and storage increases the likelihood of fruit rot caused by *T. paradoxa* (CABI 2022). Fruit can be infected through bruises, growth cracks or wounds made when they are detached. At times, after severe infections only the fruit shell is left, with few fibres inside, which can collapse under slight pressure (CABI 2022).

5.4.3.2 Likelihood of entry

Thielaviopsis paradoxa has been reported to cause rot in pineapple fruits (Wisemer and Bailey 1990; Hewajulige and Wijesundera 2014). It is recorded to be present in markets in the scope (Tonga, Sri Lanka, Fiji, Indonesia, Malaysia, New Caledonia, Taiwan, Thailand, Vanuatu, Australia, Cook Islands, Costa Rica, Papua New Guinea, Philippines and Panama) of this IRA (CABI 2022).

Thielaviopsis paradoxa can infect pineapple fruits before harvest (particularly unripe pineapple fruit as per commodity description) via broken fruit stalk (peduncle) or invade through bruised or wounded fruit skin (Hewajulige and Wijesundera 2014) without showing visible symptoms due to its ability for latent infestation phase. This decreases likelihood of detection at entry. Postharvest disease resulting from infections by pathogens in the field may not cause conspicuous symptoms that will be noticed at harvest (i.e. not observed on the fruit surface), and infections in fleshy fruits and vegetables continue to develop after harvest (Agrios 2005).

Later stages of infection on pineapple fruit by *T. paradoxa* (Hewajulige and Wijesundera 2014) are likely to be obvious and infected fruits will be discarded during harvest, processing or pre-export inspection. If fruits are only taken from fields which have no detectable signs of infection, it is unlikely that fruits for the export market will be infected with *T. paradoxa.*

The fungus is found in all markets included within the scope of this IRA, except Samoa. It is unlikely that postharvest processes will remove the fungus except for some larger mycelia on the surface. Estimated shipping times between pineapple export markets to New Zealand is between seven days to four weeks and recommended cold storage transit temperatures for is between 7-13°C (Annex.Appendix 3). *Thielaviopsis paradoxa* can survive for long periods and is likely to survive the transit conditions as the fungus becomes inactive below 10°C (Martínez et al. 1997). Furthermore, the fungus has been recorded to resume growth once returned to temperatures suitable for growth (Frossard 1978), increasing the likelihood of entry into the country without being detected. Thus, there is a low, but not negligible, likelihood of fruits being imported with early stage, non-viable infections which can develop after the fruit has been imported and sold.

Thielaviopsis paradoxa has been intercepted previously at the border. One instance of the fungus being intercepted was on coconuts from Ghana (EPPO 2022). The fungus has also been intercepted at the New Zealand border on bananas (from Ecuador), timber (from Philippines), *Sansevieria* spp. (from Costa Rica), palm seeds (from Australia), *Howea fosteriana* (from Australia) and on unidentified seeds (from Australia) between 2002 – 2013 (LIMS 2022). While the fungus has a wide host and geographic range, the reason it has not been detected at the border since 2013 could be because fungal species infecting fresh produce consignments are rarely identified. Inspected shipments to the USA, have in the past, detected the disease in up to 70% of fruits (Cappellini et al. 1988). However, it should be noted details of these shipments could not be found and may not have undergone any biosecurity measures.

Uncertainty

The uncertainty associated with the likelihood of *T. paradoxa* entering the country without detection is based upon the lack of current information found regarding latency in pineapple fruits

Given that:

- *Thielaviopsis paradoxa* has been reported to cause rot in pineapple fruits, and it is recorded as present in markets in the scope of this IRA.
- although fruits are likely to be only taken from areas of production without visible infections, *T. paradoxa* is capable of latent infection of unripe fruits with disease sypmptons becoming obvious during ripening,
- severely infected fruits are likely to be discarded during the harvest and pre-exporting processes,
- transit conditions to New Zealand are likely to not support active growth and spread of *T. paradoxa,* but the fungus has the ability to resume growth once returned to ambient temperatures,

MPI considers the likelihood of *Thielaviopsis paradoxa* entering New Zealand associated with pineapple fruit is MODERATE with MODERATE uncertainty.

5.4.3.3 Likelihood of exposure

This assessment is made on the basis that Thielavipsis paradoxa *has entered New Zealand undetected.*

Exposure is considered to be the point at which a contaminating organism becomes associated with a suitable host in New Zealand in a manner that allows it to complete a normal life cycle. This usually involves the transfer of the organism from imported material to a host of domestic origin or suitable environment, considering that the fungus can persist in the soil for long period of time (Kowalska 2003).

Pineapple fruit is intended to be sold to consumers in New Zealand and is a commodity which generates substantial amounts of unavoidable waste (due to the thick rind being removed and disposed of, and the fruit is also sometimes cored). The disposal of whole fruit (e.g., culled/unsold fruits, uneaten fruit remains) is not uncommon during wholesale, retail and by consumers. This suggests, pineapple fruits infected with *Thielaviopsis paradoxa* may have a higher likelihood of exposure than those associated with many other kinds of fresh produce (see waste analysis Annex 2.3.1).

Pineapple fruits with early or mild *T. paradoxa* infections can, and likely will, be consumed (MPI 2016). However, waste from infected fruits are usually discarded in home/commercial composts or in landfill waste (see waste analysis Annex 2.3.1). Infected fruit or fruit parts which are discarded into landfills or composts are likely to become a source of inoculum with spores present in surrounding soils (Elliott 2006). As such, the fungus can remain viable as long-lived chlamydospores in the environment and eventually find a suitable host. While the fungus could infect hosts in the immediate surroundings, the likelihood of it spreading to cultivation areas of high value hosts especially since landfills, home/commercial composts are not usually located near horticulture growing areas is low. However *T. paradoxa* (as *C. paradoxa*) has been recorded as being dispersed by Nitidulid beetles species some of which are present in New Zealand (Chang and Jensen 1974; BiotaNZ 2022). This suggests that it is possible that the fungus can be dispersed by insects to cultivation areas.

Disposal of organic waste into landfill is unlikely to be a *T. paradoxa* exposure risk. The most common method of organic waste disposal in New Zealand is via bagged waste entering landfill (Askarany and Franklin-Smith 2014). Condiering *T. paradoxa* ceases growth and becomes almost inactive at temperatures above 52.3°C (Martínez et al. 1997). This method is unlikely to be an exposure risk given waste is sealed within bags, and the processing and containment methods used in such facilities would likely inhibit *T. paradoxa* survival.

Domestic composting in contrast is likely to be a *T. paradoxa* exposure risk. Open composting systems would likely aid *T. paradoxa* exposure especially if suitable hosts commonly found in New Zealand gardens (e.g., carrots, lettuce, potatoes and ornamentals) were present within the immediate environment.

Disposal of fruit waste via use as animal feed is also likely to be a *T. paradoxa* exposure risk. Fruit waste in New Zealand may be collected from unpacking areas (e.g., supermarket preparation rooms), and taken to rural areas to be used as feed for farmed animals (MPI 2014). *T. paradoxa* present within such feed can infect suitable host within the environment as well as remain viable in the soil for long periods of time in the absence of suitable host plants.

Uncertainty

The uncertainty associated with the likelihood of *T. paradoxa* being exposed to the New Zealand environment is based upon the fact that the time needed, conditions and mechanisms required to transfer the fungus from compost soil to plant hosts, in a New Zealand context, is unknown.

Given that:

- infected fruits are likely to be discarded into landfills or composts,
- while fruits with early or mild infection are likely to be consumed, discarded skin can also be infected,
- disposal of organic waste into landfill is unlikely to be a *T. paradoxa* exposure risk because it is unlikely to survive the conditions (heat) in landfill ,
- *T. paradoxa* produces chlamydospores which are known to remain viable for long periods in soil and can survive on rotting plant debris, suggesting the fungus can survive composts
- domestic composting is likely to be a *T. paradoxa* exposure risk.
- disposal of fruit waste via use as animal feed is also likely to be a *T. paradoxa* exposure risk. It is possible that it can be spread and dispersed by insects to cultivation areas.

MPI considers the likelihood of exposure of *Thielaviopsis paradoxa* in New Zealand from pineapple fruit is HIGH with MODERATE uncertainty.

5.4.3.4 Likelihood of establishment

This assessment is made on the basis that Thielaviopsis paradoxa *has been successfully exposed to a suitable host plant in the New Zealand environment.*

Thielaviopsis paradoxa mostly infects tropical and some temperate hosts (Hassan et al. 2011), it cannot survive temperatures above 52.3°C and becomes inactive below 10°C, with optimum growing temperatures between 21 – 22°C (Frossard 1978; Hewajulige and Wijesundera 2014; Pongener et al. 2018).

While current average summer temperatures, in regions of New Zealand which grow known hosts of *T. paradoxa* (Appendix Risk Assessment of *Thielaviopsis paradoxa*: Table 1) (Plant & Food Research 2021), are conducive to the growth of the fungus, winter climate conditions (NIWA 2022) are mostly below minimum active growing temperatures. This indicates that, in current climate conditions, there is a likelihood of *T. paradoxa* establishing in most of New Zealand during summer months. Furthermore, during colder months, the fungus could cease growing, become inactive and resume growth when temperatures are optimal (Frossard 1978). This is especially likely as the fungus is able to survive for long period in soil (Kowalska 2003; Elliott 2006).

Hosts of *T. paradoxa* are available and widely cultivated in New Zealand, such as carrots, potatoes and maize (Appendix Risk Assessment of *Thielaviopsis paradoxa*: Table 1). However, preferred hosts, and on which the fungus causes significant damage (e.g. pineapple and sugarcane) are not widely cultivated in New Zealand (MPI 2016). The fungus is also known to be saprophytic and can survive in the soil for long periods of time , increasing likelihood of establishment (Elliott 2006).

Uncertainty

Uncertainty associated with the establishment of *T. paradoxa* includes the fact that its preferred hosts are mostly tropical plants (sugarcane and pineapple) which are not grown extensively in New Zealand and its association with other host plants such as potato, carrot kumara and lettuce of economic importance to New Zealand is unclear.

Given that:

- *Thielaviopsis paradoxa* has an optimum growing temperature range of between 21 – 22°C which is for it to establish in all parts of New Zealand during the summer. It cannot survive temperatures above 52.3°C and becomes inactive below 10°C,
- winter temperatures in areas where hosts are grown are likely too low for active growth of the fungus. However, the fungus has the ability to resume growth when temperatures are optimal and can survive for up to ten years in soil,
- preferred horticultural hosts which are severely affected by the fungus are mostly tropical and not widely cultivated in New Zealand. Other hosts such as *Eucalyptus* and ornamental palms and horticultural crops such as carrots and potatoes are widespread,

MPI considers the likelihood of *Thielaviopsis paradoxa* establishing in New Zealand is HIGH with MODERATE uncertainty.

5.4.3.5 Impacts in New Zealand

This assessment is made on the assumption that T. paradoxa *has successfully established in the New Zealand environment.*

Economic impacts

Most hosts, especially preferred hosts, of *T. paradoxa* are tropical and the fungus is described as a major disease of sugarcane and pineapples (Chang and Jensen 1974; Hewajulige and Wijesundera 2014). However, *T. paradoxa* has also been reported on hosts which are commonly grown in New Zealand, including *Eucalyptus* spp., *Ipomoea batatas* (kūmara), *Solanum tuberosum* (potato), *Lactuca sativa* (lettuce), *Cucurbita moschata* (pumpkin), *Daucus carrota* (carrots), and *Cupressus macrocarpa* (macrocarpa trees) (Hewajulige and Wijesundera 2014; Farr and Rossman 2022b).

The above-mentioned species are all economically significant to New Zealand but are not considered to be major or preferred hosts of *T. paradoxa.* A literature search done on Google Scholar resulted in very few articles outlining impacts on these hosts associated with *T. paradoxa* infections, suggesting that it is not often reported to be a major problem on these hosts.

An in-house MPI model predicted a low level of economic impact over 20 years.

- Assumptions: considering that *T. paradoxa* has been reported to cause disease in both tropical and temperate areas, it is expected to establish and affect host plants in the whole of New Zealand.
- Although *T. paradoxa* is known to cause 20%-80% yield loss in pineapples (Hewajulige and Wijesundera 2014), no report was found on yield loss caused by *T. paradoxa* on any host plant important to New Zealand. Yield loss of 5% was assumed for carrot, kumara, maize, lettuce and potato. A 1% yield loss was assumed for *Eucalyptus* sp. on the assumption that impacts will be less severe on established tress.
- Greatest level of annual impact: domestic and export value in New Zealand for carrot, kumara, maize, potato, lettuce, and Eucalyptus sp. are NZ$67.7m, 35m, 464.2m, 1.06 billion, 43.7m and 41.3m respectively. The total value of *Thielaviopsis paradoxa* for hosts plants in New Zealand is NZ$1.721 billion (Appendix Risk Assessment of *Thielaviopsis paradoxa*: Table 1).
- It is assumed that the fungus would take 0.5 years to achieve the greatest impact for annual crops (carrot, lettuce, kumara, maize and potatoes) and 5 years for Eucalyptus sp.
- As New Zealand already has effective control approaches/programme for fungal pathogens, it is assumed the industries would only take 0.5 – 1 year to full recovery for annual crops and 10 years for *Eucalyptus* sp. because the *T. paradoxa* can persist in the soil for 10 years (Kowalska 2003).

Uncertainty

Uncertainty associated with the economic impacts of *T. paradoxa* based on the fact that the impact it might have on crops/plant such as carrots, potato, kumara and Eucalyptus which are of economic important crops to New Zealand is not known.

Given that:

- some hosts of *T. paradoxa* are widely cultivated and economically significant to New Zealand with total annual export and import value of more than one billion dollars;
- however, no report was found on yield loss caused by *T. paradoxa* on any host plants important to New Zealand;

MPI considers the economic impact of *Thielaviopsis paradoxa* in New Zealand is LOW, with HIGH uncertainty.

Environmental impacts

The families of host species of *T. paradoxa* were checked using the Plant Conservation Network (NZPCN 2022) to determine if the families included native New Zealand species. While many native species included host families of the fungus (Farr and Rossman 2022b), none of these native species have been recorded as hosts. Some families of host species, and the native New Zealand plants in those families are Arecaceae (nīkau palm), Rubiaceae (includes many native *Coprosma* species, some of which are at risk or threatened), Cyperaceae (including some native species which are at risk), Poaceae and Meliaceae (which only has one ecologically important and common native species *Dysoxylum spectabile* (kohekohe)). There is no evidence to confirm if these species in native families could become hosts in the future.

Given that:

- no native New Zealand species are recorded as hosts of *T. paradoxa,*
- families of native species are included as hosts of the fungus,

MPI considers the environmental impact of *Thielaviopsis paradoxa* in New Zealand is VERY LOW, with MODERATE uncertainty.

Human health impacts

There are no known human health impacts from *T. paradoxa* recorded in the literature so the human health impact of *Thielaviopsis paradoxa* in New Zealand is considered to be NEGLIGIBLE, with LOW uncertainty.

Sociocultural impacts

Private home gardens could be affected by *T. paradoxa* infections, especially if pineapple fruit waste is discarded in home composts. Popular vegetables such as potatoes, kūmara, lettuce and pumpkin are grown by home gardeners could be infected. Other species such as eucalyptus and ornamental palms could also be affected, which are widely planted as amenity, indoor and residential plants.

MPI considers the sociocultural health impact of *Thielaviopsis paradoxa* in New Zealand is VERY LOW, with MODERATE uncertainty.

5.4.3.6 Overall impact to New Zealand

MPI considers the overall impact of *T. paradoxa* on the New Zealand economy, environment, health and society is LOW with MODERATE.

5.4.3.7 *Overall risk to New Zealand*

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is MODERATE, with MODERATE uncertainty
- assuming entry, the likelihood of exposure is HIGH, with MODERATE uncertainty
- assuming successful exposure, the likelihood of establishment is HIGH, with MODERATE uncertaintythe overall impact on the New Zealand economy, environment, human health, and society is considered to be LOW with MODERATE uncertainty

MPI considers the overall level of assessed risk to New Zealand from *Thielavipsis paradoxa* on pineapple fruit is LOW, with HIGH uncertainty.

5.4.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *Thielavipsis paradoxa* association with pineapple fruit been observed?

In scientific literature it was specifically stated that the pathogen is known to infect pineapple varieties Md2 in Malaysia {Kuruppu, 2022 #43442}, Mauritius in Sri Lanka {Hewajulige, 2006 #43462}, Gold Honey in Columbia {Perez, 2014 #43460} and Perola in Brazil {Sales, 2016 #43461}.

No information was found in the literature to indicate at what stage of ripeness of pineapple *T. paradoxa* is associated with.

Which part(s) of the pineapple fruit is *Thielavipsis paradoxa* associated with (e.g., fruit, bract, stem, or crown remnant) and is it detectable by visual detection?

Thielaviopsis paradoxa is a soil borne wound parasite, capable of infecting all parts of a plant. The fungus can also infect pineapple fruit via broken fruit stalk (peduncle), which usually occurs soon after harvest. Symptoms in pineapples consist of leaf spot, basal rot of the asexual propagative part of plant and fruit rot {Hewajulige, 2014 #43456}. Fruit can be infected through bruises, growth cracks or wounds made when they are detached.

At times, after severe infections only the fruit shell is left, with few fibres inside, which can collapse under slight pressure {CABI, 2022 #43445}.

Are different lifestages of the *Thielavipsis paradoxa* associated with different parts of the pineapple fruit?

No evidence of this was found in the literature.

Under what environmental conditions (temperature, season etc) are *Thielavipsis paradoxa* symptoms expressed on pineapple fruit?

Symptoms caused by *T. paradoxa* include soft, watery rot in the fruit flesh which can rapidly liquefy at 25°C, exuding a sweet odour. Following this, the infected tissue darkens and results in juice leaking from diseased tissue {Py, 1987 #43455}. The fungus cannot survive temperatures above 52.3°C, becomes inactive at temperatures below 10°C and can resume active growth when temperatures are optimal (between 21 – 22°C) {Pongener, 2018 #43477;Hewajulige, 2014 #43456;Hassan, 2011 #43441;Kowalska, 2003 #43725;Frossard, 1978 #43452}.

Does *Thielavipsis paradoxa* exhibits latent/asymptomatic traits?

The latent phase of *T. paradoxa* is reported to occur in pineapple fruits, especially on crown, stem end and perianth of the spike region {Adisa, 1983 #43476}. Furthermore, *T. paradoxa* can remain latent on the bracts of pineapples and become active during the ripening process {Frossard, 1978 #43452}. While these references are dated, no recent evidence of latency of *T. paradoxa* in pineapple fruit could be found in the available literature. No details regarding latency of *T. paradoxa* in the mentioned pineapple varieties was found. However, the fruit can be infected at harvest or during processing {Hewajulige, 2014 #43456} and storage/transit temperatures are likely to retard or stop fungal growth {Martínez, 1997 #43721}. This suggests that infections occurring at harvest or in the packhouse may not produce symptoms until the fruit is returned to ambient temperatures and fungal growth resumes, which will likely be after its pre -export phytosanitary inspection and on-arrival inspection in New Zealand.

5.4.5 *References*

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5.4.6 *Appendix to risk assessment of Thielaviopsis paradoxa*

Table 5.5 Host and geographic range of *Thielaviopsis paradoxa* (and recorded synonyms), as recorded in the current, available English literature. Markets included in the scope of this import risk analysis are marked with *. Climate similar to New Zealand is assessed using the composite match index (CMI) (Phillips et al. 2018). If a country/area/market has a CMI of ≥0.7, it is considered to have climate similar to all of New Zealand. The values in the New Zealand market of significant hosts were calculated using a report by Plant & Food Research (2021) and Arable Food Industry council (Robertson and Hurren 2022). Total domestic and export value of plant hosts of *Thielaviopsis paradoxa* is NZ$1.721 billion.

Family	Host species	Common name	Country/area/market (CMI)	Value of host for NZ market (in NZ$)	Reference
Anacardiaceae	*Mangifera indica*	mango	India (0.4 – 0.5)	-	Hewajulige and Wijesundera (2014); CABI (2022); Farr and Rossman (2022)
Annonaceae	*Annona muricata*	guanábano	Malaysia* (0.4 – 0.5)	-	Farr and Rossman (2022)
Apiaceae	*Daucus carota*	carrot	Poland (0.8–0.9), Germany (0.8–0.9)	Domestic $58 million Export $9.7 million	CABI (2022), Kowalska (2003); Weber and Tribe (2004)
Apocynaceae	*Plumeria* sp.	frangipani	USA (0.5 – 0.8)	-	Farr and Rossman (2022)
Araceae	*Anthurium andraeanum*	painter's palette	West Indies (–)	-	Farr and Rossman (2022)
	Colocasia esculenta	taro	Tonga* (–)	-	Farr and Rossman (2022)
Arecaceae	*Adonidia merrillii*	Manila palm	USA (0.5 – 0.8)	-	Farr and Rossman (2022)
	Areca catechu	date palm	India (0.4 – 0.5), Egypt (0.4 – 0.5), Kuwait (0.4), Libya (0.4 – 0.5), Oman (0.4 – 0.5), Sri Lanka* (0.4 – 0.6), Sudan (0.3 – 0.6), UAE (0.3 – 0.4)	-	Hewajulige and Wijesundera (2014)

	Bactris gasipaes	Cachipá	Brazil (0.4 – 0.6)	-	Farr and Rossman (2022)
	Borassus flabellifer	toddy palm	India (0.4 – 0.5)	-	CABI (2022)
	Butia odorata	coquinho-azedo	Uruguay (0.9 – 0.8), China (0.4 – 0.8)	-	CABI (2022); Farr and Rossman (2022)
	Cocos nucifera	coconut	Brazil (0.4 – 0.6), Brunei (0.5), China (0.4 – 0.8), Cote d'Ivoire (0.5), Cuba (0.5), Dominican Republic (0.5 – 0.7), Fiji* (0.4), Ghana (0.4 – 0.5), Guadeloupe (–), India (0.4 – 0.5), Indonesia* (0.4 – 0.6), Jamaica (0.6), Japan (0.6 – 0.8), Malaysia* (0.4 – 0.5), Mauritius (–), Mexico (0.4 – 0.8), New Caledonia* (0.6 – 0.7), Nigeria (0.4 – 0.5), Papua New Guinea* (0.4 – 0.7), Philippines* (0.3 – 0.6), Tonga* (–), Somalia (0.3 – 0.4), Sri Lanka* (0.4 – 0.6), Taiwan* (0.4 – 0.8), Thailand* (0.3 – 0.5), Vanuatu* (0.5), West Indies (–), USA (0.5 – 0.8)	-	Hewajulige and Wijesundera (2014); CABI (2022); Farr and Rossman (2022)
	Dypsis decaryi	triangle palm	China (0.4 – 0.8)	-	CABI (2022); Farr and Rossman (2022)
	Elaeis guineesis	oil palm	Benin (0.4 – 0.5), Brazil (0.4 – 0.6), Cameroon (0.3 – 0.6), China (0.4 – 0.8), Colombia (0.3 – 0.5), Congo (0.5 – 0.6), Cote d'Ivoire (0.5), DRC (0.5 – 0.6), Ghana (0.4 – 0.5), Indonesia* (0.4 – 0.6), Malaysia* (0.4 – 0.5), Nigeria (0.4 – 0.5), Sierra Leone (0.3 – 0.4), Thailand* (0.3 – 0.5)	-	Hewajulige and Wijesundera (2014); CABI (2022); Farr and Rossman (2022)
	Howea forsteriana	paradise palm	Italy (0.8 – 0.9)	-	CABI (2022)
	Phoenix dactylifera	date palm	Egypt (0.4 – 0.5), India (0.4 – 0.5), Japan (0.6 – 0.8), Kuwait (0.4), Libya (0.4 – 0.5), Qatar (0.3 – 0.4), Spain (0.8 – 0.9), USA (0.5 – 0.8)	-	CABI (2022); Farr and Rossman (2022)

	Roystonea regia	royal palm	Dominican Republic (0.5 – 0.7), Mauritius (–)	-	Farr and Rossman (2022)
	Sabal palmetto	sabal	USA (0.5 – 0.8)	-	Farr and Rossman (2022)
	Salacca zalacca	salak	Indonesia* (0.4 – 0.6), Thailand* (0.3 – 0.5)	-	CABI (2022); Farr and Rossman (2022)
Asphodelaceae	*Hemerocallis* sp.	-	USA (0.5 – 0.8)	-	Farr and Rossman (2022)
Asteraceae	*Lactuca sativa*	lettuce	Mauritius (–)	Domestic $43 million Export $0.7 million	Farr and Rossman (2022)
Bromeliaceae	*Ananas comosus*	pineapple	Australia* (0.4 – 1), Brazil (0.4 – 0.6), Cambodia (0.3 – 0.4), China (0.4 – 0.8), Cook Islands* (–), Costa Rica* (0.3 – 0.6), Cuba (0.5), Dominican Republic (0.5 – 0.7), France (0.9), Fiji* (0.4), French Guiana (0.4), Ghana (0.4 – 0.5), Guyana (0.4 – 0.5), India (0.4 – 0.5), Indonesia* (0.4 – 0.6), Jamaica (0.6) Japan (0.6 – 0.8), Kenya (0.4 – 0.8), Malaysia* (0.4 – 0.5), Mexico (0.4 – 0.8), New Caledonia* (0.6 – 0.7), Papua New Guinea* (0.4 – 0.7), Philippines* (0.3 – 0.6), Tonga* (–), Singapore (0.5), South Africa (0.5 – 0.9), Sri Lanka* (0.4 – 0.6), Suriname (0.4 – 0.5), Taiwan* (0.4 – 0.8), Tanzania (0.5 – 0.7), Thailand* (0.3 – 0.5), Trinidad and Tobago (0.5), Venezuela (0.3 – 0.8), West Indies (–), USA (0.5 – 0.8)	--	Wisemer and Bailey (1990); Farr and Rossman (2022)
Caricaceae	*Carica papaya*	papaya	Mexico (0.4 – 0.8), Dominican Republic (0.5 – 0.7)	-	Farr and Rossman (2022)
Convolvulaceae	*Ipomoea batatas*	Kūmara, sweet potato	Malaysia* (0.4 – 0.5), Nigeria (0.4 – 0.5)	Domestic $35 million	Hewajulige and Wijesundera (2014); Farr and Rossman (2022)

Cucurbitaceae	*Cucurbita moschata*	Crookneck pumpkin	Dominican Republic (0.5 – 0.7)	-	Farr and Rossman (2022)
Cupressaceae	*Hesperocyparis macrocarpa*	Monterey cypress	Kenya (0.4 – 0.8)	-	Farr and Rossman (2022)
Cyperaceae	*Eleocharis* sp.	-	China (0.4 – 0.8), Taiwan* (0.4 – 0.8)	-	Farr and Rossman (2022)
Fabaceae	*Glycine max*	soybean	Brazil (0.4 – 0.6)	-	Farr and Rossman (2022)
	Senegalia catechu	Catechu	India (0.4 – 0.5)	-	Farr and Rossman (2022)
Fagaceae	*Fagus sylvatica*	copper beach	England (0.8 – 0.9)	-	Kew (2022)
Malvaceae	*Theobroma cacao*	cocoa	Brazil (0.4 – 0.6), Cameroon (0.3 – 0.6), Ghana (0.4 – 0.5), Jamaica (0.6), Mexico (0.4 – 0.8), Venezuela (0.3 – 0.8)	-	Hewajulige and Wijesundera (2014); CABI (2022); Kew (2022) Farr and Rossman (2022)
Meliaceae	*Sandoricum koetjape*	santol	Malaysia* (0.4 – 0.5)	-	Farr and Rossman (2022)
Moraceae	*Ficus* sp.	figs	USA (0.5 – 0.8)	-	Farr and Rossman (2022)
Musaceae	*Musa* sp.	banana	Australia* (0.4 – 1), Brazil (0.4 – 0.6), China (0.4 – 0.8), Cote d'Ivoire (0.5), El Salvador (0.4 – 0.5), Fiji* (0.4), Haiti (0.5), India (0.4 – 0.5), Jamaica (0.6), Japan (0.6 – 0.8), Mexico (0.4 – 0.8), South Africa (0.5 – 0.9), Taiwan* (0.4 – 0.8), Tanzania (0.5 – 0.7), Thailand* (0.3 – 0.5), Trinidad and Tobago (0.5), Turkey (0.7 – 0.9), USA (0.5 – 0.8), West Indies (–)	-	Hewajulige and Wijesundera (2014); CABI (2022); Farr and Rossman (2022)

Myrtaceae	*Eucalyptus* sp.	eucalyptus	Brazil (0.4 – 0.6)	Overall $41.3 million	Nixon (2015); CABI (2022); Farr and Rossman (2022)
Phyllanthaceae	*Phyllanthus emblica*	Indian gooseberry	Bangladesh (0.3 – 0.4)	-	CABI (2022)
Poaceae	*Saccharum officinarum*	sugarcane	Australia* (0.4 – 1), Brazil (0.4 – 0.6), China (0.4 – 0.8), Colombia (0.4 – 0.5), Costa Rica* (0.3 – 0.6), Cuba (0.5), Dominican Republic (0.5 – 0.7), El Salvador (0.4 – 0.5), Guatemala (0.3 – 0.6), Haiti (0.5), Honduras (0.3 – 0.6), India (0.4 – 0.5), Indonesia* (0.4 – 0.6), Jamaica (0.6), Japan (0.6 – 0.8), Mexico (0.4 – 0.8), Nicaragua (0.4 – 0.6), Panama* (0.4 – 0.5), Papua New Guinea* (0.4 – 0.7), Philippines (0.3 – 0.6), South Africa (0.5 – 0.9), Taiwan* (0.4 – 0.8), Thailand* (0.3 – 0.5), Trinidad and Tobago (0.5), Venezuela (0.3 – 0.8), USA (0.5 – 0.8)	-	Hewajulige and Wijesundera (2014); Apet et al. (2015); CABI (2022); Farr and Rossman (2022)
	Sorghum bicolor	sorghum	India (0.4 – 0.5)	-	Hewajulige and Wijesundera (2014)
	Urochloa dictyoneura	-	Colombia (0.3 – 0.5)	-	Farr and Rossman (2022)
	Zea mays	maize	-	Domestic/ Export $464.2 million	Hewajulige and Wijesundera (2014); CABI (2022)
Rosaceae	*Rosa* sp.	-	Netherlands (0.9)	-	Farr and Rossman (2022)
Rubiaceae	*Coffea* sp.	coffee	Brazil (0.4 – 0.6), Cote d’Ivoire (0.5)	-	CABI (2022); Farr and Rossman (2022)
Solanaceae	*Solanum muricatum*	pepino	-	-	CABI (2022)

	Solanum tuberosum	potato	Fiji* (0.4)	Domestic $942.7 million Export $126.5 million	Hewajulige and Wijesundera (2014); Farr and Rossman (2022)

6 Pest risk assessments on insects: Diptera

6.1 *Bactrocera dorsalis* (Oriental fruit fly)

Bactrocera dorsalis is one of the most destructive insect pests of tropical and subtropical fruits and vegetables. Adult flies lay their eggs beneath the skin of fruits and vegetables. Maggots (fly larvae) hatch from the eggs and feed within the fruit, causing damage and rotting. *Bactrocera dorsalis* has a very broad host range and is highly adaptable to various climates, which has allowed it to spread to temperate areas.

6.1.1 *Taxonomic description*

Scientific name: *Bactrocera dorsalis* (Hendel, 1912)
Order: Diptera **Family:** Tephritidae
Other names: *Bactrocera invadens; Bactrocera papayae, Bactrocera philippinensis; Bactrocera (Bactrocera) variabilis; Bactrocera ferruginea; Strumeta dorsalis; Chaetodacus dorsalis; Chaetodacus ferrugineus; Chaetodacus ferrugineus dorsalis; Chaetodacus ferrugineus okinawanus; Dacus dorsalis; Dacus ferrugineus; Dacus ferrugineus dorsalis; Dacus ferrugineus okinawanus; Dacus (Bactrocera) dorsalis; Dacus (Bactrocera) semifemoralis; Dacus (Bactrocera) vilanensis* (CABI 2022).

Taxonomic notes:
Bactrocera dorsalis (*sensu stricto*) is a member of the Oriental fruit fly *B. dorsalis* species complex (CABI 2022). *Bactrocera dorsalis* was originally treated as a single species, until it was split into several species, with the description of *B. carambolae*, *B. papayae* and *B. philippinensis* (Drew and Hancock 1994). Based on a total evidence approach, Schutze et al. (2015a) synonymised *B. papayae*, *B. invadens* and *B. philippinensis* with *B. dorsalis,* but these names can still be found in numerous publications and internet website resources (Doorenweerd et al. 2018). Schutze at al. (2015a) considered *B. carambolae* to be a valid species, although it is known to hybridise with *B. dorsalis* and genetic evidence suggests that there is historic hybridisation with *B. kandiensis* (Schutze et al. 2015; Susanto et al. 2021). Records of *B. pedestris* (Bezzi) from outside of the Philippines are mostly based on misidentifications of *B. dorsalis* (CABI 2022).

6.1.2 *Hazard identification*

Bactrocera dorsalis is not known to be present in New Zealand.

- There is no entry of *Bactrocera dorsalis* in (NZOR 2022).
- *Bactrocera dorsalis* is a regulated pest for New Zealand (ONZPR (2022).
- *Bactrocera dorsalis* is an unwanted and notifiable pest for New Zealand (ONZPR (2022).
- New Zealand has country freedom status for *B. dorsalis* (MPI 2022a).
- *Bactrocera dorsalis* is one of the targeted fruit fly species in the National Fruit Fly Surveillance Programme in New Zealand (Pather 2019).

Bactrocera dorsalis has the potential to establish and spread in New Zealand.

- *Bactrocera dorsalis* is a highly invasive species (Vargas et al. 2015).

- Some parts of New Zealand (North Island: Northland, Auckland, the Coromandel Peninsula, northern Waikato, and coastal areas south to Cape Turnagain and Foxton) have a suitable climate for the establishment of *B. dorsalis* (Kriticos et al. 2007).
- *Bactrocera dorsalis* has a very broad host range (Liquido et al. 2017), including many plant species present in New Zealand.
- Adult flies have a high dispersal ability (Steiner 1957; Makumbe et al. 2020) and a relatively long lifespan (Christenson and Foote 1960).
- *Bactrocera dorsalis* has a high reproductive rate (Fletcher 1989; Ye and Liu 2007).
- *Bactrocera dorsalis* has multiple overlapping generations (Chen and Ye 2007; Ye and Liu 2007; Han et al. 2011).

Bactrocera dorsalis has the potential to cause harm to New Zealand.

- *Bactrocera dorsalis* has the potential to harm the New Zealand economy.
    - *Bactrocera dorsalis* is likely to cause impacts on many plants of economic importance in New Zealand, especially on apple (Follett et al. 2021), citrus (Kriticos et al. 2007), avocado (Kriticos et al. 2007), and kiwifruit industry (Follett et al. 2019a).
    - The impact on exports, including market access, is likely to be severe (Clarke et al. 2005; Pather 2019).
    - The cost of a biosecurity response to eradicate *B. dorsalis* would be high (MPI 2022) (Kiritani 1998; Cantrell et al. 2002).
- *Bactrocera dorsalis* has the potential to harm the New Zealand environment, as its hosts include plant genera with native New Zealand plant species (Allwood et al. 1999), and have some human health and socio-cultural impacts.

Bactrocera dorsalis is associated with pineapple fruit.

- Adults of *B. dorsalis* can oviposit inside pineapple fruits. Eggs and larvae can be found inside pineapple, and viable adults can emerge from pupae originating from pineapple (Macion et al. 1968; Moquet et al. 2021).
- In laboratory cage tests, *B. dorsalis* could infest half ripe pineapple fruits (interpreted as pre-C4) (Macion et al. 1968).
- In the field, *B. dorsalis* infested pineapple (Moquet et al. 2021). However, the fruits were overripe and potentially damaged (Moquet, personal communication, May 2022).

Given the arguments and evidence above, MPI considers *B. dorsalis* to be a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

6.1.3 *Risk assessment*

6.1.3.1 Biology

The Oriental fruit fly, *B. dorsalis,* is a highly destructive and invasive pest (Vargas et al. 2015). Gravid females lay their eggs beneath the skin of suitable hosts, especially in ripening or ripe fruits and vegetables. The hatching larvae (maggots) feed within the fruit (Christenson and Foote 1960). There are three larval instars, the last of which generally pupates either in or on the soil (Christenson and Foote 1960; Hou et al. 2006; Shi et al. 2017). Pupae maybe able to overwinter (Christenson and Foote 1960), and can also be found on the fruit surface, or in transit in packing material. The adult fly emerges from the puparium. Development is slower under cool conditions (Christenson and Foote 1960; Vargas et al. 1996). The maximum known duration of egg, larval, and pupal stage is respectively 20, 35, and 26 days (Christenson and Foote 1960, Vargas et al. 1996). Developmental times from egg to adult vary from 15 to 81 days (Christenson and Foote 1960; Vargas et al. 1996).

Adult *B. dorsalis* have relatively long lifespan, strongly affected by temperature and diet (Christenson and Foote 1960; Vargas et al. 1984). Adult *B. dorsalis* normally live for one to three months (Vargas et al. 1984), but can survive up to one year in cool mountain locations (Christenson and Foote 1960). Females usually start laying eggs between 8 and 12 days after emergence, and as early as 5 days on particular diets (Christenson and Foote 1960).

Adult *B. dorsalis* are capable of long distance flights, exceeding 40 km (Steiner 1957; Fan et al. 2001). *Bactrocera dorsalis* has a high reproductive rate, with individual females capable of laying more than 1,000 eggs during their lifespan (Ye and Liu 2007); (Shelly 2000). *Bactrocera dorsalis* has multiple overlapping generations, and the adults occur throughout the year (Ye and Liu 2007).

Damage to the fruit

Bactrocera dorsalis females lay eggs inside the host fruit, using their ovipositor to puncture the fruit skin (Xu et al. 2012). After oviposition, darker spots due to necrosis maybe visible around the oviposition puncture mark (CABI 2022). It has also been noted that *B. dorsalis* females opportunistically lay eggs into fruit that is already damaged (Theron et al. 2017). The *B. dorsalis* maggots penetrate the fruit flesh while feeding on the fruit pulp, causing severe damage to the fruit (Tara et al. 2006). Fruits infested with *B. dorsalis* become malformed, and the damage caused by the feeding maggots allows for infection by secondary pathogens. This causes the fruit to rot, and ultimately fall from the plant (Tara et al. 2006).

Geographical distribution

Bactrocera dorsalis is native to Asia, and is now found in at least 65 countries, including parts of America and Oceania, and most of continental Africa (sub-Saharan countries) (CABI 2022).

Table 6.1. Known geographic distribution of *Bactrocera dorsalis*. Information was compiled on 11 March 2022 from CPC (2022) and EPPO (2022). Countries/areas/markets with "*" are only recorded in CPC (2020); countries/areas with "**" are only recorded in EPPO (2022).
Countries/areas/markets in bold are included in the Pineapple IHS project and new markets are underlined.

Continent /Region	Country/area/market
Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Congo -Democratic Republic of the, Cote d'Ivoire, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Senegal, Sudan, Sierra Leone, Sudan, Tanzania (incl. Zanzibar), Togo, Uganda, Zambia, Zimbabwe
Asia	Bangladesh, Bhutan, Brunei, Cambodia, China (Anhui, Chongqing, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hubei, Hunan, Jiangsu, Jiangxi, Shanghai, Sichuan, Tibet, Yunnan, Zhejiang, Hong Kong), Timor-Leste, India, **Indonesia**, Laos, Macau, **Malaysia**, Myanmar, Nepal, Oman, Pakistan, **The**

	Philippines, Singapore, **Sri Lanka**, **Taiwan**, **Thailand**, United Arab Emirates, Vietnam
North America	United States (California[1], Hawaii)
South America	Guyana[2]*
Oceania	**Australia**[3]**, Christmas Island, French Polynesia, Palau, **Papua New Guinea**, Timor-Leste

1.Present, transient under eradication
2.Absent (from French Guyana) according to EPPO 2022
3. Present in Queensland, transient under eradication according to EPPO 2022

Hosts

Bactrocera dorsalis has a very broad host range, encompassing hundreds of fruiting plant species. The Oriental fruit fly was reported to be associated with a total of 632 plant taxa (Liquido et al. 2017). Of these, 481 taxa, belonging to 212 genera in 79 families, had validated records of infestation under natural field conditions in 2017 (Liquido et al. 2017). The plant families with the most taxa reported as hosts of *B. dorsalis* are the fig family (Moraceae; 38 taxa), the citrus family (Rutaceae; 37 taxa), the tomato family (Solanaceae; 33 taxa), and the squash family (Cucurbitaceae; 29 taxa) (Liquido et al. 2017).
Different fruit host species and varieties can be classified as more or less “suitable” based on the abundance of fly adults that can emerge from them (Follett et al. 2021). Follett (2021) proposed a host suitability index (HSI) for fruit flies. The HSI is a categorical index, based on the logarithmic number of adult fruit flies that can emerge from a given fruit host. Hosts are defined as “very poor, poor, moderately good, good, very good host”. At equal weight, a “moderately good host” can be infested by 10 to 100 times more fruit flies than a “poor” host (1-10 vs 0.1-1 adult fruit flies per kg of fruit respectively (Follett et al. 2021). For example, pawpaw (*Carica papaya*, Caricaceae) is a “very good” host of *B. dorsalis* (Table A2, Appendix) (Follett et al. 2021). Intact pawpaw fruits exposed to gravid *B. dorsalis* could produce more than 1000 adult flies per kg of fruit (Follett et al. 2021).

Pineapple host status

CPC (2022) does not list *A. comosus* as a host for *B. dorsalis* (CABI 2022). EPPO (2022) lists *A. comosus* as a doubtful host for *B. dorsalis* (EPPO 2022). Australia does not require any measures against *B. dorsalis* on pineapples from Taiwan (assessed 2019) or Malaysia (assessed 2012), and the IRAs are for all cultivars/varieties of commercially-produced decrowned pineapple. On the other hand, *B. dorsalis* was considered having high likelihood of introduction by USDA RA pineapples from Indonesia (2019).

There is no conclusive evidence that pineapple is a “natural host” (*sensu* ISPM 37) **of *B. dorsalis*.** A natural host is defined as “A plant species or cultivar that has been scientifically found to be infested by the target fruit fly species under natural conditions and able to sustain its development to viable adults” (ISPM 2016). ‘‘Fruit sampling is the most reliable method to determine natural host status. The status of a natural host can be determined on the basis of confirmation of natural infestation and development to viable adults by sampling fruit **during the harvest period**” (ISPM 2016).

There is only recent field evidence (Moquet et al. 2021) suggesting that *A. comosus* could be a natural host (*sensu* ISPM 37) of *B. dorsalis*. *Ananas comosus* was reported as a new host association for *B. dorsalis* in 2021 (Moquet et al. 2021). Moquet et al. (2021) conducted fruit sampling in Réunion Island (politically a French region, in the Indian Ocean) and found pineapples infested by *B. dorsalis* (Moquet et al. 2021). This provides some evidence that pineapple can be a natural host of *B. dorsalis* because "the fruit has been scientifically found to be infested by the fruit fly under natural conditions and able to sustain its development to viable adults" (ISPM 2016). However, this evidence is not conclusive, because Moquet et al. **collected pineapples seemingly past their commercial harvest period that may have been damaged.** In fact, Moquet (pers. comm.) described the infested pineapples as "very ripe", totally yellow, "C4" as per the UNECE Standard on the marketing and commercial quality control of pineapples, and hence "overripe" (UN 2013). "Fruits were randomly collected regardless of the presence or absence of potential punctures" (Moquet et al. 2021), and the possibility that the infested pineapples were damaged cannot be ruled out (Moquet, pers. comm.).

There is no evidence that pineapple is a "conditional host" (*sensu* ISPM 37) **of *B. dorsalis*.** A conditional host is defined as "A plant species or cultivar that is not a natural host but has been scientifically demonstrated to be infested by the target fruit fly species and able to sustain its development to viable adults as concluded from the semi-natural field conditions set out in this standard" i.e. in field or laboratory trials where the fruit is still attached to the tree (ISPM 2016).

In a laboratory study, *B. dorsalis* oviposited in **half or ¾ ripe whole pineapple fruits (interpreted as pre-C4)** of different varieties, **including "Smooth Cayenne"** (Macion et al. 1968). Macion et al. (1968) performed non-choice cage tests, exposing pineapple fruits to 100-10,000 fruit flies. Healthy fly adults emerged from the pupae recovered from these pineapples (Macion et al. 1968). In Macion et al's study, the fruits were intact, but detached from the plant, and their infestation does not meet the requirements to define pineapple a conditional host. "Artificial conditions are inherent in laboratory tests in which fruit flies are presented with harvested fruit that undergoes rapid physiological changes and thereby may become more susceptible to infestation. The detection of infestation in laboratory tests for the determination of host status may therefore be misleading. In addition, it has been widely documented that under artificial conditions, females of polyphagous species will lay eggs in almost any fruit presented to them and, in most cases, the larvae will develop into viable adults. Therefore, laboratory tests may be sufficient for demonstrating non-host status, but are inappropriate for demonstrating natural or conditional host status." (ISPM 2016).

Pineapple cannot be defined a "non host" (*sensu* ISPM 37) **of *B. dorsalis***, because the Oriental fruit fly can successfully infest pineapple, in natural and artificial conditions (Macion et al. 1968; Moquet et al. 2021).

Pineapple can be defined a "poor" host of *B. dorsalis*, because only few adults can emerge from infested pineapples (Follett et al. 2021). Moquet et al. collected 13 pineapples of the Victoria (Queen) variety. Three fruits (23.1%) were infested, and 1.5 adult flies per kg of pineapple emerged (Moquet et al. 2021). Based on this information, pineapples of the Victoria variety can be defined as poor/moderately good hosts of *B. dorsalis*, sensu Follett (Follett et al. 2021). Moquet et al. (2021) reported that *B. dorsalis* exploited pineapple as a new host following a niche shift in La Réunion island, linked to competition with other fruitfly species (Moquet et al. 2021).

Pineapples are not immune from *B. dorsalis* attacks, but they are resistant. Pineapples have physical and chemical defences against fruit flies. Pineapples have a hard fruit skin and are firm (15.1-2.4 kg/cm^2 (Rao et al. 2021), vs e.g. mango 1.1 -0.1 kg/cm^2 (Rattanapun et al. 2009)). As with other fruit flies, *B. dorsalis* frequently oviposit and develop in non-intact fruits (Follett et al. 2021), and prefer softer, ripe fruits (Seo et al. 1982; Rattanapun et al. 2009). Pineapples have high liquid content, and even when *B. dorsalis* can puncture the fruit skin and oviposit, the eggs are flooded and fail to hatch (Macion et al. 1968). *Bactrocera dorsalis* laid most eggs in the pineapple fruit flesh (ca 75%) and surface (ca 13%), and a small minority (3.0-5.4%) of these hatched (Macion et al. 1968). However, *B. dorsalis* laid the other eggs in the thick of the fruit skin (or shell, 12%), and most shell-laid eggs (52.0-78.6%) hatched. Pineapples might also have strong chemical defences against *B. dorsalis*. The phenolic contents in pineapple were reported to be the highest among fruits (117.75 mg GAE/100 g FW) (Rasheed et al. 2012). Among mango varieties, those resistant to *B. dorsalis* have higher phenolic contents (Verghese et al. 2012). Phenols are toxic to the maggots of another tephritid, *Rhagoletis pomonella* (Rattanapun et al. 2009), and high phenol content in fruit is associated with resistance to other fruit flies such as *Anastrepha fraterculus* and *Ceratitis capitata* (Oroño et al. 2019).

Pineapple variety susceptibility

In the laboratory, whole fruits of six varieties, including "Smooth Cayenne" and five unknown varieties, were infested by *B. dorsalis* (Macion et al. 1968).

In the field, the only variety of pineapple found infested by *B. dorsalis* was ("Queen") "Victoria" (Moquet et al. 2021). In previous field infestation testing, pineapples were not infested (Flitters et al. 1953; Armstrong and Jang 1997).

Early work from Hawaii on several varieties of pineapple (i.e., Smooth Cayenne, 59.443, D-10, D-20, 59-656) showed that export grade fruits of *A. comosus* are not hosts for *B. dorsalis* when harvested at green or colour break ripeness. Field-grown and harvested fruit from the island of Lanai did not produce any larvae or pupae of *B. dorsalis* despite there being adults in the fields and surrounding areas (Seo et al. 1973; Armstrong et al. 1979; Armstrong and Vargas 1982).

An assessment of 610 export grade pineapples (variety 59.443) harvested from the field on the island of Lanai, Hawaii, resulted in zero larvae or pupae being recovered (Seo et al. 1973). This was despite *B. dorsalis* being present in the the field and increasing in number during the harvesting period (Seo et al. 1973). The pineapples were harvested when green or at the colour break stage (Seo et al. 1973).

No *B. dorsalis* emerged from export grade pineapples (varieties Smooth Cayenne, D-10 and D-20) harvested from the island of Lanai, Hawaii, when assessing 521, 503 and 571 of each variety (Armstrong et al. 1979). The pineapples were harvested at green or colour break ripeness (Armstrong et al. 1979).

Using 500 pineapples of variety 59-656 harvested from the field on the island of Lanai, Hawaii, no *B. dorsalis* emerged (Armstrong and Vargas 1982). The pineapples were harvested when green or at colour break (Armstrong and Vargas 1982).

MPI has considered "Smooth Cayenne" pineapple resistant to *B. dorsalis*. "The scientific evidence strongly suggests that pineapple varieties with ⩾50% Smooth Cayenne genetic parentage are non-hosts of fruit flies of economic significance, including *B. cucurbitae*, *B. dorsalis* and *C. capitata*" (MPI 2014)". "This non-host status has been demonstrated using field infestation testing (Flitters et al. 1953; Armstrong and Jang 1997)". "MPI agreed that pineapple varieties with ≥50% Smooth Cayenne genetic parentage are non-hosts of fruit fly species of economic significance in Australia (MAF/DAFF 2004)" (MPI 2014). The pineapple varieties Smooth Cayenne, Aus-Jubilee (75% Smooth Cayenne parentage), MD2 (50% Smooth Cayenne parentage), and 73-50 (50% Smooth Cayenne parentage) were given "non-host" status for pineapple varieties imported from Australia to New Zealand (MPI 2014).

6.1.3.2 Likelihood of entry

***Bactrocera dorsalis* is very unlikely to be associated with the commodity.**

There is clear evidence that pineapple is a resistant and poor host for *B. dorsalis* (refer to pineapple host status in section 1.1.5.1). The Oriental fruit fly can infest pineapples when other more suitable fruit hosts are not an option (Macion et al. 1968; Moquet et al. 2021), and can infest pineapple fruits of different varieties and in a pre-harvest stage of ripeness in no-choice cage experiments (Macion et al. 1968). The only evidence of infestation in the field comes from overripe pineapples (not meeting the commodity description) (Moquet et al. 2021). Pineapple cannot be strictly defined as a "natural host", a "conditional host", or a "non-host", referring to the ISPM 37 definitions.

Since 1929 and to this date (14/04/2022), there have been no interceptions of *B. dorsalis* on pineapples imported in New Zealand. This includes historical pineapple imports from two countries where *B. dorsalis* is native and that are within the scope of this risk assessment, the Philippines and Thailand. There is no record in the EPPO non-compliance database for detections of *B. dorsalis* on pineapple in the EU (EPPO 2022).

Bactrocera dorsalis entered New Zealand on fresh produce other than pineapple from pineapple exporting countries. Between 2000 and 2020, *B. dorsalis* has been intercepted and identified (as "*B. dorsalis*" or "*B. dorsalis complex*") 76 times at the New Zealand border, mostly consignments from India (LIMS). In 15 of these interceptions, *B. dorsalis* was found associated with consignments from the Philippines and Thailand (LIMS). *Bactrocera dorsalis* was intercepted from these two countries on fruit hosts other than pineapple. *Bactrocera dorsalis* was also intercepted in consignments originating from Sri Lanka (six interceptions) and Indonesia (two interceptions). Sri Lanka and Indonesia are included in this IRA as new market access for pineapple (Table A2, Appendix). These interception records must be considered underestimates of the actual number of individuals and instances when *B. dorsalis* entered New Zealand.

New Zealand imports and is likely to keep importing mostly Smooth Cayenne pineapple varieties. No evidence could be found that Smooth Cayenne pineapples can be infested in the field, and MPI has considered these varieties non-hosts (MPI 2014). Historically, New Zealand has imported five pineapple varieties (Smooth Cayenne, Ripley Queen, Viamama, Queen Tahiti and Queen) of fresh pineapples from seven countries (Australia, Ecuador, Fiji, New Caledonia, the Philippines, Thailand and Vanuatu). The vast majority of pineapples (87% of volume) have been imported from the Philippines (MPI 2022b). The Philippines will be exporting to New Zealand Smooth Cayenne variety pineapples (MPI 2022b).

B. dorsalis is present in seven pineapple exporting markets within the scope of this IRA: Indonesia, Malaysia, the Philippines, Sri Lanka, Taiwan, Thailand, Papua New Guinea (CABI 2022; EPPO 2022), and transient and under eradication in Queensland, Australia (EPPO 2022) (Table 1). *Bactrocera dorsalis* is likely common in five new market access markets (Table 1), and this increases the likelihood of accidental introduction.

Bactrocera dorsalis shows resistance to infield insecticide usage. Wei et al. (2019) reported that due to long and highly frequent applications of certain chemicals, *B. dorsalis* has developed high levels of insecticide resistance (Wei et al. 2019). For example, *B. dorsalis* populations with a high level of resistance to trichlorphon, β-cypermethrin, and avermectin were detected in mainland China (Jin et al. 2011). More recently, resistance to malathion, trichlorfon, and cyantraniliprole has been reported (Zhang et al. 2014; Chen et al. 2015; Wang et al. 2015).

Infestation symptoms may not be visible unless the fruit is cut in half, and even when the fruit is cut. *Bactrocera dorsalis* infestations may be visually detectable in the field and/or packhouses, leading to the removal of some infested produce. Oviposition of *B. dorsalis* may cause necrosis around the puncture mark, followed by decomposition of the fruit (CABI 2022). If culling is adopted by the export markets, the practice is likely to reduce the risk to some extent, as shown in citrus (Xia et al. 2019). However, it is highly likely that infested fruits will not be detected. Fruits with a low level of infestation (fewer oviposition punctures) may not be obvious enough to be detected during general handling, especially if the volume of commodities is large. Pineapples have epicarps with uneven colour and complex texture. Flies' puncture marks might be more difficult to detect on pineapple than on other fruits such as citrus. Eggs of *B. dorsalis* are laid under the skin of the ripened or ripening fruits and the maggots feed inside the fruits (Ye and Liu 2007). Since general handling after harvesting treats the fruits' surface only, it is not effective in removing *B. dorsalis* maggots that may be present inside pineapple fruits. Fruits will need to be cut open to reveal the maggots of *B. dorsalis* inside, and eggs are harder to detect. Even when fruit is cut open, the rate of detection of infestations can be very low (Gould 1995). According to Gould (1995), the probability of detecting the larvae of the Caribbean fruit fly, *Anastrepha suspensa* by fruit cutting ranged from 1 to 36%, whereas the probability of detecting infested fruits ranged from 17.0 to 83.5% (Gould 1995). The interception records of *B. dorsalis* also show that some infested fruits cannot be detected during general handling after harvest.

Bactrocera dorsalis is likely to survive transit (refer to the transit conditions section). Between 2000 and 2020, *B. dorsalis* has been intercepted and identified 76 times at the New Zealand border (LIMS). Most *B. dorsalis* interception records (84%) reported two or more individuals, and in one case, more than 50 maggots were found associated with a mango consignment from Sri Lanka (LIMS) (Table A3, Appendix). In 73 cases, the viability of the individual or individuals intercepted was recorded. In most cases, *B. dorsalis* was alive. Eggs, maggots, pupae, and adults of *B. dorsalis* have been intercepted alive at the New Zealand border (LIMS) (Table A4, Appendix).

Uncertainty

Based on the above evidence, there is low uncertainty on the very low likelihood of *Bactrocera dorsalis* entering New Zealand in association with the commodity. There is evidence in multiple references and data supporting the view that pineapples are resistant to *B. dorsalis*. The few references reporting pineapple fruits infested show that pineapple is a "poor host" for *B. dorsalis*. Only one field study (Moquet et al. 2021) suggested that pineapple could be a "natural host" for *B. dorsalis.* However, personal communication with the main author of the study provided evidence that the fruits infested by *B. dorsalis* did not meet the commodity description (the fruits were past the harvesting stage (all yellow) and overripe, and damage was not visible but possible). On the other hand, fruits meeting the commodity description could be infested in the laboratory (Macion et al. 1968). There is strong evidence in multiple references and data supporting the view that if pineapple fruits were infested by *B. dorsalis*, the fruitfly could enter New Zealand.

Given that:

- *Bactrocera dorsalis* is very unlikely to be associated with the commodity;
- *Bactrocera dorsalis* is present in seven pineapple exporting markets in this IRA;
- Infestation symptoms may not be visible unless the fruit is cut in half, and even when the fruit is cut;
- *Bactrocera dorsalis* is likely to survive transit;
- *Bactrocera dorsalis* shows resistance to infield insecticide usage;

MPI considers that the likelihood of *Bactrocera dorsalis* entering New Zealand associated with pineapple fruit is VERY LOW, with LOW uncertainty.

6.1.3.3 Likelihood of exposure

This assesses the likelihood of B. dorsalis *transferring to a suitable host plant* ***if*** *it enters New Zealand undetected.*

Bactrocera dorsalis can survive and develop on the waste of pineapple fruit, which will be partially disposed of using high-risk methods. If pineapple fruits are disposed of as whole fruit, fruit pieces or fruit peel waste after consumption, it is likely that *B. dorsalis* can survive in this waste. Most food waste in New Zealand is disposed of using low-risk methods (bagged waste into landfill or into kitchen disposal units), so *B. dorsalis* would either be killed or unable to escape from the imported fruit or fruit waste to find a new host (see waste analysis in background information document). However, some waste is disposed of using high-risk methods, including composting waste in home gardens and using waste as animal feed.

Bactrocera dorsalis has a very broad host range. Therefore, it is likely to find a suitable host. Many hosts are widely distributed in New Zealand and are commercially grown and/or commonly found in home gardens. These include apple (*Malus domestica*), apricot (*Prunus armeniaca*), avocado (*Persea americana*), capsicum (*Capsicum annuum*), citrus (*Citrus spp.*), cucumber (*Cucumis sativus*), grapevine (*Vitis vinifera*), guava (*Psidium guajava*), loquat (*Eriobotrya japonica*), peach (*Prunus persica*), pear (*Pyrus* spp.), persimmon (*Diospyros kaki*), plum (*Prunus domestica*) and kiwifruit (*Actinidia deliciosa*) (CABI 2022). If hosts are not far from the composting site or animal feeding site (see waste analysis in background information document), adult *B. dorsalis* are very likely to locate a new host. Since the adult is highly mobile, hosts distant from the waste disposal site could also be located.

Adult *B. dorsalis* are capable of long-distance flights, and this increases their likelihood of locating a suitable host. Weldon et al. (2014) reviewed previous studies and reported mean dispersal distances recorded for *B. dorsalis* in mark–release–recapture studies range from 1 km to 3.6 km. The dispersal ability of *B. dorsalis* seems superior to that of other *Bactrocera* species, which have mean dispersal distances well under 1 km (Weldon et al. 2014).
In the field (mark, release, and recapture studies in Hawaii), one *B. dorsalis* male was recovered 38.6 km away from its release point, and many other males were captured far away from breeding sites, even at 1,100 m of altitude (Steiner 1957). In another study, 1,917 flies

were recaptured (Froerer et al. 2010). Seven flies covered a distance of more than 10 km within one day (Froerer et al. 2010). However, the vast majority of the flies (98.5%) were recaptured within 2 km from the release point (Froerer et al. 2010). In the laboratory (flight-mill system), individual *B. dorsalis* could cover 46 km in flight (Fan et al. 2001), and up to 15 km in one hour (Makumbe et al. 2020).

Adult *B. dorsalis* have relatively long lifespan, usually one to three months but up to a year. The longevity of *B. dorsalis* adults increases the likelihood of locating a suitable host.

Uncertainty
The level of uncertainty associated with the conclusion is low. There is strong evidence in multiple references that the biological characteristics of *B. dorsalis* favour its exposure.
It is unknown what proportion of composting sites are exposed or enclosed (see waste analysis in background information document). Moreover, It is unknown how frequently suitable hosts will be present near composting sites in gardens or animal feeding locations.

Given that:

- *Bactrocera dorsalis* can survive and develop on pineapple fruit waste, some of which will be disposed of using high-risk methods;
- *Bactrocera dorsalis* has a very broad host range. Many hosts are widely distributed in New Zealand, and are commercially grown and/or commonly found in home gardens;
- Adult *B. dorsalis* are capable of long-distance flights;
- As flies, adult *B. dorsalis* have relatively long lifespans;

MPI considers the likelihood of *Bactrocera dorsalis* becoming exposed to a suitable host in New Zealand from pineapple fruit to be HIGH, with LOW uncertainty.

6.1.3.4 Likelihood of establishment

This assesses the likelihood of B. dorsalis *establishing a population in New Zealand if it is successfully exposed to a suitable host plant in the New Zealand environment.*

Bactrocera dorsalis is a highly invasive species. The fly is native to Asia, but is now found in parts of America, Africa and Oceania. It is a serious pest of a wide range of fruit crops throughout its native and introduced range (CABI 2022).

Bactrocera dorsalis has a very broad host range. Therefore, host availability is unlikely to be a limiting factor for it to establish in New Zealand. The Oriental fruit fly is associated with hundreds of plant species (Liquido et al. 2017). Many hosts are commercially grown and commonly found in home gardens and parks, such as apple, apricot, avocado, capsicum, citrus, cucumber, grapevine, guava, loquat, peach, pear, persimmon and plum. Therefore, hosts are likely to be available in all seasons and present in most areas in New Zealand.

The New Zealand climate is suitable for *B. dorsalis* to establish in the North Island. *Bactrocera dorsalis* is native to Asia, and its current distribution is predominantly in the tropics and subtropics (Table 2). The current distribution includes some countries and areas with composite match indices (CMIs with all of New Zealand, here and below) (Phillips et al. 2018) of 0.7–0.8 (Phillips et al. 2018). These areas include Himachal Pradesh in India (CMI:

0.7–0.8), Anhui, Chongqing, Guizhou, Hubei, Hunan, Jiangsu, Shanghai, Yunnan, Zhejiang in China (CMI: 0.7) and Sichuan in China (CMI: 0.8). This suggests that *B. dorsalis*, or some populations of the species, can adapt to a colder temperate climate.

A modelling study indicates that many areas of New Zealand are likely to be suitable for the establishment and short-term population occurrence of *B. dorsalis* (Kriticos et al. 2007). A CLIMEX™ model indicates that under the reference climate (1961–1990), *B. dorsalis* could establish throughout much of the low-lying areas of the North Island, and most parts of New Zealand could support short-term populations during the summer months (Kriticos et al. 2007). The predicted temperature increase in the next 10–20 years (IPCC 2022) will increase the likelihood of establishment and increase the areas where *B. dorsalis* can establish long-term populations. Under current climate, *B. dorsalis* is projected to be capable of establishing permanent populations throughout Northland, Auckland, the Coromandel Peninsula, northern Waikato and in coastal areas south to Cape Turnagain and Foxton (Kriticos et al. 2007). Current climatic conditions are projected to be unsuitable for the establishment of *B. dorsalis* in the South Island (Kriticos et al. 2007). Under the future climate scenarios, the area of New Zealand projected to be climatically suitable for *B. dorsalis* increased to cover all of the lowland regions in the North Island and the warmer parts of the South Island (Kriticos et al. 2007).

Bactrocera dorsalis has a strong dispersal ability, being capable of long-distance flights. Beyond its natural dispersal ability, *B. dorsalis* could disperse via unintentional transport. Eggs and maggots of *B. dorsalis* are inside the fruit and unlikely to be visible. Therefore, transporting infested fruit is a major means by which the fruit fly can spread to areas that were not infested previously (Liebhold et al. 2006).

Bactrocera dorsalis has multiple overlapping generations. The number of generations per year and occurrence of *B. dorsalis* differ throughout its geographic distribution, but in general, *B. dorsalis* has 3–5 overlapping generations per year in most tropical areas in its distribution and may reach 10 generations per year under optimal conditions (Ye and Liu 2007). In Xishuangbana, Yunan, China (CMI: 0.6), *B. dorsalis* is present all year round (Ye and Liu 2007), while in Baoshanba, Yunan (CMI: 0.7–0.8), *B. dorsalis* occurs during April–November with the population peak in August (Chen and Ye 2007). In Hubei, China (CMI: 0.7), where the typical climate is hot and wet in summer and freezing cold in winter, five generations per year were observed (Han et al. 2011).

Bactrocera dorsalis shows high genetic variability, and this may facilitate the adaptation to a new habitat during invasion. Female *B. dorsalis* mate with multiple males (Prastiti et al. 2020). Such polyandry implies high genetic variability and that even if sperm reserves were depleted, the female could find other males and resume egg-laying (Shelly 2000). High genetic diversity within the *B. dorsalis* population was observed in its native range, and multiple introductions and hybridisation among related populations and species in the introduced range may further enhance genetic diversity (Aketarawong et al. 2007; Wan et al. 2012).

Bactrocera dorsalis has a high reproductive rate. The females of *B. dorsalis* can lay 3–30 eggs in each oviposition event (Fletcher 1989). One female can lay more than 1,000 eggs during her lifespan (Shelly 2000; Ye and Liu 2007).

Female *B. dorsalis* can release sex pheromones to attract males (Shen et al. 2019), and this increases the probability of females finding mates. Males also release a mating pheromone synthesised by *Bacillus* bacteria that influences female attraction and mate selection (Ren et al. 2021), which is made more attractive when *Bactrocera* males feed on sources of the phenylpropanoid, methyl eugenol (Wee et al. 2007). Methyl eugenol has several natural sources including numerous common garden plants (Tan and Nishida 2012).

The current National Fruit Fly Surveillance Programme reduces the likelihood of *B. dorsalis* establishing in New Zealand. *Bactrocera dorsalis* is one of the targeted fruit fly species in this surveillance programme (Pather 2019), and early detection and eradication of incipient populations is very likely. Since sexually mature male *B. dorsalis* are attracted to the parapheromone methyl eugenol (Tan and Nishida 2012), traps baited with this are effective for its trapping (Shen et al. 2019; Stringer et al. 2019). Eradication programmes for *B. dorsalis* call for the use of male annihilation technique using spot applications of insecticide mixed with methyl eugenol (Manrakhan 2020). In New Zealand, the surveillance for fruit flies uses trimedlure, cuelure and methyl eugenol as lures (Stringer et al. 2019). An analysis of 211 eradication or emergency response programs against 17 species of fruit flies in 31 countries indicated that the failure rate for fruit fly eradication programs was low globally (about 7%; (McInnis et al. 2017)), and NZ has a 100% success rate in eradicating tephritid incursions (Clarke 2019).

Uncertainty

The level of uncertainty associated with the conclusion is low. There is strong evidence in multiple references that the biological characteristics of *B. dorsalis* favour its establishment. There is evidence that the current national surveillance programme is likely to detect *B. dorsalis* incursions, and reduce the likelihood of *B. dorsalis* establishment in New Zealand. There is uncertainty around the suitability of all of New Zealand's climate for the establishment of long-term populations of *B. dorsalis*.

Given that:

- *Bactrocera dorsalis* is a highly invasive species;
- *Bactrocera dorsalis* has a very broad host range and, therefore, host availability is unlikely to be a limiting factor for it to establish in New Zealand;
- Parts of New Zealand have a climate that is suitable for the establishment of *B. dorsalis*;
- *Bactrocera dorsalis* has a strong dispersal ability;
- *Bactrocera dorsalis* has a high reproductive rate;
- *Bactrocera dorsalis* has multiple overlapping generations in both warmer and colder climates;
- The current national surveillance programme is likely to reduce the likelihood of *B. dorsalis* establishing in New Zealand;

MPI considers the likelihood of *Bactrocera dorsalis* establishing in New Zealand is MODERATE, with LOW uncertainty.

6.1.3.5 Impacts in New Zealand

This assessment is made on the assumption that B. dorsalis *has successfully established in the New Zealand environment.*

Economic impacts
New Zealand's freedom from pest fruit flies is a key feature enabling horticultural exports. Independent of direct damage, an incursion of *B. dorsalis* would have severe impacts on exports, including market access. *Bactrocera dorsalis* is of quarantine significance to EPPO (European Plant Protection Organization), APPPC (Asia and Pacific Plant Protection Commission), COSAV (Comité de Sanidad Vegetal del Cono Sur), CPPC (Caribbean Plant Protection Commission), IAPSC (Inter-African Phytosanitary Council) and OIRSA (Organismo Internacional Regional de Sanidad Agropecuaria) countries (CABI 2022). Detection of a fruit fly in the surveillance programme would be reported internationally and would be expected to result in reduced market access for New Zealand host materials, at least temporarily. Drew (1997) estimated that the incursion of *B. dorsalis* (reported as *B. papayae*) in north Queensland caused losses of nearly AU$100m, mostly due to loss of market access (Clarke et al. 2005). If *B. dorsalis* established, New Zealand would lose its pest-free status.

Bactrocera dorsalis is a devastating pest of a wide variety of fruits and vegetables throughout its range and damage levels can be up to 100% of unprotected fruit (CABI 2022). In Yunnan (CMI: 0.7), China, infestation rates by *B. dorsalis* of over 30% have been reported on mango (Yongsheng et al. 1996). In Sichuan (CMI: 0.8), infestations of *B. dorsalis* occur on pears, apple, mango, peach and guava. Infestation level of fruits is usually 20% but can be as high as 50% (Zhang and Zhao 1994). In Hubei (CMI: 0.7), *B. dorsalis* change feeding patterns depending on host availability. In a survey in the area, maggots were first found in pear fruits, following by jujube fruits and persimmons. The most serious damage occurred in the fourth generation in citrus orchards (Han et al. 2011).

Bactrocera dorsalis is likely to cause impacts on many plants of major economic importance in New Zealand, especially on apple, citrus, and avocado industries, but also on the kiwifruit industry. In New Zealand, 80% of horticultural export value came from plants that are potential fruit-fly hosts (Pather 2019). The export value of New Zealand’s horticultural industry was NZ$3.7b in 2020 (Plant and Food Research 2020). The industry has grown over time, and with it, the potential impact of a *B. dorsalis* incursion or invasion. From 2019 to 2020, reported fresh fruit export earnings have increased by 8%, with key categories including kiwifruit (10% on 2019), apples (6%) and avocado (8%) (Plant&FoodResearch 2020). The main hosts of *B. dorsalis* commercially grown in New Zealand include, but are not limited to: apple, apricot, avocado, capsicum, citrus, cucumber, grapevine, peach, pear, persimmon and plum (CABI 2022; EPPO 2022). Apples, pears, and peaches grown in areas with similar climate to New Zealand were severely damaged by infestations of *B. dorsalis* (Zhang and Zhao 1994; Yongsheng et al. 1996; Han et al. 2011).

Apple can be classified as a good ovipositional host for *B. dorsalis* (Follett et al. 2021). Follet et al. (2019, 2021) evaluated fruit host suitability for *B dorsalis*, reporting on field and laboratory screen cage tests. Fruits were exposed to gravid fruit fly females for 24 h, and then held in the laboratory for four weeks for pupal development and adult emergence (Table A1, Appendix) (Follett et al. 2021). Follett et al. (2019) found that *B. dorsalis* could produce 269 puparia per kg in fresh, intact apples (Follett et al. 2019b). Apple is a particularly important horticultural crop for New Zealand, with exports valued at NZ$876m in 2020 (Plant and Food Research 2020).

Kiwifruit can also be infested by *B. dorsalis* (Follett et al. 2019a). However, kiwifruit is a poorer ovipositional host for *B. dorsalis* when compared to fruits such as apple (Follett et al.

2021). The susceptibility of kiwifruit has varietal differences. Gold kiwifruit was classified as a moderately good/good host and green kiwifruit as a poor/moderately good host by Follett et al. (2021). In laboratory studies, *B. dorsalis* could produce an average of 54.7 puparia per kg in intact gold kiwifruit, and 1.3 puparia per kg on intact green kiwifruit (Follett et al. 2019a). Kiwifruit is New Zealand's highest value horticulture export, worth NZ$2534m in 2020 (Plant and Food Research 2020), and making up 38% of total export value (Plant&FoodResearch 2020). Gold kiwifruit accounts for about half of the total production value, and the value of this variety has consistently and substantially grown since its commercialisation (Zespri, in (Plant&FoodResearch 2020)).

Citrus and avocado are considered good hosts and could be seriously impacted. A model developed by Kriticos et al. (2007) suggested that an incursion of *B. dorsalis* in New Zealand could have a major impact on the citrus and avocado industries in particular (Kriticos et al. 2007). Almost all areas where mandarins and avocados are cultivated are in areas projected to be suitable for the establishment of *B. dorsalis* (Kriticos et al. 2007). Avocado is reported as one of the most commonly attacked species (Weems et al. 2012). The sales value (export and domestic) of citrus in New Zealand was NZ$69.7m in 2019 and the value of avocado was NZ$150.7m (Plant and Food Research 2020).

The cost of a biosecurity response to eradicate *B. dorsalis* would be high. In 1996, there was an incursion of *B. dorsalis* in New Zealand (Auckland, single fly detected in a trap, as *B. papayae*). The cost of the response was 0.225m NZD in 1996. The typical cost of fruit fly responses is millions of dollars. For example, the prompt Queensland fruit fly response in 2019 costed approximately NZ$18m (MPI 2022). In Japan, the eradication of *B. dorsalis* from the Ryukyu Islands costed more than 200m euros (Kiritani 1998). The cost for the eradication programme of *B. dorsalis* in northern Queensland (1995-1999) was AU$33m (Cantrell et al. 2002).

If *B. dorsalis* established in New Zealand, additional postharvest disinfestation costs would be necessary. In Australia, apples and citrus fruit undergo a cold treatment for fruit fly at a cost (1996 figures) of approximately AU$200/tonne. Avocados are treated with hot forced air costing approximately AU$125/tonne, and stone fruit, cucurbits and tomatoes are treated with a dimethoate dip which costs approximately AU$100/tonne (MAF 1996).

Uncertainty

The level of uncertainty associated with the conclusion is low. There is strong evidence in multiple references that *B. dorsalis* can impact horticultural industries. The main source of uncertainty is the infestation levels that *B. dorsalis* could achieve in New Zealand orchards and weather conditions.

Given that:

- *Bactrocera dorsalis* is a devastating pest of a wide variety of fruits and vegetables throughout its range, and 20-50% of protected crops can be damaged;
- In New Zealand (2019), 80% of horticultural export value (NZ$3.7b in 2020) came from plants that are potential fruit-fly hosts;
- *Bactrocera dorsalis* is likely to cause impacts on many plants of major economic importance in New Zealand, especially on the apple, citrus, and avocado industries, but also on the kiwifruit industry;

- Independent of direct damage, an incursion of *B. dorsalis* could have high impacts on exports, including market access;
- The cost of a biosecurity response to eradicate *B. dorsalis* would be high;
- If *B. dorsalis* established in New Zealand, additional postharvest disinfestation costs would be necessary;

MPI considers the economic impact of *Bactrocera dorsalis* in New Zealand to be HIGH, with LOW uncertainty.

Environmental impacts

Bactrocera dorsalis hosts include plant genera with native New Zealand plant species. Some of the native species in these genera have “At Risk” or “Threatened” conservation status, including: *Planchonella costata*, *Solanum aviculare* var. *aviculare*, *S. aviculare* var. *latifolium*, *Streblus banksia*, *St. smithii*, and *Syzygium maire*. *Bactrocera dorsalis* has been reported to attack *Syzygium* overseas (Allwood et al. 1999; Liquido et al. 2017). Native *Syzygium maire* could become an alternative host if *B. dorsalis* established near native lowland forest where the tree species predominantly occurs (MAF 2009). However, the magnitude of the impact of *B. dorsalis* on these fruiting plants is likely to be limited. *Bactrocera dorsalis* attacks only the flesh of ripe fruit, and it is unlikely to impair seed development, number or viability.

The use of insecticides to control of invasive *B. dorsalis* populations could have impacts on the environment.

Uncertainty

The level of uncertainty associated with the conclusion is moderate. The main source of uncertainty is the infestations levels that *B. dorsalis* could achieve among New Zealand native plants and in New Zealand climate, and how much impact on the host plant population dynamics it might have.

Given that:

- *Bactrocera dorsalis* hosts include plant genera with native New Zealand plant species;
- The use of insecticides to control of invasive *B. dorsalis* populations could have impacts on the environment;

MPI considers the environmental impact of *Bactrocera dorsalis* in New Zealand is LOW, with MODERATE uncertainty.

Human health impacts

No evidence could be found that *B. dorsalis* can have direct impacts on human health. The use of insecticides to control invasive *B. dorsalis* populations could have indirect impacts on human health. For some insecticides such as spinosad (the toxicant in GF-120 bait sprays), significant impacts would not be expected, given the characteristics of the product. However, other insecticides such as malathion have higher levels of toxicity. According to Salcedo Baca et al. (2010), 5.15 people are negatively affected for every 1,000 litres of insecticide (Salcedo Baca et al. 2010). Malathion is used in New Zealand (Maldison brand). However, impacts are expected to be limited given clear health and safety regulation and assuming high compliance (e.g. prohibiting people from entering areas where Maldison has been applied for

24 hours unless they are wearing full personal protective and respiratory protective equipment) (EPA 2013).
There is a possibility of people consuming infested fruit outside the market, where consumers grow their own fruit. In this case, eating locally produced infested fruit could cause gastrointestinal diseases with abdominal pain and diarrhoea (Chen et al. 2011).

Uncertainty
The level of uncertainty associated with the conclusion is moderate. There is uncertainty about the infestation levels that *B. dorsalis* could achieve, on the degree and type of insecticide usage.

Given that:

- The use of insecticides to control of invasive *B. dorsalis* populations could have impacts on human health;
- The local consumption of infested fruit could cause gastrointestinal diseases;

MPI considers the human health impact of *Bactrocera dorsalis* in New Zealand is VERY LOW, with MODERATE uncertainty.

Sociocultural impacts
Bactrocera dorsalis is damaging in terms of fruit losses or lower quality of fruit. It could damage a number of plants grown in domestic gardens and parks, such as *Vitis* spp., *Prunus* spp., *Citrus* spp. and *Malus* spp. It would be a potential nuisance pest in urban environments if it achieved high densities and e.g. aggregated in houses.

Uncertainty
The level of uncertainty associated with the conclusion is moderate. No study estimating the sociocultural impacts derived from the potential infestation of fruit flies on taonga species could be found. However, the biology of the species suggests that it would have low impacts.

Given that:

- *Bactrocera dorsalis* is damaging to a number of plants grown in domestic gardens and parks

MPI considers the sociocultural impact of *Bactrocera dorsalis* in New Zealand to be LOW, with MODERATE uncertainty.

6.1.3.6 Overall impact to New Zealand

The overall impact of *Bactrocera dorsalis* on the New Zealand economy, environment, health and society is considered to be HIGH, with LOW uncertainty.

6.1.3.7 Overall level of risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is VERY LOW
- assuming entry, the likelihood of exposure is HIGH

- assuming successful exposure, the likelihood of establishment is MODERATE
- the overall impact on the New Zealand economy, environment, human health, and society is considered to be HIGH

MPI considers the overall level of risk to New Zealand from *Bactrocera dorsalis* on pineapple fruit as MODERATE, with LOW uncertainty.

6.1.4 *Specific considerations*

On which pineapple fruit variety (or varieties) and at what stage of ripeness has the association of *B. dorsalis* with pineapple fruit been observed?
In the field, three pineapples of the ("Queen") "Victoria" variety were infested by *B. dorsalis* (Moquet et al. 2021). These pineapples were "overripe" (C4) and potentially damaged, although no damage was noticed (Moquet, pers. comm.). In no-choice cage experiments, *B. dorsalis* infested (undamaged) "Smooth Cayenne" pineapple fruits and other five non specified varieties, half or three quarters ripe (interpreted as pre-C4) (Macion et al. 1968).

Which parts of the pineapple fruit is *B. dorsalis* associated with (e.g. fruit, bract, stem or crown remnant), and is it detectable by visual inspection?
Eggs and maggots of *B. dorsalis* are found inside pineapple fruits (Moquet et al. 2021). When gravid *B. dorsalis* females lay eggs, they puncture the fruit skin with the ovipositor. The oviposition can produce marks on the fruit, but these marks may not be visible (CABI 2022). It is likely that marks on pineapple fruits would not be visible, given the size of the fruit, its uneven colour, and the complex texture of the fruit skin.

Does *B. dorsalis* burrow into the fruit without obvious symptoms?
Maggots of of *B. dorsalis* burrow in the pineapple flesh and they may not be visible (CABI 2022).

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6.1.6 *Appendix to risk assessment of Bactrocera dorsalis*

Table A1

Host Suitability Index (HSI) ranking of fruit hosts based on reports of adult flies emerging from fruit from tree sampling in the field or laboratory cage tests

(Modified from: Follett, P A; Haynes, F E; Dominiak, B C (2021) Host Suitability Index for Polyphagous Tephritid Fruit Flies. Journal of Economic Entomology 114(3): 1021-1034.)

		Average number of fruit fly adults per kilogram of fruit			
***Bactrocera dorsalis* Host**	**Host Suitability Index (HSI) category**	**Field**	**Laboratory**		**Reference**
			Intact fruit	**Punctured fruit**	
Carica papaya (papaya)	Very Good	142	500.8	625	Follett et al. (2019a)
Carica papaya (papaya)	Good/Very Good	11.5	131	315	Follett et al. (2019b)
Mangifera lalijiwa (mango)	Good	87			McQuate et al. (2017)
Hylocereus undatus (dragon fruit)	Good	16			McQuate (2010)
Actinidia chinensis (kiwifruit 'Gold')	Good/Moderately Good	15	7	36	Follett et al. (2019a)
Malus × domestica (apples 'Jazz')	Non Host/ Good	0	26	41	Follett et al. (2019b)
Mangifera casturi (mango 'Kalimantan')	Moderately Good	9			McQuate et al. (2017)
Solanum torvum (turkey berry)	Moderately Good	4			McQuate (2008)
Solanum torvum (turkey berry)	Moderately Good	10			McQuate (2008)
Vaccinium reticulatum (ohelo)	Moderately Good		5		Follett and Zee (2011)
Actinidia chinensis (kiwifruit 'Green')	Non Host/Moderately Good	0	1.3	30	Follett et al. (2019a)

Table A2

LIMS - New Zealand Interception data 2000-2020

Country of origin of *Bactrocera dorsalis*	**n interceptions**	**included in pineapple IRA**
India	24	
Thailand	8	v
Philippines	7	v
Sri Lanka	6	v
French Polynesia	4	
Vietnam	4	
China	2	
Cook Islands	2	
Indonesia	2	v
Cambodia	1	
Hong Kong	1	
Korea - South	1	
Laos	1	
Unknown	13	
total	76	

Table A3

LIMS - New Zealand Interception data 2000-2020

Fruit host of *Bactrocera dorsalis*	**n interceptions**
Mango (*Mangifera indica*)	30
Guava (*Psidium guajava*)	13
Chillies (*Capsicum frutescens*)	9
Longan (*Euphoria longana*)	5
Jujube (*Ziziphus jujuba*)	2
Lychee (*Litchi chinensis*)	2
Pawpaw, Papaya (*Carica papaya*)	2
Banana (*Musa* spp)	1
Dragon/Pitaya fruit (*Hylocereu* s sp.)	1
Mandarin (*Citrus reticulata*)	1
Plum (*Prunus salicina*)	1
Rambutan (*Nephelium lappacceum*)	1
total	68

Table A4

LIMS - New Zealand Interception data 2000-2020

***Bactrocera dorsalis* life stage and viability**	Alive	Dead	Both	total
Egg	7	8		15
Larva	36	9	1	46
Pupa	3			3
Adult	4	5		9
total	50	22	1	73

7 Pest risk assessments on insects: Hemiptera, Diaspididae (armoured scale)

7.1 *Diaspis bromeliae* (pineapple scale)

Diaspis bromeliae is an armoured scale insect that affects mostly ornamental species such as orchids, bromeliads and palms. It is native to the neotropics but is now widespread throughout the tropics and subtropics and in sheltered environments in some temperate regions. The scale insect feeds on the contents of plant cells and can affect the size and appearance of fruit, reducing its marketability. It is considered a pest of minor significance in pineapple growing regions in Australia and United States.

7.1.1 *Taxonomic description*

Scientific name: *Diaspis bromeliae* (Kerner, 1778)
Order/Family: Hemiptera/ Diaspididae
Other names: *Coccus bromeliae* Kerner, 1778; *Aspidiotus bromeliae* (Kerner, 1778); *Chermes bromeliae* (Kerner, 1778); *Aulacaspis bromeliae* (Kerner, 1778) (García-Morales et al. 2016); pineapple scale.

7.1.2 *Hazard identification*

Diaspis bromeliae is not known to be present in New Zealand.

- There is no record of *Diaspis bromeliae* in NZOR(2022), BiotaNZ (2022).
- *Diaspis bromeliae* is listed as "not present" in New Zealand in PPIN (2022).
- *Diaspis bromeliae* is a regulated pest for New Zealand, and has unwanted status (ONZPR 2022).

Diaspis bromeliae has the potential to establish and spread in New Zealand.

- Some of its recorded hosts are present in New Zealand.
- It is reported from some regions with similar climates to New Zealand.
- The first-instar nymph (or crawler) can disperse actively over short distances and passively over long distances by wind, or on other animals. Movement of infested plant material to new locations can spread the scale insect both locally and over longer distances.

Diaspis bromeliae has the potential to cause harm to New Zealand

- It could affect the cut flower industry, specifically orchid production in greenhouses.
- It is a pest of pineapple, which is grown in New Zealand and has the potential for commercial production.
- It could affect a range of amenity plants that are cultivated in gardens by collectors or botanical gardens.
- It could harm the environment indirectly by the increased use of pesticides.

Diaspis bromeliae can be associated with pineapple fruit.

- During high infestations, *D. bromeliae* infests pineapple fruit.
- Female adults have been intercepted alive at the New Zealand border on pineapple fruit.

Given the arguments and evidence above, MPI considers *Diaspis bromeliae* to be a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

7.1.3 *Risk assessment*

7.1.3.1 Biology

Description

Female *D. bromeliae* scale cover is described as greyish-white colour by Waterhouse and Sands (2001) and beige colour by Petty et al (2002). Female mature scale covering are somewhat flattened and circular, measuring between 1.3–3 mm in diameter (Petty et al 2002; Waterhouse and Sands 2001). Immature male scale coverings are white, narrow and slightly ribbed longitudinally (Waterhouse and Sands 2001).

Reproduction is sexual (Waterhouse and Sands 2001). In Queensland, Australia, the life cycle is completed in about two months (Brimblecombe 1955) and it can have up to four generations a year that can overlap (Brimblecombe 1956; Waite 1993). Oviposition occurs throughout the year, with the highest peaks in Brisbane summer (December) (Min–Max: 19.8 – 29.1 °C) and early winter (June) (Min–Max: 10.9 - 20.9 °C) (Murray 1980; Australian Bureau of Metereology 2022).

Females lay eggs under the scale cover (Petty et al 2002) and can deposit up to 100 translucent to yellowish eggs (Waterhouse and Sands 2001). In Brisbane temperature conditions, the eggs hatch after 7 days (Waterhouse and Sands 2001). Females have two nymphal instars before moulting to the adult stage and males have two nymphal instars followed by pre-pupae, pupae and orange-coloured winged adults (Waterhouse and Sands 2001). Adult males are fragile, unable to feed and, after they mate they only live for a few days (1-2 days) (Petty et al 2002; Joy et al 2013; Manners 2016)

Ecology and feeding damage

Unlike mealybugs, armoured scale insects, do not produce a sugary exudate known as honeydew and therefore are not associated with the growth of sooty mould fungi (Henderson 2011). This is because, unlike mealybugs, they do not feed from the phloem, but from plant cells or parenchyma (Henderson 2011).

Newly hatched crawlers have small energy reserves and can survive only a short period before they need to settle and feed. They usually settle about 1 m from the sessile mother. Active movement is usually restricted to the same plant rather than between plants (Greathead 1975). Crawlers are the primary dispersal stage for *D. bromeliae* (Brimblecombe 1956) as well as the stage with the highest mortality rate due to abiotic and biotic factors (Magsig-Castillo et al 2010; Brimblecombe 1956). They can be passively dispersed by wind, or by hitchhiking on animals (including humans and other insects) and agricultural equipment (Petty et al 2002; Watson 2002; Magsig-Castillo et al 2010). However, dispersal over long distances is mostly by the movement of infested planting material (Ito and Carter 1931; Petty et al 2002).

When the crawlers find a suitable place to feed, they shed their legs, insert their mouthparts and then remain at the chosen site (Petty et al 2002). While feeding, they incorporate the cast skins of the juvenile moults and cement them together with waxes to produce a cover (i.e. armour). This strong protective cover is important for adult scales because of their sedentary behaviour (Henderson 2011).

Diaspis bromeliae typically aggregates on the leaf bases of the pineapple plant, which are more shaded. From there it disperses to suckers and the underside of the fruit (Murray 1980; Waterhouse and Sands 2001). When the plants are growing in shaded positions, *D. bromeliae* can be found higher on plants (e.g., crown of developing fruit) (Petty et al 2002; Rohrbach and Johnson 2003).

The scales are not easily detected when there are low field population levels (Murray 1980) but the feeding damage is obvious. The earliest visible damage on pineapple plants are yellow spots on mature leaves and suckers where the scale feeds. Heavy infestations can kill plants 12 to 18 months old (Carter 1967). Plants assume a greyish scaly appearance, they are weakened and stunted and have foliar dieback (Watson 2002).

Pineapple fruits can be heavily infested, especially those that grow towards the walking spaces in the field (i.e., ratoon fruits). Fruits appear small with a rough grey pinched appearance and are sometimes cracked (Carter 1967; Murray 1980; Waterhouse and Sands 2001).

Plant Hosts

Diaspis bromeliae is a polyphagous species associated with plants in at least 12 families and 29 genera, amongst them pineapple (Garcia Morales et al 2016). However, Miller and Davidson (2005) believe that many of the host records are misidentifications because they have only seen specimens from Bromeliaceae and Orchidaceae (Table 7.1).

Table 7.1. Plant hosts of *Diaspis bromeliae* (Source: Claps et al 2001; Miller and Davidson 2005; Garcia Morales et al 2016).

Family	Genus/Species	Common name
Araliaceae	*Hedera helix*	Ivy
Arecaceae (Palmae)	*Areca* sp.	
	Chamaerops humilis	European fan palm
	Howea forsteriana	Kentia palm
	Lytocaryum weddellianum	Weddell’s palm
	Phoenix paludosa	Mangrove date palm
	Rhapis excelsa	Bamboo palm
	Syagrus campestris	
	Syagrus flexuosa	Acuma
Asparagaceae	*Agave vivipara*	Caribbean agave
	Anthericum sp.	
	Dracaena sp.	
Bromeliaceae	*Aechmea fasciata*	Silver varse
	Aechmea nudicaulis	
	Ananas comosus	Pineapple
	Billbergia amoena	
	Billbergia zebrina	
	Bromelia pinguin	
	Gusmania sp.	

	Chevalieria sp.	
	Neoregelia sp.	
	Nidularium innocentii	
	Tillandsia sp.	
Cannaceae	*Canna* sp.	Canna lily
Lauraceae	*Ocotea aciphylla*	Sweetwood
Malvaceae	*Hibiscus* sp.	Hibiscus
Myrtaceae	*Plinia cauliflora*	Jabuticaba
Oleaceae	*Osmanthus fragans* var. *aurantiacus*	Fragant olive
Orchidaceae	*Brassia* sp.	Spider orchid
	Cattleya sp.	
	Gomesa bifolia	Duck orchid
Poaceae	*Saccharum officinarum*	Sugarcane
Santalaceae	*Jodina rhombifolia*	Loose quebracho

Pineapple variety susceptibility

No information was found on the specific pineapple varieties that are susceptible to *D. bromeliae.* Waterhouse and Sands (2001) mentioned that in Australia both smooth and rough varieties of pineapple are susceptible to *D. bromeliae* but no further information was given. The major pineapple varieties in Queensland, Australia are Smooth Cayenne, 73-50 (sold as Bethonga Gold and Golden Circle Gold), MD-2 and Queen (Alexander, McGregor and Ripley Queen) which are a combination of smooth and rough pineapple varieties (Queensland Government, 2022).

Geographical distribution

Diaspis bromeliae is mostly present in tropical climates, but it occurs in subtropical, Mediterranean and temperate climates (Garcia Morales et al 2016). There are contrasting views on the distribution of *D. bromeliae* in temperate climates. Many authors report that *D. bromeliae* is restricted to indoor planting in cooler temperate regions e.g. France and Czech Republic (Nakahara 1982; Germain and Matile-Ferrero 2005; Malumphy et al 2008; Pellizzari and Germain 2010; Sosnovskiy and Prokopiv 2010; Kozár et al 2013; Malumphy 2014), with a Climate Matching Index (CMI) of 0.8 – 0.9 to (all of) New Zealand (Phillips et al 2018). However, Longo et al. (1995) reported *D. bromeliae* as present in northern, central and southern Italy and the island of Sicily where the climate has a CMI of 0.8 – 0.9. In Australia, *D. bromeliae* is present in northern New South Wales and south eastern Queensland (i.e, Brisbane) (Brimblecombe 1956; Waterhouse and Sands 2001) which have a CMI of 0.7 – 0.8 and a CMI of 0.6 – 0.7 respectively (Phillips et al 2018). Recently, *D.bromeliae* was identified in a fruit orchard in the province of Tashkent in Uzbekistan with a CMI of 0.7–0.8 (Yakhyoev et 2021).

Table 7.2. Geographic distribution of *Diaspis bromeliae*. Markets included within the scope of this import risk analysis are marked in bold.

Continent	Country/area/market	References
North America	Mexico (Veracruz), United States (Alabama, California*, Connecticut, District of Columbia*, Florida, Illinois*, Louisiana, Massachusetts, Missouri, New Jersey, New York*, Ohio*, Pennsylvania*, Texas, Virginia, Wyoming)	García-Morales et al 2016

Central America & Caribbean	Belize, **Costa Rica**, Guatemala, Antigua and Barbuda, Bahamas, Bermuda, Cuba, Dominica, Dominican Republic, Guadeloupe, Haiti, Jamaica, Martinique, Puerto Rico (Vieques Island), Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Virgin Islands	Gómez-Menor Ortega 1940; Hodgson and Hilburn 1991; Watson 2002; García-Morales et al 2021;
South America	Argentina (Buenos Aires, Córdoba, Salta, Tucumán), Brazil (Bahia, Espirito Santo, Minas Gerais, Rio Grande do Sul, Rio de Janeiro, Sao Paulo), Colombia, Ecuador,Guyana, Venezuela	Rogg 2000; García-Morales et al 2016; Moreno et al 2021
Asia	Japan (Bonin Islands, Ryukyu Islands, Honshu, Okinawa), Myanmar, China (Guangxi, Hainan, **Taiwan**), **Indonesia**, India, **Malaysia**, **The Philippines**, South Korea, Uzbekistan (Tashkent province)	Watson 2002; García-Morales et al 2016; Yakhyoev et al 2021
Africa	Egypt*, Kenya (Thika district) Mauritius, Morocco, Mozambique, Sierra Leone, South Africa (Eastern Cape), Tanzania	Carnegie 1959; De Lotto 1967; García-Morales et al 2016; CABI 2019
Europe	Austria, Belgium*, Portugal (Azores, Madeira), Bulgaria, Spain (Canary Islands), Czech Republic*, Denmark, France* (Corsica), Georgia*, Germany, Hungary*, Italy (Sicily), Lithuania*, Malta, Netherlands, Poland, Romania, Russia*, Sweden, Switzertland, Turkey, Ukraine*	Nakahara 1982; Germain and Matile-Ferrero 2005; Šefrová et al 2005; Malumphy et al 2008; Sosnovskyi and Prokopiv 2010; Kozár et al 2013; García-; Morales et al 2016, Batsankalashvili et al 2017; CABI 2019
Oceania	**Australia** (Queensland, New South Wales), **Cook Islands,** Federated States of Micronesia (Society Islands, Tahiti), Fiji, Hawaiian Islands (Hawaii, Kauai, Lanai, Maui, Molokai, Oahu), **New Caledonia**, Pitcair Island, Seychelles, **Western Samoa**	Waterhouse and Sands 2001; García-Morales et al 2016; Nakahara 1982

**Diaspis bromeliae* found in glasshouse

7.1.3.2 Likelihood of entry

Diaspis bromeliae is present in pineapple exporting markets that fall within the scope of this Import Risk Assessment (IRA): The Philippines, Taiwan, Indonesia, Malaysia, Australia, Cook Islands, Fiji, Western Samoa, New Caledonia and Costa Rica (García Morales et al. 2016).

Diaspis bromeliae has been reported infesting mature pineapple fruit in Australia but specifically in circumstances of high infestation levels in the field (Brimblecombe 1956). This species prefers to hide under the lower mature leaves, but as population levels rise, the mobile first instar nymphal stage move upward to the fruit and crown (Brimblecombe 1956; Murray 1980).

Detectability of *D. bromeliae* prior to harvest will depend on the infestation levels in the field. It is likely that scales will be detected in the field prior to harvest if the infestation is high, due to the easily seen damage on the leaves and fruits (Carter 1967; Watson 2002). However, when the population is low, scales are difficult to locate because they hide in shaded areas, under mature leaves, close to the base of the newly formed pineapple fruit (Murray 1980, Waterhouse and Sands 2001).

Harvesting and commercial processing of pineapples in packhouses, including cleaning, grading and inspection can greatly impact the likelihood of entry of some life stages of *D. bromeliae*. For example, the crawler stage is highly susceptible to abiotic (e.g., temperature) and biotic conditions (e.g., natural enemies) (Brimblecombe 1956; Magsig-Castillo et al. 2010) and therefore it is the stage with the highest mortality rate (Magsig-Castillo et al. 2010). Adult males are very delicate, short-lived (Carter 1967) and are likely to be disturbed, therefore they are unlikely to remain on fruit during harvesting and packhouse activities. In contrast, sessile immature (i.e., nymphal instars, prepupae and pupae) and adult stages could evade detection by visual inspection because they are small and can be inconspicuous on the complex and variable surface of a pineapple (e.g., bottom eyes of the fruit) (PestNet 2022). In addition, the protective cover of adult scale insects provides an effective barrier to insecticide penetration (Foldi 1990; Quesada et al., 2018) and pre-packing procedures such as washing and waxing (Medina and Garcia 2005; Jamieson et al., 2010). Viable eggs are protected from physical disturbance, chemicals and environmental conditions under the adult female's waxy cover (Foldi 1990, Joy et al. 2013).

No information was found on the thermal development requirements of *D. bromeliae*, thus the lower and upper temperature thresholds of this species are uncertain. However, specimens intercepted alive at the New Zealand border (LIMS 2022) indicate that it can survive storage and transport from Asia on sea cargo with temperatures as low as 7°C for three to four weeks (Camelo 2004; Freight 2022; Ports.com 2022).

There have been 25 interceptions of *D. bromeliae* at the New Zealand border between 2000–2020 on pineapple fruit from the Philippines (sea cargo) and one interception from Fiji (air cargo). In 2016, 12 live female adults were collected in one consignment of pineapples from the Philippines (C2016/38722) (LIMS 2022). From those interception records where the sex and life status was recorded (22), all were female and 91% were alive (LIMS 2021).

According to Assure Quality interception data there have been 54 interceptions of which most of the interceptions where from the Philippines, and a few from Ecuador (4) and Fiji (1). From those interceptions 19% were live female adults (AssureQuality 2022).

Given that:

- *Diaspis bromeliae* can be associated with mature pineapple fruit (as per commodity description);
- Some lifestages are likely to survive infield and pack house activities;
- Eggs and immature stages can be undetected due to the uneven and rough surface of the fruit and could hide under bracts without obvious visible symptoms;
- In the last 20 years there have been interceptions of live female adults of *D. bromeliae* at the New Zealand border on pineapple fruit coming from the Philippines, Ecuador and Fiji via sea cargo and Fiji via air cargo, suggesting that this species can survive transit;

MPI considers that the likelihood of *Diaspis bromeliae* entering New Zealand is MODERATE with LOW uncertainty.

7.1.3.3 Likelihood of exposure

This assessment is made on the basis that Diaspis bromeliae *has entered New Zealand undetected.*

Imported fresh pineapple fruit is intended for human consumption, therefore, when the fruit arrives in New Zeland it will be distributed throughout the country for wholesale or retail sale. Fresh pineapple fruit generates large amounts of unavoidable waste. The thick skin is always removed and the disposal of the fruit skin may aid the exposure of scales to suitable environments. Fruit may also be disposed of whole.

In New Zealand, organic waste that is bagged and goes to landfill is the most common method of organic waste disposal (Askarany and Franklin-Smith 2014). This method is considered low risk as it is unlikely to facilitate successful exposure. However, there are other disposal methods that could facilitate successful exposure, such as feeding waste out to animals, composting and direct disposal into the environment.

Fruit waste in New Zealand may be collected from unpacking areas (e.g., supermarket preparation rooms) and taken to rural areas where it is placed on the ground for eventual consumption by pigs or other farmed animals (Goodman-Smith 2018). Adult females with eggs under the protective scale covering could survive on pineapple fruit in supermarkets, as evidenced in other picked fruit and vegetables (Morse et al 2009; Hennessey et al 2013), if the fruit remains in good condition and the environment is adequate. However, after the removed skin or the whole pineapple fruit is placed for animal feed, the quality of the host diminishes. If the eggs are able to hatch while on the ground, newly hatched crawlers are unlikely to survive if no immediate host is available due to their small energy reserves and their susceptibility to abiotic conditions (Magsig-Castillo et al 2010).

Commercial composting is considered a low risk disposal method. Waste in commercial compost is put into tunnels for a period of three to four days at temperatures of 55 °C or higher (WasteMINZ 2009) and these conditions are likely to kill *D. bromeliae* immature stages. It is uncertain what is the upper temperature threshold of female adults, nevertheless high temperatures will accelerate the decomposition of the fruit and therefore it will no longer be a suitable host for *D. bromeliae* female adult. Worm farming is also considered a low-risk method because it is recommended that organic waste is cut into small pieces (Angima et al. 2011) which will diminish the quality of the host. In addition, it is a contained structure which will prevent the crawlers from wandering out into the environment.

Home composting increases the likelihood of exposure. A study conducted in Palmerston North found that 63% of a total of 72 households that do home composting used manufactured plastic bins for composting and the majority of others used an ‘open’ composting system, such as open compost piles and piles fenced with wire (Mensah 2017). Even though both home composting methods increase the likelihood of exposure to potential hosts, there are significant barriers for this to occur. Eggs could potentially remain viable and hatch inside the compost bin. Newly hatched crawlers are searching for a a live plant to settle on and feed from. They usually settle close (within 1m) to the sessile mother and do not actively move for long distances in search of food due to their small energy reserves

(Greathead 1975; Magsig-Castillo et al 2010). It is unlikely crawlers will survive for long periods by feeding on composting pineapple skin.

The window of opportunity for a crawler to disperse from pineapple waste to outside the compost bin or open compost is short given the dispersal stage is less than a day before they develop into a sessile stage (i.e., pre-pupation, pupation (males) and adult females) (Magsig-Castillo et al., 2010). If crawlers survive and escape a plastic bin or open compost, they are vulnerable to abiotic and biotic factors such as heavy rain, wind and natural enemies amongst others (Mendel et al 1984). Crawlers could be transferred to a potential host by wind or by hitchhiking on other animals (Washburn and Washburn 1984; Watson 2002). However, for the crawlers to be uplifted and transported successfully by the wind or an animal, the crawlers need to be at an appropriate height above the ground and be positioned at an appropriate direction on the plant or canopy (Washburn and Frankie 1981). In addition, a suitable plant host must be very close to or on the spot that the crawler lands.

The plants listed as hosts of *D. bromeliae* (Table 1) are predominantly ornamental plants. Some plants are are not widely distributed, but other such as the common ivy (*Hedera helix*) is commonly found in many gardens across New Zealand. This could increase the likelihood of *D. bromeliae* landing on a suitable host.

Pineapple waste deposited by roadsides, parks and campsites could potentially aid the exposure of *D. bromeliae* because most hosts (i.e., ornamentals) are more likely to be found in these environments. However, abiotic and biotic conditions will still represent a significant barriers for the development of eggs on discarded pineapple skin and the likelihood of dispersal of the crawler to a suitable host.

Uncertainty

*Pineapple waste***:** Information regarding food waste in New Zealand is based on general data and there is no specific information on pineapple waste. Therefore it is assumed that the percentages of discarded pineapple fruit skin in New Zealand will be much lower.

Dispersal of crawlers: No specific information was found on the dispersal capabilities of *D. bromeliae,* therefore this assessment is based on information from other scale or mealybug species.

Temperature thresholds: No information was found on *D. bromeliae* lower and upper temperature thresholds. Therefore it is unknown if *D. bromeliae* could survive under a home composting scenario.

Given that:

- *Diaspis bromeliae* may survive and develop on the surface of pineapple fruit, either whole or skin pieces;
- Most pineapple waste is likely to be disposed of using methods that are considered to be low risk, for example, in bagged waste to landfill, or by commercial composting, worm farming or home composting in plastic bins;
- Pineapple skin that is used for animal feed or open composting could expose *D. bromeliae* crawlers to the environment;
- The main dispersal stage, the crawler, is flightless and can move short distances actively or long distances passively;

- Crawlers are highly vulnerable to biotic and abiotic factors such as temperature, humidity and natural enemies;
- Crawlers that are wind or animal dispersed are unable to actively choose to land on a suitable host plant;
- *Diaspis bromeliae* has a relatively limited range of host plants that are readily available throughout New Zealand;

MPI considers that the likelihood of exposure of *Diaspis bromeliae* in New Zealand is VERY LOW with MODERATE uncertainty

7.1.3.4 Likelihood of establishment

This assessment is made on the basis that Diaspis bromeliae *has been successfully exposed to a suitable host plant in the New Zealand environment.*

The reported host plants of *D. bromeliae* are mainly ornamentals (palms, bromeliads, orchids) or tropical/subtropical crops (sugarcane, pineapple) that are not present or not widely distributed in New Zealand (Garcia Morales et al 2016; NZPCN 2022). However, plant species in some host genera may be common in some urban areas, e.g. *Hibiscus*, *Hedera* (ivy), phoenix palms.

Diaspis bromeliae females are continuously producing eggs throughout the year (Brimblecombe 1955). According to Waterhouse and Sands (2001) “females oviposit up to 100 eggs”, however it is unclear if this count refers to number of eggs per batch, number of eggs per year, or number of eggs during the female’s lifetime. The highest peaks of oviposition occurs at temperatures between 10 °C – 29 °C in Brisbane, Australia, with eggs hatching after 7 days in warm temperatures (20 °C – 29 °C) (Murray 1980; Australian Bureau of Metereology 2022). This suggests that most of the North Island and some coastal regions in the northern South Island could be suitable for *D. bromeliae* reproduction and survival (Mackintosh 2001).

Reproduction is sexual (Waterhouse and Sands 2001). This means that to establish a population in a suitable host, immature stages of both sexes must be at close proximity, survive to maturity and mate.

The dispersal of crawlers is limited due to their small energy reserves. Newly hatched crawlers stay close to the mother and move actively within the plant rather than between plants (Greathead 1975). The crawler stage is susceptible to abiotic and biotic factors limiting their dispersal activity (Magsig-Castillo et al 2010). However, crawlers can be spread to longer distances by movement of infested plant material, equipment and on animals including other insects and humans (Roda et al., 2013).

This species is mainly present in tropical climates, and its presence in temperate climates is restricted to glasshouses. However, records from Italy (Longo et al 1995), the Tashkent province in Uzbekistan, as well as northern New South Wales and south eastern Queensland, Australia (Brimblecombe 1956; Waterhouse and Sands 2001) with a CMI between 0.6-0.8 (Phillips et al 2018), suggest that *D. bromeliae* could establish in some regions in New Zealand but establishment would be restricted since *D. bromeliae* prefers deep shade and very high humidity (Panis and Pinet 1999).

Present and future projected temperatures in New Zealand are likely to improve the suitability of the New Zealand environment for *D. bromeliae*. The mean annual temperature and mean maximum temperatures for many (but not all regions in New Zealand) in 2021, were +0.51 °C to +1.20 °C above the annual average (13.56 °C) (NIWA 2021). The temperature increase projected for New Zealand due to climate change is 1.4 °C by 2090. These temperatures fall within the temperature of establishment of *D. bromeliae* in Brisbane, Australia (Brimblecombe 1956; Waterhouse and Sands 2001).

There are parasitoid wasp species present in New Zealand that are known to attack *D. bromeliae*. The species *Encarsia citrina* attacks and controls *D. bromeliae* in eastern Queensland (Waterhouse and Sands 2001) and is present in New Zealand as well as various *Aphytis* spp., e.g. *A. chrysomphali*, *A. diaspidis* (NZOR 2022) that attack this scale insect (Kondo & Watson 2022)

Uncertainty

Host plants: There is uncertainty on the host plant range of *Diaspis bromeliae*. Some authors claim that its restricted to species in the family Bromeliaceae and Orchidaceae and that other host plants might have been the result of misidentification.

Dispersal of crawlers: There is no specific information about the dispersal capability of *D. bromeliae*, so this assessment is based on the information found in other scales species.

Given that:

- Although *Diaspis bromeliae* has established in countries with climates similar to those in some parts of New Zealand, it is generally found in the tropics and subtropics and in temperate climates is found only in greenhouses;
- The mode of reproduction is sexual and this may be a significant barrier for establishment;
- The limited dispersal capability of crawlers and its susceptibility to abiotic and biotic factors;
- *Diaspis bromeliae* has a limited range of host plants that are readily available throughout New Zealand;

MPI considers that the likelihood of *Diaspis bromeliae* establishing in New Zealand is VERY LOW with MODERATE uncertainty.

7.1.3.5 Overall risk to New Zealand

Based on the assessments of likelihood above, that:

- the likelihood of entry is MODERATE with LOW uncertainty,
- assuming entry, the likelihood of exposure is VERY LOW with MODERATE uncertainty,
- assuming successful exposure, the likelihood of establishment is VERY LOW with MODERATE uncertainty,

The combined likelihood of entry, exposure and establishment is NEGLIGIBLE. Therefore, MPI considers the overall level of assessed risk to New Zealand, irrespective of the potential impacts here not assessed, from *Diaspis bromeliae* on pineapple fruit, is NEGLIGIBLE with

MODERATE uncertainty. This is based on the methodology provided in the 'Guidelines for Risk Analysis in Plant Biosecurity 1.0'.

7.1.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *Diaspis bromeliae* association with pineapple fruit been observed?
There is no specific information about the stage of ripeness *Diaspis bromeliae* is associated with but it has been reported “affecting pineapple mature fruit” in Australia in circumstances of high field infestations. No information was found on the specific varieties that are susceptible to *D. bromeliae* other that it affects both smooth and rough varieties in Australia.

Which part(s) of the pineapple fruit is *Diaspis bromeliae* associated with (e.g. fruit, bract, stem or crown remnant) and is it detectable by visual detection?
The pest is associated with all parts of the plant. *Diaspis bromeliae* eggs and immature stages can be undetected due to the uneven and rough surface of the fruit and could hide under bracts without obvious visible symptoms. The likelihood of detection is reduced at low infestation levels.

Are different lifestages of the *Diaspis bromeliae* associated with different parts of the pineapple fruit?
All lifestages can be associated with different parts of the fruit, although there is a preference for the lower section of the fruit when infestation levels are low.

Does *Diaspis bromeliae* burrows into the fruit without obvious symptoms, hides under the pineapple bract?
Diaspis bromeliae can hide under the pineapple bract without obvious visible symptoms.

7.1.5 *References*

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8 Pest risk assessments on insects: Hemiptera, Pseudococcidae (mealybugs)

8.1 *Dysmicoccus brevipes* (pink pineapple mealybug)

Dysmicoccus brevipes is a highly polyphagous (feeds on a wide range of plants) mealybug that feeds on all plant parts and is widely distributed geographically. It is common on pineapple and has also been reported in association with a number of crops that are of economic importance to New Zealand, including avocado (*Persea americana*), *Capsicum*, *Citrus*, grape vine (*Vitis vinifera*) and potato (*Solanum tuberosum*). This mealybug transmits a number of plant viruses, notably Pineapple mealybug wilt-associated viruses. It also secretes honeydew which can lead to the growth of sooty moulds.

8.1.1 *Taxonomic description*

Scientific name: *Dysmicoccus brevipes* (Cockerell, 1893)
Order: Hemiptera **Family:** Pseudococcidae
Other scientific name: *Dactylopius brevipes*; *Pseudococcus brevipes*; *Dactylopius* (*Pseudococcus*) *ananassae*; *Pseudococcus missionum*; *Pseudococcus palauensis*; *Pseudococcus cannae*; *Pseudococcus longirostralis*; *Pseudococcus defluiteri; Pseudococcus pseudobrevipes* (García Morales et al 2016; CABI 2021); Pineapple mealybug.

Taxonomic notes:
Dysmicoccus brevipes was originally described as *Dactylopius brevipes,* from specimens collected from pineapple in Jamaica in 1893 and was later renamed *Pseudococcus brevipes* (Ben-Dov 1994). There are several misidentifications of *D. brevipes* under the name *Pseudococcus bromeliae* (Williams and Watson 1988).

Ito (1938) highlighted two distinct types of pineapple mealybug in Hawaii, a pink form and a grey form. The pink form reproduced asexually, whereas the grey form reproduced sexually. Ghose (1983) later confirmed *D. brevipes* has both uniparental and biparental races. Beardsley (1959a) identified the morphological differences between the two Hawaiian types, describing the grey form as a distinct species, *D. neobrevipes* (grey pineapple mealybug). Consequently, literature before 1959 could be referring to either *D. brevipes* or *D. neobrevipes*.

8.1.2 *Hazard identification*

Dysmicoccus brevipes is not known to be present in New Zealand.

- There is no entry in NZOR (2022) or BiotaNZ (2022).
- According to PPIN (2022), one adult specimen of *D. brevipes* was found during a 1997 National Stonefruit Survey in an Auckland plum orchard. In response, two delimiting surveys were conducted in 1998, and no additional *D. brevipes* individuals were located. Given only one individual was found during three surveys, Richmond and Cowley (1998) concluded the mealybug likely failed to establish, or populations are currently below detectable levels. No subsequent detections have occurred post 1997, further supporting conclusions made by Richmond and Cowley (1998) that the mealybug failed to establish.

- *Dysmicoccus brevipes* is a regulated pest and an unwanted organism for New Zealand ONZPR (2022).

Dysmicoccus brevipes has the potential to establish and spread in the northern North Island, namely Auckland and Northland.

- *Dysmicoccus brevipes* is a highly polyphagous (feeds on a wide range of plants) mealybug that feeds on all plant parts, and has been reported from 66 families and 158 genera of plants (García-Morales et al. 2016).
- Many host species are widely distributed and grown both domestically and commercially in New Zealand. These include horticultural crops such as avocado, capsicum, celery, citrus, cucumber, grape, maize, potato, taro. In addition, common weed and forage grass species, such as clover are also hosts of *D. brevipes*.
- While the current distribution of *D. brevipes* includes countries and areas with similar climatic conditions to the general New Zealand climate, according to Wei et al. (2020), under current climate conditions New Zealand is either unsuitable, or has a low simiarlity to the preferred climate of *D. brevipes*, with the exception of the northern North Island, namely Auckland and Northland, which has a suitable climate.
- *Dysmicoccus brevipes* has the capacity to reproduce asexually.

Dysmicoccus brevipes has the potential to cause harm to New Zealand.

- *Dysmicoccus brevipes* has the potential to reduce the economic value of horticulturally-important crops in New Zealand, notably citrus, apple and grape.
- *Dysmicoccus brevipes* has the potential to harm the New Zealand environment, as the mealybug has been reported on plant genera which native New Zealand plants belong to.
- *Dysmicoccus brevipes* has the potential to cause advserse human health impacts in New Zealand by attracting *Vespula* wasps, which sting humans.
- *Dysmicoccus brevipes* has the potential to have sociocultural impacts in New Zealand, as the mealybug is associated with kūmara and taro, both of which are culturally important to Māori.

Dysmicoccus brevipes is associated with pineapple fruit.

- *Dysmicoccus brevipes* has been reported on pineapple fruit (González-Hernández et al. 1999; Milek et al. 2009), although the authors do not indicate where on sampled fruit or at what lifestage *D. brevipes* individuals have been observed.
- *Dysmicoccus brevipes* is widely associated with pineapple plants, and has been reported infesting fruit, blossom cups, crowns, leaves and roots (CPC, 2021). While multiple surveys confirm *D. brevipes* infests *Ananas cosmosus* (pineapple) plants (Sether et al. 2001; Culik et al. 2007; Huang and Lin 2014; Moreno et al. 2021), only two surveys found (González-Hernández et al. 1999; Milek et al. 2009), specifically note that the mealybug was detected on ‘pineapple fruit’.

MPI considers *Dysmicoccus brevipes* a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

8.1.3 *Risk assessment*

8.1.3.1 Biology

Biology and reproduction
Dysmicoccus brevipes is a broadly oval to round pinkish species. The adult female grows to around 3 mm long and is covered in waxy filaments (MPI, 2009).

There are asexual and sexual forms of *D. brevipes* (Lim 1973; CABI 2021). Lim (1973) studied the biology of the sexual form of *D. brevipes*. The author observed females have three nymphal instars, reaching maturity in about 24 days, while males have two nymphal instars: a prepupal and a pupal stage, also maturing at 24 days. Eggs hatch within the female body, and live larvae numbering between 19–137 are born over about nine days (MPI, 2009). On average, adult females live for about 17–49 days and males 1–3 days (MPI, 2009).

The lowest thermal thresholds observed in a laboratory study by Colen et al. (2000) for first and second instar, cocoon and final third instar development were 12.1, 13.5, 12.8 and 12.8 ºC respectively. According to Bertin et al. (2019), the optimal temperature for third instar survival was 28.6°C, while the maximum temperature for third instar development reported by Colen et al. (2000) was 35°C. The highest longevities observed occurred at 20°C for females and at 20 and 25°C for males. In contrast, Bertin et al. (2019) concluded that 30°C was the most suitable temperature for *D. brevipes* development.

Dispersal
The first instar, often referred to as a ‘crawler’, is the primary dispersal stage of the mealybug and moves around actively for no more than a day on average (Martin-Kessing and Mau 1992; CABI 2021). The crawlers are spread over longer distances via wind and a number of ant species (Lim 1973; Jahn and Beardsley 2000; Jahn et al. 2003). Notably, the big-headed ant *Pheidole megacephala*, which is present in New Zealand (BiotaNZ 2022), has been observed by Lim (1973) carrying *D. brevipes* from one plant to another. However, first instar mealybugs are vulnerable to predation and desiccation (Mendel et al. 1984), limiting their capacity to disperse long distances. All life stages may be spread by plant material traded nationally and internationally (CABI 2021).

Hosts and geographical distribution
Dysmicoccus brevipes is highly polyphagous (feeds on a wide range of plants), has a wide host and geographic range.

Dysmicoccus brevipes has been reported from 66 families and 158 genera of plants (García-Morales et al. 2016). Many host species are widely distributed and grown both domestically and commercially in New Zealand, including horticultural crops such as avocado, capsicum, celery, citrus, cucumber, grape, maize, potato, taro. Common weed and forage grass species, such as clover are also hosts of *D. brevipes*. In addition, a number of plant families that New Zealand native flora belong to include hosts of *D. brevipes*. For example, Asteraceae (including At Risk *Abrotanella rosulata* and *Abrotanella spathulata*), Cyperaceae (including Threatened *Carex albula* and *Carex capillacea*), Myrtaceae (including Threatened *Kunzea amathicola* and *Kunzea ericoides*), Orchidaceae (including Threatened *Caleana minor* and *Calochilus herbaceus*), and Poaceae (including At Risk *Agrostis oresbia* and *Agrostis pallescens*) (NZPCN 2022).

The mealybug was first recorded on pineapple in Jamaica, and has been reported in Asia, Africa, North America, South America, Europe and Oceania (García-Morales et al. 2016; CABI 2021) (Table 7.3).

Table 7.3. Geographic distribution of *Dysmicoccus brevipes* (CABI 2022; Scalenet 2022). Markets included within the scope of this import risk analysis are marked in bold. Composite match index (CMI) calculated via Phillips et al. (2018) indicating similar climates to the whole of New Zealand (CMI: 0.7–1.0).

Continent/Region	Country/Area/Market	CMI
Asia	Bangladesh, Bonin Islands, Brunei, Cambodia, China (Beijing, Fujian, Guangdong, Guangxi, Hainan, Hunan, Xizang, Yunnan), India (Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Karnataka, Kerala, Maharashtra, Odisha, Tamil Nadu, Tripura, West Bengal), **Indonesia (Irian Jaya, Java, Sumatra),** Iran, Israel, Japan (Ryukyu Islands), Laos, Lebanon, **Malaysia (Peninsular Malaysia, Sabah, Sarawak)**, Pakistan, **The Philippines**, Singapore, **Sri Lanka**, **Taiwan**, **Thailand**, Turkey, Vietnam	0.2–0.8
Africa	Angola, Ascension Island, Benin, Burkina Faso, Burundi, Cameroon, Cape Verde, Chad, Congo, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Guinea, Kenya, Madagascar, Malawi, Mali, Mauritius, Mozambique, Niger, Nigeria, Réunion, Rwanda, Saint Helena, São Tomé and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Tromelin Island, Uganda, Zambia, Zanzibar	0.3-0.9
North America	Antigua and Barbuda, Bahamas, Barbados, Belize, Bermuda, Cayman Islands, **Costa Rica**, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, Martinique, Mexico (Chiapas, Nayarit), Montserrat, Nicaragua, **Panama**, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Trinidad and Tobago, U.S. Virgin Islands, United States (California, Florida, Hawaii, Louisiana)	0.2-0.8
South America	Argentina (Chaco, Misiones, Salta, Santa Fe, Santiago del Estero, Tucuman), Bolivia, Brazil (Bahia, Ceara, Columbia, Espirito Santo, Mato Gerais, Minas Gerais, Parana, Pernambuco, Piaui, Rio de Janeiro, Rio Grande do Sui, Santa Catarina, Sao Paulo), Chile (Easter Island), Colombia, **Ecuador**, French Guiana, Galapagos Islands, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela	0.3–0.9
Europe	Croatia, France, Greece, Italy (Sicily), Netherlands, Portugal (Azores, Madeira), Sloveniz, Spain (Canary Islands)	0.3–0.9
Oceania	American Samoa, **Australia (New South Wales, Northern Territory, Queensland and Western Australia)**, **Cook Islands**, Federated States of Micronesia (Caroline Islands, Chuuk, Pohnpei, Ponape Islands, Truk Islands, Yap), **Fiji**, French Polynesia, Guam, Hawaiian Islands, Kiribati, Marshall Islands, **New Caledonia**, Niue, Northern Mariana Islands, Palau, **Papua New Guinea**, **Samoa**, Solomon Islands, Tokelau, **Tonga**, Tuvalu, **Vanuatu**, Wallis and Futuna Islands	0.4–0.9

Symptoms

Dysmicoccus brevipes is largely found below ground and just above ground level on the roots and stems of host plants (Jahn et al. 2003). However, in the absence of *D. neobrevipes*, which only infests aerial plant parts (Beardsley 1960), *D. brevipes* is commonly found infesting the crown and developing fruit (Jahn et al. 2003). The mealybug may spread upwards on fruit to feed in floral cavities, resulting in a disorder called black spot (CABI 2021). Symptoms of *D. brevipes* infestation on pineapple fruit include discolouration, the presence of honeydew and sooty moulds (CABI 2021). Similarly, heavy infestations on plants result in large quantities of honeydew and sooty moulds, which result in a reduction in photosynthetic area (Jahn et al. 2003). This can lead to a loss of plant vigour, fruit yield and in severe cases death (MPI, 2008). Ornamental plants and produce can lose their market value (CABI 2021). Furthermore, the production of honeydew also attracts ants which feed on it (Jahn and Beardsley 2000).

Dysmicoccus brevipes has also been identified as the vector of a number of plant viruses (Table 7.4), notably Pineapple mealybug wilt disease, which is the leading cause of economic loss in pineapple production (Jahn et al 2003; Dey et al 2018). The disease is associated with a number of Pineapple mealybug wilt-associated viruses (PMWaV), which *D. brevipes* acquires and transmits to host plants during feeding (Jahn et al. 2003).

Table 7.4: Viruses known to be vectored by *Dysmicoccus brevipes*, and their presence in markets within the scope of this IRA.

Virus name	Known hosts	Presence in IRA markets	Reference
Cacao mild mosaic virus (CaMMV)	*Theobroma cacao*	Indonesia	(Puig et al. 2021)
Banana streak GF virus (BSMYV)	*Musa* spp.	Australia	(Geering et al. 2000; Su 2000; Kubiriba et al. 2001)
Banana streak MY virus (BSMYV)	*Musa* spp.	Australia and Tonga	(Geering et al. 2000; Su 2000; Kubiriba et al. 2001; Stainton et al. 2015)
Banana streak OL virus (BSOLV)	*Musa* spp.	Australia	(Meyer et al. 2008; James et al. 2011)
Pineapple bacilliform comosus virus (PBCoV)	*Ananas comosus*	Australia	(Gambley et al. 2008a)
Pineapple bacilliform erectifolius virus (PBErV)	*Ananas comosus*	Australia	(Gambley et al. 2008a)
Pineapple mealybug wilt-associated viruses (PMWaV)	*Ananas comosus*	Australia, Costa Rica, Malaysia, the Philippines, Sri Lanka, and Taiwan	(Sether et al. 2001; Gambley et al. 2008b)

8.1.3.2 Likelihood of entry

Dysmicoccus brevipes is present in every market included in the scope of this IRA (García-Morales et al. 2016; CABI 2021) (Table 1).

Dysmicoccus brevipes is widely associated with pineapple plants, and has been reported infesting fruit, blossom cups, crowns, stems, leaves and roots (CABI 2021). While multiple surveys confirm *D. brevipes* infests pineapple plants (Sether et al. 2001; Culik et al. 2007; Huang and Lin 2014; Moreno et al. 2021), only two surveys found specifically note that the mealybug was detected on ‘pineapple fruit’ (González-Hernández et al. 1999; Milek et al. 2009). However, LIMS (2022) border interception data between 1929 and 2019 confirms the mealybug is commonly associated with pineapple fruit imported into New Zealand at all lifestages. The Australian Department of Agriculture (2019) states *D. brevipes* is the most commonly intercepted mealybug from the USA ports of entry, with fresh produce including pineapple fruit.

The prevalence of interceptions of *D. brevipes* into New Zealand on decrowned pineapple fruit may decline relative to previous interceptions given New Zealand previously imported pineapple fruit with the crown intact. This is due to the mealybug more commonly being associated with the crown of pineapple fruit (CABI 2021) rather than the fruit itself.

Furthermore, insecticide use during commercial pineapple production may not be effective at controlling *D. brevipes*. Mealybugs in general are difficult to control by insecticide when present on surfaces which provide areas to hide. This is particularly applicable to pineapple fruit given the surface features cracks and bracts, both of which *D. brevipes* could inhabit and go unnoticed during inspection post insecticide application. Furthermore, the mealybug’s waxy protective coating may enable *D. brevipes* to survive commercial cleaning of fruit (Manners and Duff 2015).

Dysmicoccus brevipes would likely be detected during packhouse activities. This is due to symptoms of *D. brevipes* infestation on pineapple fruit including discolouration, the presence of honeydew and sooty moulds (CABI 2021), all of which are visible to the naked eye.

Dysmicoccus brevipes has the capacity to remain viable through sea and air cargo freight transit times and conditions (summary of conditions provided). This is indicated by interceptions at the New Zealand border: between 1929 and 2019, there were 523 sea and air cargo interceptions predominantly on pineapple and banana (LIMS 2022). Within this data set, all lifestages of *D. brevipes* have been detected, the majority of which were live specimens. Furthermore, thermal tolerances observed by Colen et al. (2000) fall within the range of cold storage shipping temperatures.

Given that:

- *Dysmicoccus brevipes* is widely associated with *Ananas cosmosus* (pineapple) plants, and has been reported on pineapple fruit;
- Insecticide may not be effective at controlling *D. brevipes* on pineapple fruit, as such, the mealybug is likely to be associated with pineapple fruit during harvest;
- *Dysmicoccus brevipes* would likely be detected during packhouse activities;
- *Dysmicoccus brevipes* is commonly detected on imported pineapple fruit nationally and internationally;
  Dysmicoccus brevipes can remain viable through sea and air cargo freight transit times and conditions;

MPI considers the likelihood of *Dysmicoccus brevipes* entering New Zealand associated with pineapple fruit is MODERATE, with LOW uncertainty.

8.1.3.3 Likelihood of exposure

This assessment is made on the basis that Dysmicoccus brevipes *has entered New Zealand undetected. Exposure is considered to be the transfer of a pest or disease from an imported commodity or inanimate object, to a host or environment suitable for the completion of development or production of offspring.*

Successful exposure of *D. brevipes* would likely be climate dependant as indicated by the thermal thresholds observed by Bertin et al. (2019) and Colen et al. (2000), and limited to the north of the North Island. According to Colen et al. (2000), lower thermal tolerances for first and second instar, cocoon and final third instar development were 12.1, 13.5, 12.8 and 12.8 ºC respectively. In addition, according to Bertin et al. (2019), the optimal temperature for third instar survival was 28.6°C, while the maximum temperature for third instar development reported by Colen et al. (2000) was 35°C. The highest longevities observed occurred at 20°C for females and at 20 and 25°C for males. In contrast, Bertin et al. (2019) concluded that 30°C was the most suitable temperature for *D. brevipes* development. This suggests successful exposure would likely occur be limited to the summer months across New Zealand, and the north of the North Island outside of this period.

Successful exposure of *D. brevipes* would also be dependant on the mealybug's reproductive capacity. In order to produce a viable population, the sexual form of *D. brevipes* would require at least one male and one female on or within the same quantity of pineapple fruit waste. This is a consequence of the limited dispersal capacity of the third instar, which is the reproductive lifestage of the mealybug. The asexual form of *D. brevipes*, however, would not require a suitable mate in order to produce a viable population. Given border interception data between 1929 and 2019 predominantly reports the presence of only one specimen on imported produce (LIMS 2022), the likelihood of multiple mealybugs being present on the same item is unlikely. Therefore, it is unlikely the sexual form of *D. brevipes* would have the capacity to produce a viable population on or within the same quantity of pineapple fruit waste. In contrast, the asexual form of *D. brevipes* would have the capacity to produce a viable population in the absence of more than one individual.

Fresh pineapple fruit produce generates substantial amounts of unavoidable waste; the thick rind is always removed and disposed of, and the fruit is also sometimes cored (see waste section 2.1.3). In addition, the disposal of whole fruit (e.g. culled/unsold fruit, uneaten fruit remains) is not uncommon during wholesale, retail and by consumers. Consequently, the primary methods in which organic waste is disposed of in New Zealand are important factors when assessing *D. brevipes* exposure risk. In New Zealand, the primary methods of organic-waste disposal consist of landfill, composting, and animal feed.

Disposal of organic waste into landfill is unlikely to be an *D. brevipes* exposure risk. The most common method of organic waste disposal in New Zealand is via bagged waste entering landfill (Askarany and Franklin-Smith 2014). This method is unlikely to be an exposure risk given waste is sealed within bags, and the processing and containment methods used in such facilities would inhibit *D. brevipes* survival and dispersal.

Commercial composting and worm farming are also unlikely to be an *D. brevipes* exposure risk. Waste in commercial compost is put into tunnels for a period of three to four days at temperatures of 55 °C or higher and these conditions are likely to kill *D. brevipes* at all lifestages (Colen et al. 2000; Bertin et al. 2019). Worm farming is considered a low-risk method, because organic waste is contained within a rigid, contained structure, which likely inhibits mealybug dispersal by acting as a physical barrier.

In contrast, domestic composting is likely to be a *D. brevipes* exposure risk. According to a home composting study conducted in Palmerston North, the primary means in which households compost organic waste is via contained plastic bins, and ‘open’ composting systems, such as compost piles and piles fenced with wire (Mensah 2017). The design of contained plastic bins, namely the rigid structure and lid, may inhibit *D. brevipes* exposure by acting as a physical barrier to dispersal. However, open composting systems, which lack a physical barrier, would likely aid *D. brevipes* exposure if suitable hosts commonly found in New Zealand gardens (e.g., citrus and ornamentals) were present and nearby. Furthermore, given *D. brevipes* has a wide host range (Table 1) and feeds on all plant parts (CABI 2021), the likelihood of a suitable host being present within a domestic garden is relatively high. According to (Mendel et al. 1984), if a suitable host is not present nearby, mealybug crawlers are vulnerable to predation, dessication, and being washed away by rain.

Disposal of fruit waste via use as animal feed is also likely to be a *D. brevipes* exposure risk. Fruit waste in New Zealand may be collected from unpacking areas (e.g., supermarket preparation rooms), and taken to rural areas to be used as feed for farmed animals (MPI 2014a). *Dysmicoccus brevipes* crawlers present within such feed may have the capacity to disperse via wind or livestock, and land on a suitable host, such as a weed or grass species, nearby. However, mealybug crawlers are vulnerable to predation, dessication, and being washed away by rain. Therefore, long-distance dispersal is unlikely.

Uncertainty

There is moderate uncertainty associated with the likelihood of *D. brevipes* exposure. This is attributed to differing ways in which organic waste is disposed of throughout New Zealand, and how these methods may inhibit or facilitate *D. brevipes* exposure. More specifically, there is uncertainty relating to whether *D. brevipes* has the capacity to survive in and disperse from environments created within landfill, worm farming, domestic composting, and animal feed. Furthermore, transferring from disposed pineapple fruit to a suitable host from these environments is reliant on *D. brevipes* dispersing waste to a host. Given the mealybug is vulnerable to predation, dessicantion and being washed away by rain, there is uncertainty relating to whether *D. brevipes* would survive dispersal events.

Given that:

- successful exposure of *D. brevipes* would likely be climate dependant as indicated by the thermal thresholds observed by Bertin et al. (2019);
- successful exposure of *D. brevipes* would also be dependant on the mealybug’s reproductive capacity;
- disposal of organic waste into landfill is unlikely to be an *D. brevipes* exposure risk,
- commercial composting and worm farming are also unlikely to be an *D. brevipes* exposure risk;
- domestic composting is likely to be an *D. brevipes* exposure risk;
- disposal of fruit waste via use as animal feed is also likely to be an *D. brevipes* exposure risk;

MPI considers the likelihood of exposure of *Dysmicoccus brevipes* in New Zealand from pineapple fruit is LOW, with MODERATE uncertainty.

8.1.3.4 Likelihood of establishment

This assessment is made on the basis that Dysmicoccus brevipes *is successfully exposed to a suitable host plant in the New Zealand environment.*

Dysmicoccus brevipes is highly polyphagous (feeds on a wide range of hosts), and has been reported from 66 families and 158 genera of plants (García-Morales et al. 2016). Many host species are widely distributed and grown both domestically and commercially in New Zealand, including horticultural crops such as avocado, capsicum, celery, citrus, cucumber, grape, maize, potato, taro. In addition, common weed and forage grass species, such as clover are also hosts of *D. brevipes*.

Given *D. brevipes* has the capacity to reproduce asexually, and females produce 19-137 larvae over about nine days (CABI 2021), the potential for *D. brevipes* to establish a viable population with minimal propagule pressure via the asexual form is likely.

However, climate is likely to act as a barrier to establishment in most regions of New Zealand despite the mealybug’s current distribution including climatic conditions similar to the whole of New Zealand (Table 1). According to Wei et al. (2020), under current climate conditions New Zealand is either unsuitable, or has a low simiarlity to the preferred climate of *D. brevipes*, with the exception of the northern North Island, namely Auckland and Northland, which has suitable climate. This conclusion is further supported by the fact the mealybug is commonly found in tropical and subtropical areas (Ben-Dov 1994), indicating climatic conditions in Auckland and Northland are likely more favourable to establishment of *D. brevipes* relative to the rest of New Zealand.

In addition, previous detections of *D. brevipes* in New Zealand and subsequent surveys indicate the mealybug is unlikely to establish. According to PPIN (2022), one adult specimen of *D. brevipes* was found during a 1997 National Stonefruit Survey in an Auckland plum orchard. In response, two delimiting surveys were conducted in 1998, and no additional *D. brevipes* individuals were located. Given only one individual was found during three surveys, Richmond and Cowley (1998) concluded the mealybug likely failed to establish, or populations are currently below detactable levels. No subsequent detections have occurred post 1997, further supporting conclusions made by Richmond and Cowley (1998) that the mealybug failed to establish.

Given that:

- *Dysmicoccus brevipes* is a highly polyphagous (feeds on a wide range of host plants) mealybug that feeds on all plant parts, and hosts are present, diverse and widespread in New Zealand;
- *Dysmicoccus brevipes* has both asexual and sexual forms;
- climate is likely to act as a barrier to establishment in most parts of New Zealand, with the exception of the northern North Island;
- Previous detections of *D. brevipes* present in New Zealand and subsequent surveys indicate the mealybug is unlikely to establish;

MPI considers the likelihood of *Dysmicoccus brevipes* establishing in New Zealand is LOW, with MODERATE uncertainty.

8.1.3.5 Impacts in New Zealand

This assessment is made on the assumption that D. brevipes *has successfully established in the New Zealand environment.*

Economic impacts

Economically important hosts of *D. brevipes* in New Zealand include avocado (*Persea americana*), *Capsicum* species, *Citrus* species (lemon and orange), grape (*Vitis vinifera*) and potato (*Solanum tuberosum*).

Infestations of *D. brevipes* result in the production of honeydew that provides a medium for sooty moulds. Sooty-mould accumulation leads to a reduction in photosynthetic area (Jahn et al. 2003), which in turn results in a loss of plant vigour, fruit yield and in severe cases death (MPI 2008). In addition, the mealybug commonly feeds on the roots of host species (CABI 2021), further reducing horticultural yields. Ornamental plants and produce can lose their market value as a consequence (CABI 2021). The annual value of horticultural exports within the top ten value markets to the year ending June 2021 that would likely be at least partially impacted by the establishment of *D. brevipes* include apples, valued at NZ$876.3m ; avocados, valued at NZ$112.3m; valued at wine produced from grapes, valued at NZ$1,908.5m, and potatoes, valued at NZ$129.2m (Plant & Food Research 2020, 2021). However, damage would likely be restricted to crops grown in the northern North Island, which has moderate to high habitat suitability for *D. brevipes*. The annual value to the year ending June 2021 of horticultural imports and exports within *D. brevipes*' main host range grown in Auckland and Northland consist of avocados, valued at NZ$122.1m; citrus, valued at NZ$3.0m, wine grapes, valued at NZ$46.4m, and potatoes, valued at NZ$23.8m (Plant & Food Research 2020, 2021).

An in-house MPI model predicted a very low total economic impact over 20 years involving avocado, citrus, wine grapes and potato crops grown in Auckland and Northland.

- The model focused on horticultural import and export crops within *D. brevipes*' main host range. The annual value of horticultural crops within these markets to the year ending June 2021 grown in Auckland and Northland consist of avocados, valued at NZ$122.1m; citrus, valued at NZ$3.0m, wine grapes, valued at NZ$46.4m, and potatoes, valued at NZ$23.8m (Plant & Food Research 2020, 2021).
- It was assumed that the greatest level of combined annual economic impact on all associated horticultural crops in Auckland and Northland would be NZ$2 million. This is based on the assumption of a worst case scenario, where 1% of the apple, avocado and potato industries with a combined 2021 annual export value of NZ$49,494.7m are affected. The value of 1% considers that the mealybug would likely be climatically limited, with the most damage likely restricted to crops in the northern North Island, namely Auckland and Northland. Both regions, according to 2017 data collected by Plant & Food Research (2020), have combined land use allocations for avocado, citrus, wine grapes, and potato production of 48.4%, 25.5%, 2.5%, and 23.8% respectively.
- The mealybug is assumed to take five years to achieve greatest impacts to allow time for spread across Auckland and Northland.
- Due to effective chemical controls existing targeting mealybugs in-field, it is assumed industries would take two years to recover.

In Brazil, *D. brevipes* is one of most abundant mealybugs in *V. vinifera* vineyards, with infestations reducing marketability and productivity (Daane et al. 2012). While *D. brevipes* is commonly found on *V. vinefera* roots, the pest has also been observed infesting leaves, stems and grape clusters (Daane et al. 2012; de Sá and de Morais Oliveira 2021), causing damage during harvest through sooty-mould facilitation (Daane et al. 2012). However, given surveys conducted by de Sá and de Morais Oliveira (2021) were in tropical semi-arid areas of Brazil (CMI 0.5), population densities of *D. brevipes* may not reach such a level to cause the same level of impact in New Zealand.

In addition, *D. brevipes* has also been identified as the vector of a number of plant viruses only associated with pineapple, banana and cacao (Table 1), including Pineapple mealybug wilt disease, which is the leading cause of economic loss in pineapple production (Jahn et al 2003; Dey et al 2018). Therefore, the mealybug has the potential to cause economic impacts on pineapple and banana horticulture in New Zealand. Mealybug wilt disease is associated with a number of Pineapple mealybug wilt-associated viruses (PMWaV), which *D. brevipes* acquires and transmits to host plants during feeding (Jahn et al. 2003). Importantly, PMWaV are present in a number of markets included in the scope of this IRA (Table 1). While these viruses are primarily associated with pineapple plants, it is unknown whether they have the capacity to transfer to a novel host species.

Trade disruptions and associated potential trade losses with countries that have international quarantine regulations would occur if *D. brevipes* were to establish in New Zealand. These countries are Egypt, French Polynesia, the Republic of Korea, Seychelles, and South Africa (ONZPR 2022). According to Plant & Food Research (2021), the Republic of Korea is one of the top ten export destinations in the kiwifruit (*Actinidia*) and squash (*Cucurbita*) markets, with a combined annual export value of $128 M. Given squash is a known host of *D. brevipes*, squash trade with the Republic of Korea may experience trade disruptions and associated trade losses if *D. brevipes* were to establish in New Zealand as a consequence of international quarantine regulations.

Uncertainty

There is moderate uncertainty associated with the likelihood of *D. brevipes* causing economic impacts in New Zealand. This is attributed to uncertainty associated with whether *D. brevipes* would cause similar levels of grape-crop damage experienced in Brazil. Given New Zealand's climate differs from the tropical semi-arid areas of Brazil (CMI 0.5), population densities of *D. brevipes* may not reach such a degree to cause the same level of impact in New Zealand.

Given that:

- Economically important hosts of *D. brevipes* in New Zealand include avocado (*Persea americana*), *Capsicum*, *Citrus* species (lemon and orange), grape (*Vitis vinifera*) and potato (*Solanum tuberosum*);
- direct and indirect damage caused to economically-important horticultural crops worldwide;
- trade disruptions and associated potential trade losses with countries that have international quarantine regulations would occur if *D. brevipes* were to enter and establish in New Zealand;

the economic impact of *Dysmicoccus brevipes* in New Zealand is considered to be VERY LOW, with MODERATE uncertainty.

Environmental impacts
While no direct evidence is available regarding whether native New Zealand plants could be potential hosts of *D. brevipes,* according to Beever et al. (2007), there are existing records of New Zealand native plants becoming hosts for introduced cosmopolitan mealybug species (MAF 2008). Examples include the vine pest *Pseudococcus calceolariae,* which has been recorded on kōwhai (*Sophora microphylla*), akeake (*Dodonaea viscosa*), *Coprosma australis* (*C. grandifolia*) and maire (*Nestegis lanceolata*) (MAF 2008). However, according to Brockerhoff et al. (2010), exotic oligophagous and polyphagous sapsuckers observed on native woody plants had minor impacts. This suggests, given *D. brevipes* is polyphagous, that the environmental impacts caused by the mealybug may also be minor.

In addition, a number of plant families that New Zealand native flora belong to include hosts of *D. brevipes*. For example, Asteraceae (including At Risk *Abrotanella rosulate* and *Abrotanella spathulata*), Cyperaceae (including Threatened *Carex albula* and *Carex capillacea*), Myrtaceae (including Threatened *Kunzea amathicola* and *Kunzea ericoides*), Orchidaceae (including Threatened *Caleana minor* and *Calochilus herbaceus*), and Poaceae (including At Risk *Agrostis oresbia* and *Agrostis pallescens*) (NZPCN 2022).

Uncertainty associated with potential environmental impacts caused by *D. brevipes* in New Zealand is attributed to a lack of evidence relating to whether native plants could be potential hosts of *D. brevipes*.

Given that:

- there are existing records of New Zealand native plants becoming hosts for introduced cosmopolitan mealybug species,
- a number of plant families that New Zealand native flora belong to include hosts of *D. brevipes*,

MPI considers the environmental impact of *Dysmicoccus brevipes* in New Zealand is VERY LOW, with MODERATE uncertainty.

Human health impacts
Searches using terms ‘Dysmicoccus brevipes’ in PubMed, Google Scholar, CAB Abstracts and Google found no mention of adverse effects on humans or animals. Hence, no direct evidence was found to indicate *D. brevipes* cause human health impacts.

However, there is indirect evidence *D. brevipes* has the potential to facilitate negative human-health impacts given the mealybug secretes honeydew, which attracts invasive *Vespula* wasps present in New Zealand (Harris 1991). High numbers of wasps in urban and recreational areas may adversely impact human health via stings and allergic reactions to stings (MAF 2008). However, given most of New Zealand has unsuitable or low habitat suitablilty for *D. brevipes*, with the exception of the northern North Island, populations are unlikely to reach levels that would significantly influence *Vespula* wasp population levels.

Given that:

- there is a lack of evidence indicating *Dysmicoccus brevipes* has adverse effects on humans or animals,
- there is a indirect evidence *Dysmicoccus brevipes* has potential to facilitate adverse human health impacts by attracting *Vespula* wasps via honeydew secretion,

MPI considers the human health impact of *Dysmicoccus brevipes* in New Zealand is NEGLIBLE, with LOW uncertainty.

Sociocultural impacts

Dysmicoccus brevipes has the potential to have sociocultural impacts in New Zealand, as the mealybug is associated with kūmara (*Ipomoea batatas*) and taro (*Colocasia esculenta*), both of which are culturally important to Māori (Maanaki-Whenua 2022). There is currently a lack of literature relating to the direct impacts on kūmara and taro. However, if heavy infestations of *D. brevipes* were to occur on these culturally significant species, the likely consequence would be the production of large quantities of honeydew that provides a medium for sooty moulds. Sooty-mould accumulation leads to a reduction in photosynthesic area (Jahn et al. 2003), which in turn results in a loss of plant vigour, fruit yield and in severe cases death (MAF 2008). In addition, the mealybug commonly feeds on the roots of host species (CABI 2021), further reducing horticultural yields. However, given most of New Zealand has unsuitable or low habitat suitablilty for *D. brevipes*, with the exception of the northern North Island, populations are unlikely to reach levels that would constitute heavy infestations of host.

Uncertainty associated with potential sociocultural impacts caused by *D. brevipes* in New Zealand is attributed to a lack of evidence relating to direct impacts of *D. brevipes* infestation on kūmara and taro crops.

Given that:

- *Dysmicoccus brevipes* is associated with kūmara (*Ipomoea batatas*) and taro (*Colocasia esculenta*), both of which are culturally important to Māori,
- there is currently a lack of literature relating to the direct impacts on kūmara and taro,

MPI considers the sociocultural impact of *Dysmicoccus brevipes* in New Zealand is VERY LOW, with MODERATE uncertainty.

8.1.3.6 Overall impact to New Zealand

MPI considers the overall impact of *D. brevipes* on the New Zealand economy, environment, health and society is LOW, with MODERATE uncertainty.

8.1.3.7 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is to be MODERATE, with LOW uncertainty,
- assuming entry, the likelihood of exposure is LOW, with MODERATE uncertainty,
- assuming successful exposure, the likelihood of establishment is considered to be LOW, with MODERATE uncertainty,
- the overall impact on the New Zealand economy, environment, human health, and society is considered to be LOW,

MPI considers the overall level of assessed risk to New Zealand from *Dysmicoccus brevipes* on pineapple fruit is LOW, with MODERATE uncertainty.

Note: Based on the risk assessment, the overall risk of *D. brevipes* can be at the high end of very low according to the 'Guideline for Risk Analysis in Plant Biosecurity 1.0'. However, given that *D. brevipes* has a very wide range of hosts, wide geographical distribution (including some areas with similar climate to New Zealand) and can be reproduce asexually, MPI considers that a low overall risk is more appropriate.

8.1.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *Dysmicoccus brevipes* association with pineapple fruit been observed?
Available literature indicates the *D. brevipes* is associated with pineapple plants in general, and does not appear to be variety specific. Furthermore, no information was found regarding ripeness association.

Which part(s) of the pineapple fruit is *Dysmicoccus brevipes* associated with (e.g. fruit, bract, stem or crown remnant) and is it detectable by visual detection?
Dysmicoccus brevipes is widely associated with pineapple plants, and has been reported infesting fruit, blossom cups, crowns, leaves and roots (CABI 2021)**.** While multiple surveys confirm *D. brevipes* infests *Ananas cosmosus* (pineapple) plants (Sether et al. 2001; Culik et al. 2007; Huang and Lin 2014; Moreno et al. 2021), only two surveys found specifically note that the mealybug was detected on 'pineapple fruit' (González-Hernández et al. 1999; Milek et al. 2009). Furthermore, *D. brevipes* is likely to be detectable by visual inspection as indicated by interception data at the New Zealand border between 1929 and 2019 (LIMS (2022).

Are different lifestages of the *Dysmicoccus brevipes* associated with different parts of the pineapple fruit?
New Zealand border interception data between 1928 and 2022 confirms the mealybug is commonly associated with pineapple fruit imported into New Zealand at all lifestages (LIMS 2022).

Does *Dysmicoccus brevipes* burrow into the fruit without obvious symptoms, and/or hides under the pineapple bract?
Symptoms on pineapple fruit infested with *D. brevipes* include discolouration, the presence of honeydew and sooty mould (CABI 2021). Given the biology of mealybugs in general, notably their small size, *D. brevipes* is likely to have the capacity to hide under pineapple bracts.

8.1.5 *References*

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8.2 *Dysmicoccus neobrevipes* (grey pineapple mealybug)

Dysmicoccus neobrevipes is a mealybug with a largely tropical distribution and a pest of pineapple, banana and other crops. It damages pineapple plants by sucking phloem sap, causing green spot and vectoring pineapple mealybug wilt disease. Sooty mould growth on mealybug honeydew exudates can affect plant photosynthesis and appearance.

8.2.1 *Taxonomic description*

Scientific name: *Dysmicoccus neobrevipes* Beardsley, 1959
Order: Hemiptera **Family:** Pseudococcidae
Other names: gray pineapple mealybug; Annona mealybug; annona mealybug; Banana-kona-kaigara-musi.

Taxonomic Notes:

- Beardsley (1959b) described *Dysmicoccus neobrevipes* as a new species in his taxonomic study of pineapple mealybugs in Hawaii. The species had previously been considered a form of *Dysmicoccus brevipes* (Cockerell) which is a closely related but distinct species. The grey and pink forms of *D. brevipes* studied in Hawaii by Ito (1938) are now known to be *D. neobrevipes* and *D. brevipes*, respectively.

8.2.2 *Hazard identification*

Dysmicoccus neobrevipes is not known to be present in New Zealand.

- There is no entry for *D. neobrevipes* in NZOR (2022) or BiotaNZ (2022).
- *Dysmicoccus neobrevipes* is listed as “not present” in New Zealand in PPIN (2022). *Dysmicoccus neobrevipes* is a regulated pest for New Zealand, and has unwanted status (ONZPR 2022).

Dysmicoccus neobrevipes has the potential to establish and spread in New Zealand.

- *Dysmicoccus neobrevipes* has a mainly tropical distribution but is also present in some subtropical areas. It has been recorded from locations in China (Kunming, 25˚2’18.39" N, 102˚ 39’53.26" E; (Wang et al. 2019)) and Ecuador (-78.153378, -1.399153) (Wei et al. 2020)) with a composite match index (CMI) of 0.7 or greater in a climate comparison with all of New Zealand (Phillips et al. 2018), indicating potential for *D. neobrevipes* to establish in parts of New Zealand, particularly warmer northern regions and sheltered environments.
- *Dysmicoccus neobrevipes* is polyphagous, with hosts reported from 40 plant families (García Morales et al. 2016). Hosts include citrus (*Citrus* spp.) which is grown both commercially and domestically in New Zealand especially in areas with climates more likely suited to *D. neobrevipes*. Other hosts, such as tomato (*Solanum lycopersicum*), eggplant (*Solanum melongena*) and *Acacia* spp., are also grown in New Zealand.
- *Dysmicoccus neobrevipes* reproduces sexually (Beardsley 1959b); adult females produce sex pheromones (Tabata and Ohno 2015) to attract adult males which, unlike the females, have wings. Adult females are ovoviviparous, producing large numbers of live nymphs (larvae) (Sartiami and Kondo 2022). The first instar nymph or crawler is the main dispersal stage and can move both actively for short distances and

passively by wind and by ants (Sartiami and Kondo 2022). Movement of infested plant material to new locations can spread the mealybug both locally and longer distances.

Dysmicoccus neobrevipes has the potential to cause harm to New Zealand.

- *Dysmicoccus neobrevipes* has the potential to harm plants of economic importance to New Zealand. Its best known hosts are pineapple and banana (*Musa*) (Curry 2022) which are grown in New Zealand and have potential for commercial production. Other hosts include citrus (*Citrus* spp.), tomato (*Solanum lycopersicon*), beans (*Phaseolus* spp.), and eggplant (*Solanum melongena*) (García Morales et al. 2016) which are commercial crops in New Zealand.

Dysmicoccus neobrevipes is associated with pineapple fruit.

- Pineapple is a host of *D. neobrevipes.* The mealybug is found on the aerial parts of the plant, including leaves, stems, flowers and fruit (Beardsley 1959b). Live immature and mature *D. neobrevipes* have been found inside the closed blossom cups of pineapple fruit (Jahn 1993).
- *Dysmicoccus neobrevipes* (live adults and nymphs) was intercepted at the border 18 times between 2005 and 2020 on fresh fruit of pineapple (*Ananas comosus*) imported from the Philippines, according to the LIMS (2022) database.

Given the arguments and evidence above, *Dysmicoccus neobrevipes* is considered to be a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

8.2.3 *Risk assessment*

8.2.3.1 Biology

Hosts and geographical distribution

Dysmicoccus neobrevipes is polyphagous and is associated with plant species in 67 genera in 40 plant families (García Morales et al. 2016). Pineapple and banana are the best known main hosts (Curry 2022). Sisal (*Agave sisalana*) is an important host in South China (Qin et al. 2011). Other reported hosts (Curry 2022) are listed in Table 7.5.

Table 7.5 Plants recorded as hosts for *Dysmicoccis neobrevipes* in Curry (2022) (and references therein). Although this list is not exhaustive, it indicates the wide range of families and species recorded as hosts. According to Curry (2022), ‘Main’ = main crop hosts on which economic damage occurs; ‘Other’ = other crops/plants attacked by the pest, but not as often or not as severely; ‘Unknown’ = host information sourced from a data mining exercise - the rank/importance has not been assessed by an author or editor.

Plant family	Plant name
Asparagaceae	**Main:** *Agave, Agave sisalana* (sisal hemp), *Polianthes, Polianthes tuberosa* (tuberose), *Yucca* **Unknown:** *Agave americana* (century plant), *Beaucarnea recurvata, Dracaena, Yucca elephantipes* (spineless yucca)
Annonaceae	**Main:** *Annona, Annona reticulata* (bullock's heart), *Annona squamosa* (sugar apple) **Unknown:** *Annona muricata* (soursop)

Apocynaceae	**Main:** *Wrightia arborea* (lanete) **Unknown:** *Plumeria* (frangipani)
Araceae	**Main:** *Aglaonema, Philodendron* **Unknown:** *Aglaonema commutatum*
Arecaceae	**Main:** *Cocos nucifera* (coconut)
Asteraceae	**Unknown:** *Helianthus* (sunflower), *Helianthus annuus* (sunflower)
Bignoniaceae	**Other:** *Crescentia alata*
Boraginaceae	**Unknown:** *Cordia alliodora* (Ecuador laurel), *Tournefortia argentea*
Bromeliaceae	**Main:** *Ananas comosus* (pineapple) **Unknown:** *Ananas*
Cactaceae	**Main:** *Opuntia* (prickly pear) **Unknown:** *Opuntia ficus-indica* (prickly pear), *Opuntia megacantha*
Celastraceae	**Unknown:** *Euonymus japonicus* (Japanese spindle tree)
Cucurbitaceae	**Main:** *Cucurbita maxima* (giant pumpkin)
Euphorbiaceae	**Main:** *Codiaeum* (ornamental croton) **Unknown:** *Jatropha integerrima* (peregrina)
Fabaceae	**Main:** *Acacia* (wattles), *Acacia farnesiana* (huisache), *Acacia koa* (koa), *Arachis, Cajanus, Phaseolus* (beans), *Samanea, Samanea saman* [syn. *Albizia saman*] (rain tree), *Vigna unguiculata* (cowpea) **Unknown:** *Arachis hypogaea* (groundnut), *Piscidia piscipula*, *Vigna unguiculata* subsp. *sesquipedalis* (asparagus bean), *Cajanus cajan* (pigeon pea)
Heliconiaceae	**Main:** *Heliconia* **Unknown:** *Heliconia latispatha*
Lamiaceae	**Main:** *Clerodendrum* (Fragrant clerodendron), *Tectona* **Unknown:** *Tectona grandis* (teak)
Lecythidaceae	**Main:** *Barringtonia* **Unknown:** *Barringtonia asiatica* (sea poison tree)
Myrtaceae	**Main:** *Psidium guajava* (guava)
Malvaceae	**Main:** *Gossypium* (cotton), *Theobroma*, *Theobroma cacao* (cocoa), *Thespesia*, *Thespesia populnea* (portia tree)
Moraceae	**Main:** *Artocarpus* (breadfruit trees), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit) **Unknown:** *Ficus*
Musaceae	**Main:** *Musa* (banana), *Musa acuminata* (wild banana), *Musa* x *paradisiaca* (plantain)
Pandanaceae	**Main:** *Pandanus* (screw-pine)
Pinaceae	**Unknown:** *Pinus* (pines)
Polygonaceae	**Main:** *Coccoloba* (sea grape) **Unknown:** *Coccoloba uvifera* (sea grape)
Primulaceae	**Main:** *Anagallis arvensis* (scarlet pimpernel)
Punicaceae	**Main:** *Punica, Punica granatum* (pomegranate)
Rubiaceae	**Main:** *Coffea* (coffee) **Unknown:** *Coffea arabica* (arabica coffee), *Coffea canephora* (robusta coffee), *Guettarda, Guettarda speciosa, Ixora*
Rutaceae	**Main:** *Citrus, Citrus aurantiifolia* (lime), *Citrus reticulata* (mandarin), *Citrus sinensis* (sweet orange) **Unknown:** *Citrus limon* (lemon)
Sapindaceae	**Main:** *Nephelium lappaceum* (rambutan)

Sapotaceae	**Main:** *Manilkara zapota* (sapodilla)
Solanaceae	**Main:** *Solanum lycopersicum* (tomato), *Solanum melongena* (eggplant)
Tamaricaceae	**Unknown:** *Tamarix aphylla* (athel)
Urticaceae	**Unknown:** *Pipturus argenteus*
Zingiberaceae	**Main:** *Alpinia, Alpinia purpurata* (red ginger)
Orchidaceae	**Unknown:** *Brassavola subulifolia*
Araliaceae	**Unknown:** *Nothopanax*

Dysmicoccus neobrevipes occurs widely in the tropics but can also be found in some subtropical areas (Table 7.6). Most of its recorded distribution has a low composite match index (CMI) when compared with all of New Zealand (Phillips et al. 2018) although some locations (China (Kunming, 25˚2’18.39" N, 102˚ 39’53.26" E; CMI 0.7 (Wang et al. 2019) and Ecuador (-78.153378, -1.399153), CMI 0.8 (Wei et al. 2020) have a CMI of 0.7 or greater, indicating similar climate conditions to most of New Zealand. *Dysmicoccus neobrevipes* has been recorded in countries in Europe (Italy, Lithuania, Netherlands), but it is not clear if any of these are records are for populations established in the field or if they occur only in sheltered environments such as glasshouses and indoor plantings. Sartiami and Kondo (2022) note that records from high latitudes are from under glass.

Table 7.6. Known geographic distribution of *Dysmicoccus neobrevipes*. Information compiled June 2022 from Curry (2022), García Morales et al. (2016) and (Shao 2022). Markets in bold are potential exporting markets under consideration in this import risk analysis.

Continent/Region	Country/area/market
Africa	Cote d’Ivoire, Uganda
Asia	Cambodia, China, India, **Indonesia**, Japan, Laos, **Malaysia**, Pakistan, **The Philippines**, Singapore, **Sri Lanka**, **Taiwan**, **Thailand**, Vietnam
Europe	Italy, Lithuania, Netherlands
North America	Antigua and Barbuda, Bahamas, Barbados, **Costa Rica**, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, **Panama**, Puerto Rico and Vieques Island (Puerto Rico), Trinidad and Tobago, US Virgin Islands, United States (Florida)
Oceania	American Samoa, **Cook Islands**, **Fiji**, Guam, **Hawaii** (USA), Kiribati, Marshall Islands, **New Caledonia**, Northern Mariana Islands, **Samoa**
South America	Brazil, Colombia, **Ecuador**, Peru, Suriname

Climate modelling using MaxEnt (Wei et al. 2020) indicates a very low probability of establishment for *D. neobrevipes* in New Zealand (< 25%) under the current and future climate scenarios they investigated. Thermal conditions influenced the modelled distribution for *D. neobrevipes* much more than precipitation, with the minimum temperature of the coldest month and mean temperature of the coldest quarter being the factors that had the greatest influence (Wei et al. 2020). The occurrence data used in the model was analysed using a climate matching tool (Phillips et al. 2018). The 35 data points coincided with 29 CMI cells, of which only 6.9% had CMI ≥ 0.7 when compared with all of New Zealand (CMI ≥ 0.7 indicating similar climate conditions to most of New Zealand).

Signs or damage

Mealybugs suck sap from the host plant which reduces plant vigour. Waxy exudates give a cottony appearance to the plant. Honeydew, or excreted plant sap, is found at mealybug feedings sites. Sooty moulds which grow on the excreted honeydew are also a sign that mealybugs are present. Pineapple leaves can develop green spotting from a reaction to a secretion from the mealybug (Martin Kessing and Mau 1992).

In many places where pineapples are grown, *D. neobrevipes* vectors pineapple mealybug wilt-associated viruses. Pineapple mealybug wilt disease, or mealy bug wilt of pineapple, can occur as either a slow or a quick wilt and has been a limiting factor contributing to the reduction of yield in many pineapple-growing countries (Dey et al. 2018). The leaves of diseased plants droop and dry out, and the plants produce either smaller fruit or no fruit, and yields are severely reduced (Martin Kessing and Mau 1992; Sether and Hu 2002; Sether et al. 2005). The disease has a complex etiology that is not fully understood. It appears to be associated with the presence of certain viruses, mealybug vectors, ants which can tend and spread the mealybugs, and environmental factors (Dey et al. 2018; Larrea-Sarmiento et al. 2021). Several pineapple mealybug wilt-associated virus (PMWaV) species have been recognised (*Pineapple mealybug wilt-associated virus 1* (PMWaV-1), PMWaV-2 and PMWaV-3) with other potential species yet to be characterised (e.g., Larrea-Sarmiento et al 2021). Pineapple mealybug wilt-associated viruses are in the genus *Ampelovirus*. Other viruses such as *Pineapple bacilliform CO virus* (PBCOV), a *Badnavirus* also vectored by *D. neobrevipes*, may also be involved with the disease (Sether et al. 2012; Dey et al. 2018). Pineapple mealybug wilt-associated viruses are not known to be present in New Zealand and are regulated species (ONZPR 2022). *Pineapple bacilliform CO virus* is also a regulated species (listed as Pineapple bacilliform virus) (ONZPR 2022).

Visibility or detectability

Adult females are oval, and around 1.5 mm long and 1.0 mm wide with a heavy coat of white mealy wax, often in tufts, and an overall greyish appearance (Beardsley 1959b). The mealybugs, which produce live young (ovoviviparous), often aggregate and when present in large numbers will be detectable by the cluster’s white cottony appearance, along with excreted honeydew and the sooty moulds that grow on it. Individual mealybugs may go undetected when populations are low, especially the early instars, and may be hidden in crevices on the pineapple fruit which has a complex architecture. Adults and other life stages have been found inside the closed blossom cup of the fruit and will not be detected unless the fruit is cut open (Jahn 1993).

Pineapple variety susceptibility

Generally, the pineapple variety has not been given for host records and other literature on *D. neobrevipes*. Given the wide host range across many plant families, it is likely that *D. neobrevipes* will feed on many or all pineapple varieties. The results from laboratory experiments using two named pineapple varieties (Qin et al. 2011), indicate *D. neobrevipes* may find some varieties of pineapple better hosts than others regarding reproductive rate and other developmental parameters.

Reproduction and spread

Dysmicoccus neobrevipes reproduces sexually (Beardsley 1959b). Adult females produce sex pheromones (Tabata and Ohno 2015) to attract adult males which, unlike the females, have wings. Eggs hatch inside the females which produce live nymphs (ovoviviparous) (Martin Kessing and Mau 1992). Females can produce large numbers of live nymphs (around 350 nymphs, although some can produce up to 1000 (Martin Kessing and Mau 1992)). Ito (1938) observed that “occasionally ovoid bodies, possibly eggs which were prematurely laid and which remained unhatched for a few days, were encountered, but these incidents were rare”.

The first instar nymphs or crawlers are the main dispersal stage and can move actively for short distances. For mealybugs, the data on how far crawlers can walk is variable but the distance is thought to be small (metres) (MPI 2014b). Crawlers are also moved passively by wind and by ants (including species present in New Zealand such as *Pheidole megacephala* (ONZPR 2022)). Movement of infested plant material to new locations can spread the mealybug both locally and longer distances.

Development

Population parameters for *D. neobrevipes*, such as fecundity, longevity and development times, are influenced by both climate and plant host (Ito 1938; Qin et al. 2011; Qin et al. 2013; Doan et al. 2016; Wei et al. 2020).

Ito (1938) studied the life history of *D. neobrevipes* under laboratory conditions by caging individuals in glass tubes and supplying them with leaves from pineapple crowns. The average temperature was 74.4° F [23.6^{o}C] with a maximum of 83.9° F [28.8^{o}C] and a minimum of 61.3° F [16.3^{o}C]. Females moulted three times before reaching maturity. Adult females (20) produced on average 347 progeny (first instar nymphs). The average length of life (first instar to death of adult) was 95 days for mated females and 148 days for unmated females. Males moulted four times before reaching the winged, adult stage and fed only during the first two instars. They lived for an average length of 37 days (first instar to death of adult) and had an active adult life of about two days from the time of emerging from their cocoons until death.

Doan et al. (2016) reared *D. neobrevipes* on the surface of pumpkin (*Cuscuta moschata*) in the laboratory at 28 ± 2 °C and 70 ± 5% RH. The total life cycle (1st instar nymph to adult) was 30.5 ± 0.3 days (mean ± SE).

A study by Qin et al. (2011) indicated that host plant can influence the population dynamics of *D. neobrevipes*. Laboratory studies were carried out on four host plants (*Agave sisalana*, *Ag. americana* var. *marginata*, *Ananas comosus* Baili and *An. comosus* Smooth Cayenne) at 26 + 1 ^{o}C, 75–90% RH and 14:10 (L:D) photoperiod. The development, survivorship, longevity, reproduction and life table parameters of *D. neobrevipes* differed among the host plants. In their study, the shortest developmental period (first instar nymph to adult) was recorded on *An. comosus* Smooth Cayenne (22.4 days for females and 21.3 days for males), and the longest was recorded on *An. comosus* Baili (25.6 days for females and 24.7 days for males). The highest survivorship was on *An. comosus* Baili (98% for both females and males) and the lowest was on *Ag. americana* var. *marginata*. Fecundity and values for net reproductive rate, intrinsic rate of increase and finite rate of increase were highest on *Ag. sisalana*. The mean generation time was shortest on *An. comosus* Smooth Cayenne.

Qin et al. (2013) investigated the development, survivorship, longevity and reproduction of *D. noebrevipes* on sisal (*Agave sisalana*) using six constant temperatures (17, 20, 23, 26, 29 and 32 ^{o}C) under laboratory conditions. They estimated the lower temperature thresholds for females and males from the first instar nymph to adult to be 8.7 and 10.3 ^{o}C, respectively. The thermal constants for females and males were 370.4 and 312.5 degree-days (DD) respectively. Their results indicated that the optimum temperature range for population growth of *D. neobrevipes* is 23–29 ^{o}C. In their study, the developmental period of *D. neobrevipes* females (from the first instar nymph to adult) on sisal was 16.9 days at 29 ^{o}C and 55.4 days at 17 ^{o}C while that of the males was 16.2 days at 29 ^{o}C and 54.0 days at 17 ^{o}C. The average longevity of adult females and males was 30.0 days and 2.5 days respectively at 26 °C, and increased to 95.0 days and 5.6 days respectively at 17 °C. The average number of nymphs laid per female reached a maximum (409.4) at 23°C.

8.2.3.2 Likelihood of entry

Dysmicoccus neobrevipes has a mainly tropical distribution but is also found in some subtropical locations (Table 1). It is present in most of the markets in scope for this IRA: Costa Rica (Williams and Granara de Willink 1992), Ecuador (Williams and Granara de Willink 1992), Panama (Williams and Granara de Willink 1992), Sri Lanka (Sirisena et al. 2013), the Philippines (Beardsley 1959b), Malaysia (Williams 2004), Indonesia (Gavrilov-Zimin 2017), Thailand (Williams 2004), Taiwan (Shao 2022), Fiji (Beardsley 1965), New Caledonia (Mille et al. 2016), Cook Islands (Williams and Watson 1988), Samoa (Williams and Watson 1988).

Pineapple is one of the main hosts of *D. neobrevipes* (Curry 2022). The mealybug is found in many areas where pineapple is grown (Martin Kessing and Mau 1992) and can be an economically important pest affecting commercial production (Beardsley 1959b; Martin Kessing and Mau 1992).

D. neobrevipes is found on the aerial parts of the plant, including leaves, stems, flowers and fruit (Beardsley 1959b; Jahn et al. 2003). As well as feeding on the external surface of fruit, the mealybugs can live inside closed blossom cups (blossom cavities) of pineapple fruit. Jahn et al. (2003) examined 30 unripe pineapple fruits from an abandoned field in Hawaii and found that all fruits contained live mature and immature *D. neobrevipes* in over half of their blossom cups. In addition, live adults and nymphs have been intercepted multiple times at the New Zealand border on fresh pineapple fruit imported from the Philippines (LIMS 2022). These observations indicate that all life stages of *D. neobrevipes* can be associated with pineapple fruit at different stages of fruit maturity.

Infestations may be visible on pineapple crops in the field as white cottony clusters, along with sugary honeydew excretions and sooty mould growth, and associated green spotting on leaves, especially when the infestation level is high. However, at low levels of infestation, *D. neobrevipes* may be difficult to detect in the field because of its small size and tendency to feed deep in the leaf axils, under sepals, and inside blossom cups (Jahn et al. 2003).

In-field management is likely to take place where *D. neobrevipes* occurs in commercial pineapple crops, partly because *D. neobrevipes* itself and associated sooty moulds affect the growth and appearance of pineapples. However, in many places *D. neobrevipes* also vectors pineapple mealybug wilt-associated viruses which cause pineapple mealybug wilt disease whereby leaves droop and dry out, plants produce either smaller fruit or no fruit, and yields are severely reduced (Martin Kessing and Mau 1992; Sether and Hu 2002; Sether et al. 2005).

During the post-harvest period, mealybugs on the surface of pineapple fruit are likely to be both detected and removed to some degree by general handling and processing, including measures such as washing, in the packhouse. However, pineapple fruit has complex surface architecture, and it is much more difficult to detect or remove mealybugs hidden in crevices, especially when infestation rates are low. In addition, live adults and immatures inside blossom cups will not be detected by visual inspection of the fruit surface or be removed by general processes in the packhouse.

Dysmicoccus neobrevipes may remain viable through freight transit times and conditions. Storage and transport of pineapple consignments from export markets to New Zealand are likely to occur at cool temperatures, with the length of time for shipment depending on the export market (Appendix 2). Recommended cold storage conditions for pineapple are temperatures 7–13°C and relative humidity at 85–90% moisture (Appendix 2). The approximate storage life of the commodity under these conditions is 14–28 days (2–4 weeks). Live adults and nymphs of *D. neobrevipes* have been intercepted at the border from fresh fruit of pineapple (*Ananas comosus*) imported from the Philippines (18 records between 2005 and 2020 in the LIMS (2022) database). The estimated shipping time from Manila in the Philippines to Auckland, New Zealand is 2–3 weeks (Appendix 2). Therefore, some *D. neobrevipes* adults and nymphs will survive transit, depending on transport temperatures and times.

Uncertainty

Based on the above information there is low uncertainty on the rating for likelihood of entry. There is strong evidence that *D. neobrevipes* is associated with pineapple fruit and is widely distributed in areas where pineapple is grown commercially. Frequent interceptions at the border of live adults and immature stages of *D neobrevipes* support its association with the commodity post-harvest, and its ability to survive freight transit times and conditions for at least some of the pathways.

Given that:

- Pineapple is one of the main hosts of *D. neobrevipes* and all life stages of the mealybug are associated with the fruit;
- However, some in-field management is likely in commercial production because *D. neobrevipes* is a vector of pineapple mealybug wilt disease;
- Post-harvest processes are not likely to remove all mealybugs from infested fruit due to their small size, tendency to hide and occurrence inside blossom cups on fruit;
- *Dysmicoccus neobrevipes* adults and immatures can survive freight transit times and conditions;

MPI considers the likelihood of *Dysmicoccus neobrevipes* entering New Zealand associated with pineapple fruit is MODERATE, with LOW uncertainty.

8.2.3.3 Likelihood of exposure

This assessment is made on the basis that Dysmicoccus neobrevipes *has entered New Zealand undetected.*

Imported fresh pineapple fruit for human consumption will be distributed throughout New Zealand for wholesale or retail sale to consumers. Fresh pineapples produce large amounts of unavoidable waste. The thick skin is always removed, and the disposal of the fruit skin may aid the exposure of mealybugs. In New Zealand, the most common method of disposing organic waste is by bagging the waste and sending it to landfill (Askarany and Franklin-Smith 2014); section 2.3.1) which is unlikely to result in successful exposure. However, other methods, such as composting, animal feed and direct disposal into the environment, could potentially aid the exposure of *D. neobrevipes*.

Commerical composting and worm farming are considered low risk methods of waste disposal. Waste in commercial compost is put into tunnels for a period of at least three to four days at temperatures of 55 °C or higher for pasteurisation (section 2.3.1) and these conditions are likely to kill all stages of *D. neobrevipes*. For worm farming, organic waste is generally cut into small pieces (Angima et al. 2011) which are put into a contained structure preventing the mealybug from reaching the external environment.

Disposal methods where the mealybug can encounter the external environment pose a higher risk of transfer to a new host plant. A study conducted in Palmerston North found that 63% of a total of 72 households that did home composting used manufactured plastic bins for composting and the majority of others used an ‘open’ composting system, such as open compost piles and piles fenced with wire (Mensah 2017). Even though both home composting methods increase the likelihood of exposure of the mealybug to nearby host plants in gardens, compost in plastic bins is lower risk than open compost largely due to a higher level of containment. Fruit waste in commercial settings (e.g., supermarket preparation rooms) may be collected from unpacking areas and taken to rural locations where it is placed on the ground for eventual consumption by pigs or other farmed animals (MPI 2014b). Direct disposal of pineapple fruit skin into the environment (e.g. by roadsides, parks, campsites) could potentially aid the exposure of the mealybug.

Dysmicoccus neobrevipes may survive and develop on the surface of pineapple fruit (whole or skin pieces) as the fruit skin is robust and does not break down as quickly as softer skinned fruits. Some adult females survived on the surface of harvested pineapple fruits held at 23–24^{o}C for at least the 8-week duration of a laboratory experiment (Jahn and Beardsley 1996) and pumpkin (*Cucurbita moschata*) fruits held at 28 ± 2 °C were used to rear > 30,000 *D. neobrevipes* in the laboratory (Doan et al. 2016). Crawlers are the main dispersal stage and can walk short distances. The movement of crawlers from inside piles of organic matter will be limited but crawlers at the edges of piles can search for suitable host plants within a limited area. Crawlers at the top of piles can be passively dispersed by wind or by feeding animals. However, crawlers that are passively dispersed are unable to actively choose to land on a suitable host plant. Successful exposure therefore depends on suitable hosts being very close to the waste pile or to where the mealybug lands after wind dispersal. If no host is available nearby, the crawler is vulnerable to predation, dehydration or being washed away by the rain (Mendel et al. 1984).

Dysmicoccus neobrevipes is polyphagous, and known hosts such as beans, tomato, citrus, sunflowers, wattle and eggplant are often found in home gardens or grow as weeds (e.g, Japanese spindle tree, *Euonymus japonicus*) or as commercial crops (e.g. citrus) in New Zealand. Therefore, suitable host plants are likely to be available especially in warmer northern regions of the North Island.

Temperature will affect the ability of crawlers to develop and to move to enable dispersal and settling on a new host. Ambient temperatures will vary according to location and time of year. Qin et al. (2013) estimated the lower temperature thresholds for females and males of *D. neobrevipes* from the 1st instar nymph to adult to be 8.7 and 10.3 ^{o}C, respectively. In their study, using six constant temperatures (17, 20, 23, 26, 29 and 32 ^{o}C) under laboratory conditions, the developmental period of *D. neobrevipes* females (from the first instar nymph to adult) on sisal (*Agave sisalana*) was 55.4 days at 17 ^{o}C while the males’ was 54.0 days at

17 °C. The average longevity of adult females and adult males was 95.0 days and 5.6 days respectively at 17 °C.

Uncertainty
Information on food waste in New Zealand is based on general data and there is no specific information on pineapple waste to inform the likelihood of exposure for *D. neobrevipes*. However, it is assumed that pineapple will form a very small part of total food waste.

Given that:

- *Dysmicoccus neobrevipes* may survive and develop on the surface of pineapple fruit (whole or skin pieces);
- Fresh pineapples produce large amounts of unavoidable waste as skins and whole fruit, most of which is disposed of using methods that pose low risk of transfer to a new host;
- However, some waste is disposed of by methods that pose a higher risk of transfer to a new host, including composting in gardens and using it as animal feed;
- Crawlers, which are the main dispersal stage and are flightless, can move short distances actively or long distances passively;
- Crawlers are vulnerable to extremes of temperature and humidity, predation and other factors that result in mortality;
- Crawlers that are wind or animal dispersed are unable to actively choose to land on a suitable host plant;
- *Dysmicoccus neobrevipes* is polyphagous, and known hosts grow in New Zealand as commercial crops, in domestic gardens and as weeds;

MPI considers the likelihood of exposure of *Dysmicoccus neobrevipes* in New Zealand from pineapple fruit is LOW, with MODERATE uncertainty.

8.2.3.4 Likelihood of establishment

This assessment is made on the basis that Dysmicoccus neobrevipes *has been successfully exposed to a suitable host plant in the New Zealand environment.*

Dysmicoccus neobrevipes is found largely in tropical areas extending to some subtropical areas, so it is likely that climate conditions through most of New Zealand do not favour its establishment. Most countries/areas where *D. neobrevipes* is present have a low composite match index (CMI <0.7) with all of New Zealand, indicating low similarity in climate. Records of *D. neobrevipes* from higher latitudes (e.g., Italy (Longo et al. 1995) and Lithuania (Malumphy et al. 2008)) are from protected situations such as glasshouses and indoor plantings (Sartiami and Kondo 2022). However, the mealybug has been recorded from a (field-collected) location in China (Kunming, 25˚2’18.39" N, 102˚ 39’53.26" E; Wang et al. (2019)) with CMI 0.7 and a location in Ecuador (-78.153378, -1.399153, Wei et al. (2020)), with CMI 0.8, indicating some potential for *D. neobrevipes* to establish in parts of New Zealand, particularly warmer subtropical northern regions of the North Island and in sheltered environments.

Wei et al. (2020) used MaxEnt to develop models for the potential distribution of *D. neobrevipes* under climate change scenarios. The predicted distribution maps based on their models indicate that the probability of establishment in New Zealand is very low (< 25%) for

D. neobrevipes in the current and future climate scenarios investigated. The minimum temperature of coldest month and mean temperature of coldest quarter were the major factors influencing the distribution of *D. neobrevipes* in their models.

Qin et al. (2013) estimated the lower temperature thresholds for female and male *D. neobrevipes* from the first instar nymph to adult to be 8.7 and 10.3 ^{o}C, respectively. The thermal constants for females and males were 370.4 and 312.5 degree-days (DD) respectively. The results of their laboratory study indicated that the the optimum temperature range for population growth of *D. neobrevipes* was 23–29 ^{o}C and that *D. neobrevipes* continued to develop and reproduce, albeit more slowly, at 17 ^{o}C which was the lowest of the constant temperatures used in their study. Based on this information, there are likely to be locations in Northland where *D. neobrevipes* can develop. However, the number of generations per year is likely to be low compared with most places where the mealybug is established. For example, the average growing degree-day totals above base 10^{o}C at the Kaitaia Observatory in Northland are 2086 annually (Chappell 2013).

Climate is, therefore, likely to limit the establishment of *D. neobrevipes* in most of New Zealand, but there may be locations in the subtropical region in the north of the North Island that would allow establishment and suitable locations are likely to increase as climate changes. In addition, populations could survive in sheltered environments, including glasshouses.

Hosts are available in the parts of New Zealand that are most climatically suitable for establishment. *Dysmicoccus neobrevipes* is polyphagous on a range of unrelated plant species. Some of these hosts are grown in home gardens and amenity areas (e.g., beans, tomato, citrus, eggplant, pumpkin, yucca, wattles), and as commercial crops (e.g., citrus, tomato, eggplant) or occur as environmental weeds (e.g, Japanese spindle tree, *Euonymus japonicus*), especially in the warmer northern regions of New Zealand. The most well-known hosts, pineapple and banana, although not widely grown in New Zealand, are more likely to occur in the subtropical northern region.

Dysmicoccus neobrevipes reproduces sexually. Adult females, which are wingless, produce pheromones that attract the winged males which increases the likelihood of a female finding a mate. Females are ovoviparous, producing live young rather than eggs which develop inside the body. Females produce around 350 nymphs, although some can produce up to 1000 (Martin Kessing and Mau 1992).

First instar nymphs or crawlers are the main dispersal stage and are capable of moving short distances to reach a new feeding site. Crawlers can also be moved passively by wind. Although a wind-dispersed crawler is unable to actively choose where it lands, the large numbers of crawlers produced by a single female increase the likelihood of reaching a suitable host plant. Ants, which feed on honeydew, have been observed moving *D. neobrevipes* to new locations. The big headed ant *Pheidole megacephala*, which is associated with *D. neobrevipes* in Hawaii (Jahn and Beardsley 1996), is also present in New Zealand and may enable some mealybugs to move to nearby plants. Mealybugs can be moved over longer distances in infested plant material and produce and other contaminated items.

Uncertainty

There is uncertainty around the suitability of the climate for establishment in New Zealand. Although *D. neobrevipes* occurs in subtropical areas, the northern subtropical region of New

Zealand appears not well-suited to establishment based on known geographic distribution, CMI values and the results of a modelling study. However, it can’t be ruled out that there are locations within the region that are climatically suitable and that these may increase with climate change.

Given that:

- Climate may limit the establishment of *D. neobrevipes* in most of New Zealand but may not be a limiting factor for the mealybug to establish in the warmer northern region of the North Island and in sheltered environments;
- *Dysmicoccus neobrevipes* is polyphagous and hosts are available in the parts of New Zealand most climatically suited for establishment;
- *Dysmicoccus neobrevipes*, which reproduces sexually, uses sex pheromones to attract males which increases the likelihood of finding a mate;
- *Dysmicoccus neobrevipes* has a moderate to high fecundity producing around 350 to 1000 live young;
- First instar crawlers are the main dispersal stage and can move actively for short distances to reach new feeding sites, and passively by wind, animals and movement of infested plant material and produce;

MPI considers the likelihood of *Dysmicoccus neobrevipes* establishing in New Zealand is VERY LOW, with MODERATE uncertainty.

8.2.3.5 Impacts in New Zealand

This assessment is made on the assumption that Dysmicoccus neobrevipes *has successfully established in the New Zealand environment*

Economic impacts

Pineapple and banana, the best known hosts of *D. neobrevipes* are not well-established industries in New Zealand but there are currently growers of both these crops with potential for these industries to develop, especially in the warmer areas of New Zealand where the climate is most suited to establishment of *D. neobrevipes*. Establishment of *D. neobrevipes* could affect these emerging industries through additional pest control costs. *Dysimicoccus neobrevipes* is a vector for viruses associated with pineapple mealybug wilt disease which has a high economic impact on commercial production of pineapples elsewhere, e.g., Hawaii (Beardsley 1959b). However, pineapple is the only known host for pineapple mealybug wilt-associated ampeloviruses which are absent from New Zealand and are regulated organisms (ONZPR 2022).

Other recorded hosts of *D. neobrevipes* that are grown commercially in New Zealand include citrus (orange, mandarin, limes), tomato and eggplant. No specific information was found in the literature on the impact of *D. neobrevipes* on these industries elsewhere. The presence of *D. neobrevipes* may require additional control measures if existing measures for other pests are insufficient to manage the mealybug. New Zealand has established chemical treatments against a range of mealybugs (Charles 2004), however, these are not used in all situations such as when populations are low enough to not cause significant problems.

Crops that are most likely to be directly impacted by *D. neobrevipes* are those growing in the subtropical areas in the northern part of the North Island because climate is more suitable than in other parts of the country. However, even in this region *D. neobrevipes* may not reach population levels that have a high impact on crop production as the climate is likely to limit the number of generations per year compared with most regions where the mealybug occurs (see 1.1.4.4).

Crops that are often grown in commercial glasshouses, such as tomatoes, are likely to have existing pest management measures to manage mealybugs and other pests and may not require additional measures to manage *D. neobrevipes*.

An in-house MPI model[49] predicted a negligible to very low level of economic impact over 20 years.

- Assumptions: given that no report was found on infestation/yield loss caused by *D. neobrevipes* for any plant hosts important for New Zealand but that the mealybug is known to be able to cause damage to plants, 1% – 5% was assumed to be the range of greatest level of impact that the mealybug can have on a known main host[50]. The model only considered the impact on production in Northland as this is the area where *D. neobrevipes* is most likely to establish in New Zealand. The plant host considered was citrus which is a main host for *D. neobrevipes* and one of the main horticultural crops in Northland.
- The greatest level of annual impact: combined domestic and export value in New Zealand for citrus is NZ$71.6m[51]. The proportion of production area in Northland compared to the whole of New Zealand is 18% for citrus[52]. As such, the annual crop value for citrus in Northland was calculated to be NZ$13m. The greatest level of annual impact in Northland is 1–5% of this value.
- It is assumed that the mealybug would take 5 years to achieve the greatest impact based on its dispersal capability.
- As New Zealand already has effective control approaches and programmes for mealybugs, it is assumed the industry would take 1–2 years for full recovery.
- In addition to considering the impact on citrus in Northland, the model was used to consider the impact on five other crops that were of less significance in Northland but represented known main hosts of *D. neobrevipes* (from Curry 2022), and other recorded hosts from the literature. However, with the addition of these five crops, the model continued to predict a negligible to very low level of economic impact over 20 years.

The presence of *D. neobrevipes* in New Zealand may affect existing requirements for some exported produce. China, Japan, Mexico and South Korea have quarantine regulations for this mealybug (ONZPR 2022) and it is a high priority pest of pineapples in Australia where it is absent (Plant Health Australia 2022).

Uncertainty

There is uncertainty on the suitability of the New Zealand climate for *D. neobrevipes* to establish and reach levels that would be damaging to hosts in commercial production. There is also a lack of information in the literature on damage to host plants that are of economic importance to New Zealand.

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[49] Main inputs to the model are greatest level of annual impact, time taken to achieve the greatest impact and time taken to full recovery.

[50] Host status according to Curry (2022)

[51] Export values were taken from Plant & Food Research (2021) and domestic values were taken from Plant & Food Research (2020) because they were not provided in the former.

[52] Values are percentage of New Zealand production area (Plant & Food Research 2021).

Given that:

- Cultivated plants of economic importance to New Zealand are known hosts of *D. neobrevipes* but no specific information was found in the literature on the impact of *D. neobrevipes* on these industries elsewhere;
- Controlling *D. neobrevipes* could increase production costs for some crops, however New Zealand has established chemical treatments against a range of mealybugs.
- There could be increased phytosanitary requirements for some of New Zealand's export crops;
- Climate is likely to limit the establishment of *D. neobrevipes* to warmer northern regions of the North Island and sheltered environments;
- *Dysmicoccus neobrevipes* may have difficulty reaching population levels that have a high impact on crop production as the climate is likely to limit the number of generations per year;

MPI considers the economic impact of *Dysmicoccus neobrevipes* in New Zealand is VERY LOW, with MODERATE uncertainty.

Environmental impacts

Dysimicoccus neobrevipes is a polyphagous species with recorded hosts in 40 plant families (García Morales et al. 2016). None of the known host species are native to New Zealand. Given the wide host range across many plant families there is potential for some New Zealand species to be hosts but there is no evidence that *D. neobrevipes* is likely to have unwanted impacts on any native species. *Dysmicoccus neobrevipes* can damage plants directly by feeding on sap, and by excreting honeydew which enables sooty mould growth that can inhibit plant photosynthesis. Beever et al. (2007) reported that 25% of exotic mealybugs established in New Zealand have been recorded to attack native plants, and most introduced species that attack native plants are polyphagous. However, these authors also pointed out that highly damaging polyphagous species appear to be exceptional, and that the impact of relatively specialised organisms is likely to be greater.

Given *D. neobrevipes* has a mostly tropical distribution that extends into subtropical areas, establishment is more likely in warmer northern regions of the North Island. Temperature is likely to restrict population growth and direct impacts on plants are likely to be within a limited area in New Zealand.

Uncertainty

There is a lack of specific information on which native New Zealand plant species could act as hosts for *D. neobrevipes* and what the level of impact would be on these plant species.

Given that:

- *Dysmicoccus neobrevipes* has a wide range across many plant families which means there is potential for some New Zealand native plant species to be hosts;
- There are records of exotic mealybugs attacking native plants in New Zealand, but severe damage or outbreaks have not been recorded;
- *Dysmicoccus neobrevipes* is likely to have a very limited distribution due to climatic factors;

MPI considers the environmental impact of *Dysmicoccus neobrevipes* in New Zealand is VERY LOW, with MODERATE uncertainty.

Human health impacts
There are no known direct human health impacts associated with *D. neobrevipes.*

Given that:

- There are no known direct human health impacts associated with *D. neobrevipes*;

MPI considers the human health impact of *Dysmicoccus neobrevipes* in New Zealand is NEGLIGIBLE, with LOW uncertainty.

Sociocultural impacts
Dysimicoccus neobrevipes is polyphagous and some of its plant hosts are grown as amenity and home garden plants, for example, tomato (*Solanum lycopersicum*), eggplant (*S. melongena*), lime (*Citrus aurantiifolia*), mandarin (*C. reticulata*), sweet orange *(C. sinensis*), pomegranate (*Punica granatum*), guava (*Psidium guajava*), beans (*Phaseolus*), wattle (*Acacia*), giant pumpkin (*Cucurbita maxima*), pineapple (*Ananas comosus*), sunflower (*Helianthus annuus*), *Samanea saman* and *Yucca*.

None of the known host plant species for *D. neobrevipes* are native to New Zealand, although poroporo (*Solanum laciniatum* and *S. aviculare)* is in the same genus as recorded hosts of *D. neobrevipes* (*Solanum lycopersison*, *S. melongena*). Given the wide host range across many plant families there is potential for some New Zealand species to be hosts but there is no evidence that *D. neobrevipes* is likely to have unwanted impacts on any culturally significant species.

Dysmicoccus neobrevipes can directly damage plants by feeding on sap, and by excreting honeydew which enables sooty mould growth that can inhibit plant photosynthesis. Honeydew deposits and associated sooty moulds can be unsightly on both plants and items below affected plants. Infestations of *D. neobrevipes* may lead to additional pest control costs or loss of produce for home gardeners who are not already controlling other mealybugs.

Given *D. neobrevipes* has a mostly tropical distribution that extends into subtropical areas, establishment is more likely in warmer northern regions of the North Island. Temperature is likely to restrict population growth and direct impacts on plants are likely to be within a limited area in New Zealand.

Uncertainty
There is a lack of specific information on which native New Zealand plant species could act as hosts for *D. neobrevipes* and what the level of impact would be on these plant species.

Given that:

- *Dysmicoccus neobrevipes* is polyphagous and some of its known hosts are grown as garden and amenity plants in New Zealand;
- Given the wide host range across many plant families there is potential for some New Zealand species to be hosts, but there is no evidence that *D. neobrevipes* is likely to have unwanted impacts on any culturally significant species;
- *Dysmicoccus neobrevipes* is likely to have a very limited distribution due to climatic factors;

MPI considers the sociocultural impact of *Dysmicoccus neobrevipes* in New Zealand is VERY LOW, with MODERATE uncertainty.

8.2.3.6 *Overall impact to New Zealand*

MPI considers the overall impact of *Dysmicoccus neobrevipes* on the New Zealand economy, environment, health and society is VERY LOW, with MODERATE uncertainty.

8.2.3.7 *Overall risk to New Zealand*

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is MODERATE, with LOW uncertainty,
- assuming entry, the likelihood of exposure is LOW, with MODERATE uncertainty,
- assuming successful exposure, the likelihood of establishment is VERY LOW, with MODERATE uncertainty,
- the overall impact on the New Zealand economy, environment, human health, and society is considered to be VERY LOW, with MODERATE uncertainty,

MPI considers the overall level of assessed risk to New Zealand from *Dysmicoccus neobrevipes* on pineapple fruit is NEGLIGIBLE, with MODERATE uncertainty.

8.2.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *Dysmicoccus neobrevipes* association with pineapple fruit been observed?

- *Dysmicoccus neobrevipes* has been recorded on pineapple fruit of varying stages of ripeness, including green fruit and mature fruit. It has frequently been intercepted on fruit that has been commercially produced and shipped to New Zealand, and therefore is likely to be present on pineapple fruit of the level of maturity that meets the commodity description for this IRA.
- No information was found in the literature to indicate that *D. neobrevipes* is specific to some pineapple varieties or that some varieties are not hosts. A study on the effects of host plant on the development, survivorship and reproduction of *D. neobrevipes* found differences in these parameters for mealybugs reared on the two varieties, *Ananas comosus* Baili and *A. comosus* Smooth Cayenne in laboratory conditions (Qin et al. 2011). Given *D. neobrevipes* is polyphagous across many plant families and is associated with pineapple in many regions where the plant is grown, it is likely all pineapple varieties are hosts, but some may be better than others.

Which part(s) of the pineapple fruit is *Dysmicoccus neobrevipes* associated with (e.g. fruit, bract, stem or crown remnant) and is it detectable by visual detection?

- *Dysmicocccus neobrevipes* is a sap-sucking insect found on all aerial parts of the host plant, including fruit. It tends to feed deep in sheltered parts of the plant such as leaf axils, under sepals, and inside blossom cups (Jahn 1993; Jahn et al. 2003). Therefore, although it is possible for *D. neobrevipes* to occur anywhere on the fruit surface, it is more likely to be found in sheltered locations such as under bracts and inside blossom cups.
- Adult females, which are around 1.5 mm long and 1.0 mm wide with a heavy coat of white mealy wax (Beardsley 1959), can be visually detected on the fruit surface, and mealybugs often aggregate in groups that are visible as white cottony clusters, with excretions of sugary honeydew that are a substrate for sooty mould growth. However,

D. neobrevipes may go undetected at low numbers, especially at the crawler stage. Mealybugs inside closed blossom cups will go undetected no matter the life stage.

Are different lifestages of the *Dysmicoccus neobrevipes* associated with different parts of the pineapple fruit?

- All life stages (from crawlers to adults) are associated with pineapple fruit. However, adult males are winged, capable of flight and short-lived and so are not likely to remain associated with fruit that has been handled. Given *D. neobrevipes* is an external feeder on plant surfaces, it can be found on any part of the fruit surface. Females produce live young and although the crawlers are mobile, mealybugs at different developmental stages are often found together in clusters.

Does *Dysmicoccus neobrevipes* burrows into the fruit without obvious symptoms, hides under the pineapple bract?

- Although *D. neobrevipes* feeds on plant surfaces, it tends to hide in protected parts of the pineapple surface, including bracts and blossom cups (Jahn et al. 2003), reducing the likelihood of visual detection. All life stages can occur inside closed blossom cups (Jahn 1993) and go undetected by visual inspection, unless the fruit is cut open.

8.2.5 *References*

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8.3 *Ferrisia virgata* (striped mealybug)

Ferrisia virgata is a mealybug species with a widespread tropical and subtropical distribution. It is also found in some temperate areas. It is highly polyphagous, with hundreds of reported host plant species, including pineapple. Many host plants are of economic importance to New Zealand, for example citrus, tomato and grapevine.

8.3.1 *Taxonomic description*

Scientific name: *Ferrisia virgata* (Cockerell, 1893)
Order: Hemiptera **Family:** Pseudococcidae
Other names: *Dactylopius ceriferus*; *Dactylopius magnolicida*; *Dactylopius segregatus*; *Dactylopius setosus*; *Dactylopius talini*; *Dactylopius virgatus farinosus*; *Dactylopius virgatus humilis*; *Dactylopius virgatus madagascariensis; Dactylopius virgatus*; *Ferrisia neovirgata; Ferrisiana setosus*; *Ferrisiana virgata; Pseudococcus bicaudatus; Pseudococcus magnolicida; Pseudococcus marchali; Pseudococcus segregatus; Pseudococcus virgatus farinosus; Pseudococcus virgatus humilis; Pseudococcus virgatus madagascariensis; Pseudococcus virgatus* (García-Morales et al. 2016; DAWR 2019); striped mealybug; grey mealybug; guava mealybug; white-tailed mealybug

Taxonomic notes:
Ferrisia virgata has been recognised as a species complex for many years (Ben-Dov 1994; Gullan et al. 2010). Based on nucleotide sequence data, Gullan et al. (2010) recognised that some mealybugs previously referred as "*F. virgata*" in the USA were genetically different from those in Thailand, Ghana, South Africa, Mexico and Jamaica. Later, Kaydan and Gullan (2012) revised the genus *Ferrisia* and redescribed *F. virgata*, distinguishing it from related species. They recognised 18 species in the genus, eight of them new to science.

Ferrisia virgata is easily confused with *F. malvastra* (Ben-Dov 1994). These two species are highly similar morphologically and very difficult to distinguish based on simple superficial features. *Ferrisia virgata* is reported to be biparental except from the observation in Awadallah et al. (1979b), whereas reproduction in *F. malvastra* is parthenogenetic. Descriptions of *F. virgata* before 1980 likely contain a combination of features of *F. virgata* and *F. malvastra*. Kaydan and Gullan (2012) also found that *F. dasylirii* is very difficult to distinguish morphologically from *F. virgata* and exhibits significant variability. Before 2012, it was incorrectly considered a synonym of *Ferrisia virgata*. As such, early records of *F. virgata* may need to be verified due to confusion with the new species described by Kaydan and Gullan (2012).

Kaydan and Gullan (2012) further suggested that with the exception of records of *F. malvastra*, all other reports of *Ferrisia* from outside the Nearctic and Neotropical regions are of *F. virgata*. Thus, descriptions of immature stages and studies of the biology of *F. virgata* in Egypt and India (e.g. Ghose and Paul (1972) cited in Kaydan and Gullan (2012); Awadallah et al. 1979a; Awadallah et al. 1979b) probably do refer to this species.

In this pest risk assessment, "*Ferrisia virgata*" refers to the species in the strict sense (*sensu stricto*), rather than the species complex.

8.3.2 *Hazard identification*

Ferrisia virgata is not known to be present in New Zealand.

- There is no entry for *Ferrisia virgata* in the New Zealand Organisms Register (NZOR 2022).
- *Ferrisia virgata* is not recorded in BiotaNZ (2022).
- *Ferrisia virgata* is not recorded in PPIN (2022).
- *Ferrisia virgata* is a regulated pest and an unwanted organism for New Zealand (ONZPR 2022).

Ferrisia virgata has the potential to establish and spread in New Zealand.

- Ferrisia virgata is polyphagous and has plant hosts (García-Morales et al. 2016) that are common and/or commercially grown in New Zealand, such as sweet potato/ kūmara and grapevine.
- Ferrisia virgata is found mainly in the tropics and subtropics, but it is also present in areas that have similar climate conditions to New Zealand, such as France and Chile (CABI 2021).

Ferrisia virgata has the potential to cause harm to New Zealand.

- *Ferrisia virgata* has the potential to harm plants of economic importance to New Zealand,
- *Ferrisia virgata* has the potential to harm the New Zealand environment,
- It has potential to cause sociocultural impacts by affecting taonga.
- It has the potential to indirectly cause human health impacts by supporting populations of harmful ant species.

Ferrisia virgata is associated with pineapple fruit.

- Live *F. virgata* mealybugs have been intercepted on fresh pineapple fruit at the New Zealand border (LIMS 2022).

Given the arguments and evidence above, MPI considers *Ferrisia virgata* is a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

8.3.3 *Risk assessment*

8.3.3.1 Biology

Based on the morphological description of adult females provided by Kaydan and Gullan (2012) and McCorquodale and Hodges (2017), *F. virgata* has two conspicuously dark grey longitudinal dorsal stripes on its whitish mealy/waxy covering, two long tail filaments and long, hair-like crystalline rods extending laterally from its body. The adult female is elongate oval, around 2.10– 4.48 mm long and 0.94–2.52 mm wide (excluding tail filaments which are about half the body length). The adult male is small, dark and fly-like, also with two long white tail filaments.

Ferrisia virgata females have three nymphal instars while males have four. The first and second instar nymphs of both sexes are light yellow (McCorquodale and Hodges 2017). All stages except very young first instars (crawlers) are covered with a white mealy/waxy secretion, through which the body colour can be seen in places. First instars are 0.44–0.65 mm long and 0.21–0.34 mm wide, and dull orange on hatching and later changing to purplish. Second instars are 0.67–1.24 mm long and 0.35–0.62 mm wide and purplish in colour (Awadallah et al. 1979a). It is difficult to differentiate between male and female nymphs until after the third instar. Following the third instar females become adults and males enter a pupal phase and emerge as winged adults (McCorquodale and Hodges 2017). Third instar females are 0.93–1.67 mm long and 0.48–0.78 mm wide and purplish in colour, while males are 1.26–1.40 mm long and 0.42–0.54 mm wide and enveloped in a loose woolly cocoon. Fourth instar males (pupae) are 1.28–1.43 mm long and 0.38–0.51 mm wide (Awadallah et al. 1979a).

Eggs are oval, pale yellow, around 0.36–0.44 mm long and 0.20–0.21 mm wide, when laid (Awadallah et al. 1979a). Adult females do not produce ovisacs; eggs are laid directly onto a pad made of whitish waxy filaments (McCorquodale and Hodges 2017).

Reproduction

Information on reproduction on *F. virgata* is contradictory in the literature. Most studies reported that *F. virgata* reproduce biparentally. In the laboratory only mated females produced offspring, whereas unmated females did not produce any eggs (Ghose and Paul (1972) cited in Kaydan and Gullan 2012; Oliveira et al. 2014b). However, although Kaydan and Gullan (2012) argued that parthogenesis of *F. virgata* is "highly unlikely", Awadallah et al. (1979b) reported that it can reproduce uniparentally and Kaydan and Gullan (2012) consider the *Ferrisia* species in Awadallah et al. (1979b) is *F. virgata*. Oliveira et al. (2014) showed that *F. virgata* reproduced exclusively via a sexual form when feeding on cotton, but they also cited two study reported that *F. virgata* can reproduce uniparentally when feeding on other hosts, but we have no access to these reports and as such we cannot evaluate the information in the reports.

Mealybugs are gregarious, and adult female *F. virgata* produce sex pheromones to attract adult males (Tabata and Ichiki 2017). Eggs hatch usually within 30 minutes of being laid (Ghose and Paul (1972) cited in Kaydan and Gullan 2012). The fecundity of *F. virgata* is moderate to high. It has been reported as 64–78 to 222–237 eggs per adult female (Awadallah et al. 1979b; Ghose and Paul (1972) cited in Kaydan and Gullan 2012). In nature, adult females prefer the lower surface of leaves and the junction of the petiole with the stem to deposit eggs (Ammar et al. 1979).

Development

Ferrisia virgata fecundity, longevity and population density are influenced by climate and host variation (Ammar et al. 1979; Awadallah et al. 1979b; da Silva-Torres et al. 2013; Oliveira et al. 2014a; Ata et al. 2019). However, no studies have been conducted specifically to determine the optimal temperature and lower development threshold in laboratory conditions. When reared at 16–29°C and 54–71% relative humidity (RH) on sprouting potatoes, Awadallah et al. (1979b) reported the total life span of *F. virgata* females as 76.2–154.6 days while males lived 19–49 days (from egg to adult death). Other studies with a smaller temperature variation reported that a complete life cycle requires 44–53 days at 27–30°C on *Coccinia indica* (Vigneswaran et al. 2016) or 53.6–63.5 days at 25–28°C on cotton (Oliveira et al. 2014a). *Ferrisia virgata* can have multiple overlapping generations per year when climate permits (Ammar et al. 1979; Awadallah et al. 1979b). Awadallah et al. (1979b) also observed no significant changes in the incubation duration and hatching rate of eggs within this temperature range. In this study, *F. virgata* eggs hatched successfully when incubated at 16.6–17.4°C and 71% RH, but all nymphs hatched from these eggs died at the second instar and Awadallah et al. (1979b) think that it was probably due to cooler weather in winter.

Ferrisia virgata is believed to have overwintering behaviours, though the timing, duration and life stages associated with this function are not well studied (Ammar et al. 1979; Nabil et al. 2020). In Egypt, a two-year (2014–2015) field population investigation conducted on *Acalypha* shrubs showed that both *F. virgata* female adults and immatures began to be active in early June (average daily temperature at 23–25°C), increased population density gradually and peaked around early-mid October (average daily temperature at 21–25°C), and then disappeared from host plants from the mid of January (average daily temperature at 13–14°C) without detailing the status of dormancy (Nabil et al. 2020). It appears that *F. virgata* overwinters at any developmental stage, contrary to a previous study that suggested this mealybug probably overwintered as adult females (Ammar et al. 1979). The closely related species *F. gilli* overwintered as second or third instars. However, in another two-year *F. virgata* population survey on ornamental corn shrubs (*Dracena fragrans*) (in Egypt), weekly monitoring results showed that adult females could be present year-round on leaves, with lowest population densities occurring in spring (Ata et al. 2019). Overwintering sites include cracks and junctions of trunks and large branches, fallen leaves and soil (Ammar et al. 1979). Given the limited literature information, the cold tolerance of this mealybugs cannot be inferred from their overwintering behaviours.

Spread

In common with most mealybugs, all life-stages of *F. virgata* (except eggs and the male pupae) are able to walk or fly, but late instars and female adults are largely sessile when suitable food is present and their active dispersal distance is considered to be short. Mealybugs can passively disperse over longer distances by wind, waterways and by phoresy[53]. Long distance movement also occurs by the movement of infested plant materials (Mani and Shivaraju 2016).

Damage

Like other mealybugs, *F. virgata* affects nutrient levels in plants through sap-sucking, causing plants to yellow, wither and dry, causing premature leaf and fruit fall, and causing reduced growth and even plant death in severe scenarios. Large aggregations of mealybugs on plants appear as conspicuous white, sticky masses of wax; filamentous egg pads are likely to be visible. All mealybugs produce honeydew, which can lead to the growth of black sooty moulds on foliage and fruit and reduce the photosynthetic ability of the plant (McCorquodale and Hodges 2017).

Species vectored

Ferrisia virgata has been reported to vector plant viruses, including *Citrus tristeza virus* (reported as lime dieback), *Cacao swollen shoot virus* (CSSV), Cocoa Trinidad virus (Diego Martin Valley isolate) and *Piper yellow mottle virus* (PVMV) (Thorold 1975; Bhat et al. 2003; CABI 2021). Regarding *Citrus tristeza virus*, DAWR (2019) considered that the original study by Hughes and Lister (1953) referencing *F. virgata* as a vector was unsubstantiated, because 1) the study pre-dates the period before this virus species was characterised and the identification information cannot be confirmed specific to the disease; and 2) apart from the original report, there are no subsequent reports of any mealybug species transmitting the virus which is one of the most extensively studied plant viruses. *Ferrisia virgata* was also reported to be able to carry '*Candidatus* Liberibacter asiaticus' (Las), which is the causal agent of huanglongbing (a devastating disease of citrus) (Hoffman et al. 2011).

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[53] Phoresy is an interaction in which a phoretic animal (or phoront) latches itself onto a host animal for the purpose of dispersal (White 2017).

The later laboratory study found that Las populations transmitted by the mealybugs did not cause disease in host plants (Pitino et al. 2014). In this pest risk assessment, therefore, only CSSV, Cocoa Trinidad virus and PVMV are considered transmitted by *F. virgata*.

Hosts and geographical distribution

Ferrisia virgata is one of the most polyphagous mealybugs. It is associated with plant species belonging to some 221 genera in 79 families (García-Morales et al. 2016). Apart from *A. comosus* (pineapple), other main host plants are *Abelmoschus esculentus* (okra), *Acalypha* (copperleaf), *Albizia lebbeck* (Indian siris), *Anacardium occidentale* (cashew nut), *Annona* spp., *Cajanus cajan* (pigeon pea), *Carica papaya* (pawpaw), *Citrus* spp., *Coccoloba uvifera* (sea grape), *Cocos nucifera* (coconut), *Codiaeum variegatum* (garden croton), *Coffea* spp. (coffee), *Colocasia esculenta* (taro), *Corchorus* (jutes), *Cucurbita maxima* (giant pumpkin), *Cucurbita pepo* (marrow), *Dracaena* spp., *Elaeis guineensis* (African oil palm), *Ficus* spp., *Gossypium* spp. (cotton), *Ipomoea batatas* (sweet potato/kūmara), *Leucaena leucocephala* (leucaena), *Litchi chinensis* (lichi), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Manilkara* spp., *Musa* spp. (banana), *Nicotiana tabacum* (tobacco), *Phaseolus* spp. (beans), *Phoenix dactylifera* (date palm), *Piper betle* (betel pepper), *Piper nigrum* (black pepper), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Solanum lycopersicum* (tomato), *Solanum melongena* (aubergine), *Solanum nigrum* (black nightshade), *Theobroma cacao* (cocoa), *Vigna unguiculata* (cowpea), *Vitis vinifera* (grapevine) and *Zingiber officinale* (ginger) (CABI 2021).

Ferrisia virgata is found mainly in the tropics and subtropics, but its range can extend into some temperate regions. It has been reported from all zoogeographical regions, including Africa, Asia, North America, South America and Oceania (CABI 2021). Compared with the climate of all of New Zealand using Climate Matching Index (CMI) by Phillips et al. (2018), some affected areas share a high climatic similarity with New Zealand, such as northern states in USA, France and Chile (CMI, 0.8–0.9).

8.3.3.2 Likelihood of entry

Ferrisia virgata is present in all the markets in the scope of this IRA, which are: Australia, Costa Rica, Ecuador, Fiji, Indonesia, Malaysia, New Caledonia, Cook Islands, Panama, Papua New Guinea, the Philippines, Samoa, Sri Lanka, Taiwan, Thailand, Tonga and Vanuatu (CABI 2021).

Ferrisia virgata is known to infest pineapple plants (Culik et al. 2006; García-Morales et al. 2016). However, we found no further information regarding affected plant parts, cultivars and ripeness. Studies on cotton (rather than pineapple) found that *F. virgata* crawlers infested all plant parts including leaves, petioles, stem, fruiting buds, flowers and open bolls, without preference among cotton cultivars (da Silva-Torres et al. 2013; Oliveira et al. 2014). Da Silva-Torres et al (2013) further highlighted that *F. virgata* was likely not affected by plant morphological differences between cultivars, such as leaf variation (e.g., size, texture and the presence of trichomes) and plant development stage. On cocoa trees, N'Guessan et al. (2019) showed that *F. virgata* was present on both immature and mature cocoa trees, but the study did not provide statistical details on plant ages. Other mealybug species, such as *Dysmicoccus brevipes* and *D. grassii,* have been reported to affect roots, leaves, stems, fruit and crowns of pineapple (Sipes and Wang 2017). Live *F. virgata* mealybugs have been intercepted on fresh pineapple from the Philippines twice and mini pineapple fresh flowers once in 2004 from Thailand at the New Zealand border (LIMS 2022). Given that eggs are laid on leaves and adult males can fly (refer to section 1.1.4.1 Biology), only *F. virgata* nymphs, adult females and pupae can be considered associated with decrowned fruit. There is no evidence to suggest that pineapple cultivar or ripeness affect their presence on the commodity.

MPI found no evidence in the available English-language literature directly documenting the extent of the association of this mealybug with pineapple fruit, although pineapple is regarded as a main host by CABI (2021). Sipes and Wang (2017) considered *F. virgata* to be of less economic importance for pineapple than *Dysmicoccus brevipes* and *D. grassii* which are the most common and important species. Also, *F. virgata* has been excluded from the revised checklist of pests of pineapple in Taiwan (where the mealybug is established), due to the dubious association (Huang and Wang 2016). As such, *F. virgata* is unlikely to have a strong association with pineapple fruit.

Visual inspection is likely to detect infestations of *F. virgata* on decrowned pineapple fruit. Like all mealybugs, *F. virgata* has relatively limited mobility (excepting crawlers and adult males). Infestations on the commodity are likely to appear in clusters due to the mealybug's gregarious nature. In severe infestations, the mealy/waxy white covering of the mealybugs is conspicuous. However, at low population densities or as individuals, especially on pineapple fruit with a tough diamond pattern and creamy-green to yellow-orange skin, it can be difficult to detect mealybugs both in the field and in the packhouse. *Ferrisia virgata* crawlers are very small (< 1 mm), so inspection of pineapple fruit may require a 10x magnifier. Late second- or third-instar nymphs and adults may not always be detected because mealybugs often live inside plant cracks and crevices (e.g. under the bract of the pineapple surface and stem end), and they are still comparatively small (McCorquodale and Hodges 2017). Pineapples have tough multicoloured skin, making visual inspection harder.

Heavy infestations in the field may damage or weaken plants, directly causing leaf and fruit drop and even plant death. Even if infestations are not apparent, sooty mould and ant activities induced by producing honeydew may also be a sign of infestations. General handling in commercial orchards (described in section 2.1) may not be sufficient to remove/kill all mealybugs. In common with other mealybugs, *F. virgata* is very difficult to control with water-based insecticides because its wax-covered body can repel aqueous solutions, which reduces the effectiveness of insecticides and removal by washing (Franco et al. 2009). The mobile early instar nymphs may hide in sheltered places (e.g. under the bracts of pineapple). Other life stages tend to be stationary but can attach to their hosts very firmly. For example, Jamieson et al. (2010) applied high pressure (between 50 and 200 psi) water to clean commercially produced capsicum and found that only 58–84% of live mealybugs were washed off. Given that fresh capsicum fruit have a very smooth surface, it is likely that comparable treatments on pineapple would be even less effective. In addition, some other biological attributes of the mealybug, such as its cryptic behaviour, clumped spatial distribution on host plants and overlapping generations can increase the difficulty of chemical pest control and aid the development of insecticide resistance (Franco et al. 2009). As such, general commercial production handling is unlikely to eliminate mealybugs on the commodity.

Ferrisia virgata may survive cold conditions during sea transit. Live *F. virgata* adults and nymphs have been intercepted at New Zealand border 35 times on the fresh produce pathway and seven times on the cut flowers/foliage pathway (other than on pineapple) from 1998 to 2019 (LIMS 2022). Live *F. virgata* have also been detected at the European Union and Australian borders (DAWR 2019; EPPO 2022). Generally, the recommended cold storage temperature for pineapple is 7–13°C (and RH at 85–90%) as storage below this temperature can result in chilling injury to the fruit (Camelo 2004). Although Awadallah et al. (1979b) showed that *F. virgata* reared at 16.6–17.4°C and 71% RH did not complete their lifecycle (with 100% mortality of the second instar), other life stages may be able to survive temperatures below 16°C. Some mealybug species that hibernate overwinter are reported to be cold-resistant, such as *Phenococcus solenopsis* (Spodek et al. 2018) and *Ferrisia gilli* (Haviland et al. 2012). Cool storage may only slow or halt the development of nymphs and other pre-adult stages, rather than kill them. Adult males are short lived, fragile and do not feed (Awadallah et al. 1979b; Tabata and Ichiki 2017). They are unlikely to survive transit conditions and be introduced into New Zealand as adults, though adults may emerge from pupae.

Uncertainty

Ferrisia virgata is a species complex composed of some morphologically similar but genetically different species (Gullan et al. 2010; Kaydan and Gullan 2012). Kaydan and Gullan (2012) described a number of new species from the complex. As such, there may be uncertainties in this PRA on the assessment of its biological characters (particularly host and distribution records) arising from the interpretation of older literature.

We found no information indicating the temperature thresholds for each development stage of *F. virgata* in laboratory conditions. This contributes to uncertainty when assessing the survival rate during shipping in a cold environment.

We also found that no information directly describing the biological association between *F. virgata* and pineapple fruits. However, the mealybug has been intercepted on pineapple fruit.

Given that:

- pineapple is a host of *F. virgata* and live *F. virgata* nymphs and adults have been intercepted twice on fresh pineapple fruit at the New Zealand border;
- nymphs, pupae and female adults can be associated with decrowned fruit at the time of harvest, while eggs may only be present on leaves;
- MPI found no information to suggest that pineapple cultivar or ripeness affects the association of *F. virgata* with pineapple fruit;
- in general, infestation of *F. virgata* is likely to be visible, but at low population levels, nymphs (especially crawlers) and adult females may not always be detected during routine post-harvest activities due to their small size and tendency to hide;
- nymphs (except crawlers) and adult females may remain attached to fruit during general washing, due to their wax-covered body, secure attachment to the fruit surface and tendency to hide; and
- Nymphs, pupae and adult females may survive shipping to New Zealand;

MPI considers the likelihood of *F. virgata* entering New Zealand on imported pineapple fruit to be LOW, with MODERATE uncertainty.

8.3.3.3 Likelihood of exposure

This assesses the likelihood of F. virgata *being exposed to a suitable host if it enters New Zealand undetected.*

Although there is no specific study on the development of *F. virgata* on pineapple fruit, a laboratory study in New Zealand (Whyte et al. 1994) showed that the long tailed mealybug, *Pseudococcus longispinus*, survived up to 49 days on oranges (if whole fruit was not consumed or decayed). *Ferrisia virgata* may survive and develop on the surface of pineapple fruit (whole or skin pieces) as the fruit skin is robust and does not break down as quickly as softer skinned fruits. The survivorship and development on pineapple waste also depend on the environment where the waste is discarded. If the mealybug arrive in New Zealand in the colder part of New Zealand (especially during the cold season), it may not be able to survive or develop into a stage that it can find a host given that it is mainly found in the tropics and subtropics (refer to Hosts and geographical distribution in Section 1.1.1.4). However, there is uncertainty around it. Awadallah et al. (1979b) observed that *F. virgata* eggs hatched successfully when incubated at 16.6–17.4°C, but all nymphs hatched from these eggs died at the second instar which probably due to cooler weather in winter. However, F. virgata has been intercepted on fresh pineapple and the recommended storage temperature for pineapple is 7–13°C (refer to section transit condition). There is no experimental study found on cold tolerance of this mealybug.

Imported pineapple fruit will be distributed throughout New Zealand for wholesale or retail sale. Fresh pineapples produce large amounts of unavoidable waste. The thick skin is always removed, and the disposal of the fruit skin or whole fruit may aid the exposure of mealybugs. The most common method of disposing of organic waste in New Zealand is bagged waste to landfill (see section 2.3.1), which is unlikely to result in successful exposure. However, there are other methods that could increase the likelihood of exposure of this mealybug, for example direct disposal into the environment, or using waste as animal feed or for composting.

Direct disposal of pineapple waste into the environment may increase the likelihood of the mealybugs being exposed to a suitable host. In this scenario, the mealybugs may be able to passively disperse for longer distances by wind or phoresy, particularly if the waste is discarded near to a suitable host plant. For crawlers, the likelihood of finding a host is higher, because they can move around actively for a short period. However, crawlers are vulnerable to predation, dehydration and being washed away by the rain (Mendel et al. 1984).

Other waste disposal methods may also result in increased likelihood of exposure, including home composting and use as animal feed. Fresh pineapple waste can generally remain a suitable food source for mealybugs for reasonably long periods, supporting their continuous development. However, as the fruit decays it may become unsuitable and the mealybug is likely to seek another food source. Although plastic bins used for home composting may limit the transfer of mealybugs to the environment, some other composting facilities (without a cover) are still widely used in individual gardens, such as open compost pile, wooden box and wire fence (Mensah 2017). If infested waste is discarded in uncovered home compost bins with suitable hosts nearby, this would increase the likelihood of exposure.

Commercial composting is a common way to deal with organic waste in New Zealand. In aerobic composting, waste is subject to a heat process within a comparatively closed environment (composting tunnels, 55°C or higher) for weeks (Pandey et al. 2016), and then transferred to an open area for air exposure for more weeks (or months) before the compost is used. These conditions, for example the exposure to high temperature and potentially long starvation, are likely to kill all stages of *F. virgata*.

Ferrisia virgata is highly polyphagous, and many host plants are commonly planted in home gardens, such as beans, cauliflower, *Citrus* spp., grapevine and tomato. Other hosts, including avocado, maize, eggplant, cucurbits, and kūmara (sweet potato) are also widely grown in New Zealand. Therefore, lack of suitable host plants is unlikely to limit exposure.

The reproductive characters of *F. virgata* is likely to aid its exposure to a suitable host. Although most study reported biparental reproduction, uniparental reproduction has also been reported for *F. virgata* (refer to Reproduction in Section 1.1.1.4). Female adults are relatively long lived and the longevity of ovipositing females seem not to be significantly affected by temperature in the range of 17.5–28.9°C (Awadallah et al. 1979b). Although average temperature in New Zealand are well below these in many places and female adults are relatively sedentary, these reproductive characteristics can support them to remain alive on discarded imported product and continue to produce crawlers.

Uncertainty

No information has been found from New Zealand specific to pineapple waste. This contributes to some uncertainties when interpreting waste data to assess the exposure likelihood of *F. virgata*, because the consumption of pineapple fresh produce consists of a very small part of total organic waste. No experimental study has been found on cold tolerance of *F. virgata*. Also, there is no study found on the development of *F. virgata* on pineapple fruit.

Given that:

- *Ferrisia virgata* may survive on pineapple waste, but it may not be able to successfully find a suitable host if it arrives in New Zealand in the cold season;
- fresh pineapples produce large amounts of unavoidable waste, however, most is likely to be disposed of as bagged waste to landfill or into in-sink disposal units. These methods are unlikely to result in successful exposure;
- commercial composting is unlikely to result in successful exposure since mealybugs will not survive the process;
- direct disposal of pineapple waste in the environment may result in successful exposure, but only a very small amount of infested imported material is likely to be disposed of by this method;
- home composting in gardens and use as animal feed could increase the likelihood of successful exposure since suitable host plants are very likely to be available;
- the reproductive characters of *F. virgata* is likely to aid its exposure to a suitable host;
- however the likelihood of the mealybugs locating a suitable host is low, because most life stages have limited mobility (apart from crawlers) while passive movement by wind or phoresy cannot guarantee to locate a suitable host;

MPI considers the likelihood of *F. virgata* being exposed to a suitable host in New Zealand from pineapple fruit to be LOW, with MODERATE uncertainty.

8.3.3.4 Likelihood of establishment

This assesses the likelihood of F. virgata *establishing a population if it is successfully exposed to a suitable host plant in the New Zealand environment.*

Climate may be a limiting factor for *F. virgata* to establish in New Zealand, since this mealybug species is largely found in tropical and subtropical areas. Most countries/areas where *F. virgata* is reported to be a pest with annual overlapping generations share low climate similarity (CMI<0.7) with New Zealand, such as lower Egypt (Ammar et al. 1979), south-east Asian areas (Suasa-ard 2010), central India (Bhat et al. 2014), central America (Hernández-Arenas et al. 2011), Guangdong and Yunnan in China (Weicai et al. 2013; Bai et al. 2017), and the state of Pernambuco in Brazil (Oliveira et al. 2014b).

Ferrisia virgata has been reported from some temperate areas with a high climatic similarity (CMI>0.7)) to New Zealand, such as northern states in USA and France (CABI 2021). However, directly interpreting the literature (especially that published decades ago) may result in uncertainties, due to mis-identification with *F. malvastra* (Ben-Dov 1994) and the new species described by Kaydan and Gullan (2012). In Maryland, for example, the presence of *F. virgata* was first reported by Highland (1956), and later cited by many scholars, such as Ben-Dov (1994), Kosztarab (1996) and CABI (2021). However, *F. virgata* is a highly polyphagous and invasive mealybug species, yet there have been no subsequent reports of any impacts or field populations in Maryland. Gullan et al. (2003) speculated *Ferrisia* specimens from Maryland belonged to a new species. Gullan et al. (2010) further found that some specimens referred as "*Ferrisia virgata*" from other temperate/subtropical states (e.g. Arizona, California, Florida, Virginia in the study) were not the true *F. virgata*. Additionally, responding to the revision of the genus *Ferrisia* by Kaydan and Gullan (2012), CDFA (2020) considered that *F. virgata* was no longer present in California. Apart from misidentifications, some early records of its distribution in most northern countries/areas may be based on greenhouse collections (CABI 2021).

In France, the original study referencing the first record of *F. virgata* from France was from the French Mediterranean Hyères islands, rather than mainland France (Foldi 2000). In a more recent study using DNA barcoding to analyse 40 mealybugs populations affecting crops and ornamental plants in urban areas of Egypt and France, no *F. virgata* specimens were found to be from France (Abd-Rabou et al. 2012). There are no other reports of its presence in France or other European countries. This suggests it may not be present, or at least not prevalent there, because *F. virgata* has a wide range of commercially significant hosts, can cause serious economic impacts and is readily detectable in the field. In Australia, *F. virgata* has only been reported from Western Australia, Northern Territory and Queensland (Williams 1985; DAWE 2021; Atlas of Living Australia website 2022). It does not appear to have spread to the southern states despite having been present in the north for at least 50 years (Williams 1985). Despite its invasive potential, an absence of any controls and an abundance of hosts, no reports of its presence or impacts in southern states suggests that the distribution may be limited by cooler conditions.

There is no clear data for lower thresholds for development. In the study by Awadallah et al. (1979b), *F. virgata* eggs hatched successfully when incubated at 16.6–17.4°C and 71% RH, but all nymphs died at the second instar. The authors speculated that the cool winter weather caused the death of all nymphs, without supporting experimental data to detail its lifespan at such cool temperatures (16.6°C). This temperature may theoretically be near to its real lower development threshold. However, most of New Zealand reaches or exceeds this temperature during summer (NIWA 2022), meaning establishment is possible during the warmer season. Also, *F. virgata* may complete a lifecycle in warmer seasons when environmental conditions are suitable. For example, development durations from egg to adult are about 26, 20 and 19 days at 25, 27 and 28°C in laboratory conditions, while pre-reproductive period of adults is about 19 days at 25 and 27°C and 16 at 28°C (Oliveira et al. 2014a). However, as the average temperature for most Northland areas (the warmest part of New Zealand) in the summer months are just below 20°C, the life cycle of *F. virgata* is likely to be longer but establishment is still possible. As such, it is likely that summer populations (at least, in the northern North Island) could survive but survival through the winter months is unlikely.

Ferrisia virgata has a moderate to high fecundity and reproduces quite rapidly under tropical conditions (Schreiner 2000). Although information on whether *F. virgata* can reproduce uniparentally is contradicted and most study reported that it can only reproduce biparentally, both reproduction forms have been reported (refer to Reproduction in Section 1.1.4). The likelihood of biparental mealybug establishing is lower than that of the uniparental mealybug since reproduction requires that at least one male and female survive to sexual maturity, and mate successfully. If *F. virgata* has population that can reproduce uniparentally and if this population arrive in New Zealand, this will increase the likelihood of its establishment. Mealybugs are gregarious and adult female *F. virgata* produce sex pheromones to attract adult males, but adult males are short lived, fragile and do not feed (Awadallah et al. 1979b; Tabata and Ichiki 2017). They are unlikely to survive transit conditions and be introduced into New Zealand as adults, though adult males may emerge from pupae.

Host availability is unlikely to be a limiting factor for establishment since *F. virgata* is extremely polyphagous. Hosts present in New Zealand include but are not limited to economically important crop species, ornamental and garden species.

Greenhouse conditions are likely to enable the establishment of a permanent population of this mealybug species, though these populations may be relatively easy to eradicate in the early stages of an invasion. Like other countries, New Zealand uses greenhouses to produce many crops such as cucumber, eggplant, tomato and some ornamentals like *Cordyline fruticosa* which are able to host *F. virgata* (García-Morales et al. 2016).

Uncertainty

Most uncertainty is related to the correct identification of *F. virgata* (as discussed in the Taxonomy section). Records of *F. virgata* prior to 2012 documenting its distribution and host range may be incorrect and need to be verified. There are no reports specific to the lower temperature thresholds of this mealybug species. The information describing its overwintering behaviours and reproduction mode are inconsistent.

Given that:

- *Ferrisia virgata* has moderate to high fecundity;
- although most studies reported that it can only reproduce biparentally, both uni- and biparental reproduction forms have been reported;
- females produce pheromones to attract males, which increases the likelihood of finding a mate, increasing its likelihood of establishment;
- *Ferrisia virgata* is highly polyphagous, and acceptable hosts are widely available in nature and modified environments in New Zealand;

However,

- climate conditions do not favour establishment throughout New Zealand, but it is likely that summer populations in the field (at least, in the northern North Island) or permanent populations in protected environments (such as greenhouses and glasshouses) could survive;

MPI considers the likelihood of *F. virgata* establishing a population in New Zealand to be LOW, with MODERATE uncertainty.

8.3.3.5 Impacts in New Zealand

This assessment is made on the assumption that F. virgata *has successfully established in the New Zealand environment.*

Economic impacts

Ferrisia virgata is an economically important pest in many tropical and subtropical areas. In southeast Mexico, for example, this species is reported as the most important mealybug pest in the rambutan orchards with a mean infestation of 35% (Hernández-Arenas et al. 2011). Like other mealybug pests, *F. virgata* clusters around the terminal shoots, leaves and fruit. When the mealybugs suck the sap of the plant, it affects the plant's nutrient levels and causes the plants to yellow, wither and dry. The plant sheds leaves and fruit, its growth is reduced, and it may even die. If *F. virgata* becomes established in New Zealand, damage to fresh produce can directly impact on productivity and quality for various crops. As the mealybug species with the widest range of food sources, *F. virgata* has the potential to affect many cultivated plants of economic importance to New Zealand, including grapes, potatoes, avocadoes, tomatoes, citrus, sweet potatoes (kūmura), watermelons, cauliflowers, pumpkins, beans, eggplants, asparagus and olives (Hardy et al, 2007). All of these crops represent an approximate sales value of NZ$3.37b for New Zealand's horticultural industries in 2020 (Plant & Food Research 2020). *Ferrisia virgata* is also reported to be associated with *Cordyline fruticosa* and *Polianthes tuberosa* (García-Morales et al. 2016), cut flower and foliage species in New Zealand. Damage to ornamental plants would potentially lead to loss of market value, which was NZ$38.5m in 2020 (Plant & Food Research 2020). *Ferrisia virgata* can also excrete large quantities of sticky honeydew on foliage and fruit, reducing host plants' photosynthetic capability. Black sooty moulds can grow on the honeydew, which would lower the market value of ornamental plants and fresh produce.

However, impacts of the mealybug are mainly reported from tropical and sub-tropical areas and few studies have quantified economic impacts. These countries/areas generally have a low climate similarity with New Zealand, where *F. virgata* may have fewer generations annually and consequently lower infestation levels. In Australia, no reports of economic impacts have so far been found associated with its known hosts in southern temperate areas. Similarly, its impacts in mainland China are only documented in tropical and subtropical provinces, such as Guangdong and Yunnan (Weicai et al. 2013; Bai et al. 2017).
Ferrisia virgata seems unlikely to cause significant economic impacts in temperate zones. Even, taking a 2°C increase in global temperature into consideration, areas down to the northern part of the South Island may become suitable for establishment, but significant economic impact is still unlikely except possibly for the extreme north. In addition, New Zealand has mature biological control programmes against mealybugs, with a suite of natural enemies (Charles 2004). The establishment of *F. virgata* may only increase the cost to control the impact of mealybugs as a whole, rather than significantly change current pest control programmes or cause significant economic losses to farmers.

An in-house MPI model[54] predicted a very low level of direct economic impact over 20 years.

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[54] Main inputs to the model are grestest level of annual impact, time taken to achieve the greatest impact and time taken to full recovery.

- Assumptions on affected hosts and level of infestation in New Zealand: given that no report found on infestation level/yield loss on any important plant hosts important to New Zealand caused by *F. virgata* but the mealybug is known to be able to cause damage on plants, 1% – 5% was assumed as the range of greatest level that the mealybug can infest a main known host[55]. The model only considers the impact in Northland, as it is the area where *F. virgata* is likely to establish in New Zealand. Plant hosts considered are citrus, sweet corn, kūmara and grape, which are the main hosts of *F. virgata* and are considered to be some of the main horticultural crops in Northland.
- Greatest level of annual impact: domestic and export value in New Zealand for citrus, sweet corns, kūmara and grape are NZ$71m, 64m, 35m and 1857m respectively[56]. The values for Northland have considered the proportion of production area or production of Northland to the whole of New Zealand (18%, 2%, 1%, 0.33%[57]). As such, annual crop values for citrus, sweet corns, kūmara and grape in Northland are estimated to be NZ$13m, 0.01m, 1.75m and 0.31m respectively. The greatest level of annual impact in Northland is 1% - 5% of these values for each crop.
- It is assumed that the mealybug would take five years to achieve the greatest impact based on its dispersal capability.
- As New Zealand already has effective control approaches/programme for mealybugs, it is assumed the industries would only take about one year to full recovery.

Establishment of *F. virgata* may also result in increased phytosanitary measures required for export to countries where the pest is absent. So far, *F. virgata* has not been considered present in most European countries. The European market is an important trading partner for New Zealand. Egypt, Israel, Japan and South Korea have quarantine regulations for this mealybug (ONZPR 2022). However, the impact on market access is unlikely to be high, as this mealybug is reported from most of New Zealand's trading partners, such as China, Australia and the USA. In addition, infestations of *F. virgata* may also result in some indirect consequences, such as an increase in pest control costs and/or potential disruption of existing pest control programmes. There could also be adverse effects on market access if industry has to change current pest control programmes, for example, shifting from current low chemical production regimes to high concentrations or those with high toxicity, leaving extra residue on commodities.

Ferrisia virgata is known to vector at least three plant viruses, CSSV, Cocoa Trinidad virus and PVMV, but none of these viruses is known to be associated with pineapple, and as such, the likelihood for these viruses introduced into New Zealand by the mealybug is very low. CSSV and PVMV are regulated and Cocoa Trinidad virus is unassessed, but it is not known to be present in New Zealand (Veerakone et al. 2015; NZ Fungi 2022; PPIN 2022). The host plants of CSSV are *Adansonia digitata* (baobab), *Ceiba pentandra* (kapok), *Cola chlamydantha*, *C. gigantea* and *Theobroma cacao* (cocoa) (Ameyaw et al. 2014), which are all tropical species. The known hosts of PYMV are *Piper nigrum (*black pepper*), P. betle, P. argyrophyllum, P. attenuatum, P. barberi, P. colubrinum, P. galeatum, P. longum, P. ornatum, P. sarmentosum* and *P. trichostachyon* (Bhat et al. 2014). *Piper nigrum* and *P. betle*

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[55] Host status was attained from CABI (2021).

[56] Export values are attained from Plant & Food Research (2021) and domestic values are from Plant & Food Research (2020) as there is no domestic values on specific crops available from the 2021 report; kūmara only has domestic value and grape only has export value from these reports.

[57] The value for grape is percentage of production; the values for other crops are percentage of production area (Plant & Food Research 2021).

are present in New Zealand (NZOR 2022), but the distribution is unlikely to be nationally wide because of their tropical nature.

Uncertainty

There is uncertainty around the extent to which current and future climate will influence the mealybug's establishment and spread and around its potential impacts under these two scenarios. There is also uncertainty around trade impacts if the Mealybug were to establish here.

Given that:

- many cultivated plants of economic importance to New Zealand are known hosts of *F. virgata*;
- controlling *F. virgata* could increase production costs for a number of crops, but the impact is likely to be limited as current mealybug control programmes in New Zealand are likely to assist in control of *F. virgata* populations;
- there could be reduced market access overseas for some of New Zealand's export crops, but this impact is unlikely to be high as it is reported from most of New Zealand's trading partners, such as China, Australia and the USA;
- the mild temperate climate in New Zealand is likely to limit the impact of *F. virgata*;
- *F. virgata* can transmit viruses but the plants these viruses can affect are not of economic importance to New Zealand, and these viruses are not associated with pineapple;
- Global climate change may move the southern limit of *F. virgata*'s distribution further south in the future, resulting in some uncertainties in assessing its impacts;

MPI considers the economic impact of *F. virgata* in New Zealand to be VERY LOW, with MODERATE uncertainty.

Environmental impacts

Ferrisia virgata has a broad host range, and two plant species attacked by *F. virgata* overseas are *Piper betel* and *Piper nigrum*. The family Piperaceae is represented by a very common native species *Piper excelsum*, which is widespread in coastal areas of New Zealand. Three subspecies, *Piper excelsum* subsp. delangei, *P. excelsum* subsp. peltatum, and *P. excelsum* subsp. psittacorum, have "at risk" conservation status (NZPCN 2022). There is the potential for *F. virgata* to attack these plants as an alternative host. However, many areas where this species has populations are likely to be climatically unsuitable for *F. virgata*.

Species of *Cordyline*, *Ipomoea*, *Canavalia*, *Euphorbia*, and *Sophora* are all documented hosts of *F. virgata*. New Zealand has native species in these genera that have "at risk" conservation status (NZPCN 2022): *Co. obtecta* (Three Kings cabbage tree), *I. cairica*, *I. pescaprae* subsp. *brasiliensis*, *Ca. rosea*, *E. glauca*, *S. fulvida* (Kowhai), *S. longicarinata* and *S. molloyi*. Potential impacts by *F. virgata* on these species cannot be ruled out. Exotic sapsuckers (both polyphages and oligophages) have been reported attacking native woody plants in New Zealand, however their impacts appear to be mostly minor (Brockerhoff et al. 2010). In addition, Beever et al. (2007) state "there is no evidence of any detrimental impact of currently adventive polyphagous insect species on populations of native New Zealand plants. Highly damaging polyphagous species appear exceptional, and it has been postulated that the impact of relatively specialised organisms is likely to be greater than highly polyphagous species".

Because *F. virgata* may affect native *Piper* species, potential environmental impacts of PVMV vectored by the mealybugs cannot be ruled out. However, the risk posed by vectors is generally unlikely to be high, because successful introduction of the pathogen that requires the vector to: i) acquire the pathogen from its host (pineapple); ii) remain infectious during transit and after arrival in New Zealand; and then iii) successfully find and transmit the pathogen to another suitable plant host (native *Piper* species) in which the pathogen is able to establish (and cause unwanted impacts). Given that i) no association is found between PVMV and pineapple fruit, ii) no association is documented between PVMV and native *P. excelsum* species, and iii) most life stages of *F. virgata* have limited mobility, the environmental impact of PVMV transmitted by *F. virgata* is considered negligible.

If *F. virgata* becomes established in New Zealand and needs to be controlled, the application of insecticides, especially of broad-spectrum chemicals, would be likely to have adverse impacts on native invertebrates and also on the soil and aquatic environment. However, given that New Zealand has established chemical treatments against mealybugs, the incursion of *F. virgata* is unlikely to lead to a new high environmental risk.

Uncertainty

There is no information directly indicating that *F. virgata* could impact New Zealand native species.

Given that:

- *Ferrisia virgata* is likely to attack the native species *P. excelsum*, but many areas where *P. excelsum* has populations are unlikely to be climatically suitable for *F. virgata*;
- *Ferrisia virgata* may attack some plant species that have nationally threatened conservation status, but there is very little evidence that of exotic sapsuckers (particularly polyphagous species) having significant impacts on New Zealand indigenous species and ecosystems; and
- insecticides or other chemical that may be deployed during an incursion of *F. virgata* are unlikely to have serious environmental impacts;

Because of this, MPI considers the environmental impact of *F. virgata* in New Zealand to be VERY LOW, with MODERATE uncertainty.

Human health impacts

There is no evidence that *F. virgata* causes direct human or animal health impacts.

This mealybug may impact human activities indirectly. *Vespula* wasps are attracted to honeydew excreted by some insects, and high numbers of wasps in recreational, urban or other areas may adversely impact health (painful stings or allergy to stings) and social activities. However, as there are already many sap-sucking insects in New Zealand that can produce honeydew, the impact is likely to be minor.

Pesticide application activities responding to the outbreak of *F. virgata* may result to some health and safety issues to human, if the applicators practise incorrectly. However, as New Zealand has developed successful pest control programmes against mealybugs, the negative impact may be minor.

Given that:

- many honeydew-producing insects are already present in New Zealand, and new human health impacts via wasps attack induced by *F. virgata* is unlikely to be serious; and
- New Zealand has successful pest control programmes against mealybugs;

MPI considers the human health impact of *F. virgata* in New Zealand to be NEGLIGIBLE, with LOW uncertainty.

Sociocultural impacts
Kūmara (sweet potato) and taro are hosts of *F. virgata* (CABI 2019, 2021), and they are of cultural importance to Māori and Pacific Islanders. However, no information was found that this mealybug species can cause significant yield losses to the production of root crops such as taro and kūmara.

Vespula wasps are attracted to honeydew excreted by some insects, and high numbers of wasps in recreational, urban or other areas may adversely impact on health (painful stings or allergy to stings) and social activities. However, climate conditions in New Zealand can't favour wide establishment of *F. virgata,* and consequently the mealybug populations are unlikely to be high enough to increase the wasp population to a noticeable level across New Zealand.

Given that *F. virgata* can attack kūmara and taro which are of cultural importance to Māori and Pacific communities, but the impacts is unlikely to be high. MPI considers the sociocultural impact of *F. virgata* in New Zealand to be VERY LOW, with MODERATE uncertainty.

8.3.3.6 Overall impact to New Zealand

MPI considers the overall impact of *F. virgata* on the New Zealand economy, environment, health and society is LOW, with MODERATE uncertainty.

8.3.3.7 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is LOW with MODERATE uncertainty;
- assuming entry, the likelihood of exposure is LOW with MODERATE uncertainty;
- assuming successful exposure, the likelihood of establishment is LOW with MODERATE uncertainty; and
- the overall impact of this mealybug on the New Zealand economy, environment, human health and society would be LOW with MODERATE uncertainty;

MPI considers the overall level of risk to New Zealand from *F. virgata* on pineapple fruit to be VERY LOW, with MODERATE uncertainty.

8.3.4 Specific considerations

On which pineapple variety (or varieties) and at what stage of ripeness has *F. virgata* association with pineapple fruit been observed?

MPI found nothing in the literature associating *F. virgata* with the stage of ripeness or with specific pineapple varieties.

- A study of this mealybug species' host preference and establishment on four cotton cultivars in Brazil reported that the presence of *F. virgata* was unlikely to be affected by morphological differences between plant cultivars, such as leaf variation (e.g. size, texture and the presence of trichomes) and plant development stage (da Silva-Torres et al. 2013)
- As a sap-sucking insect, however, the performance (and subsequent infestation level) of mealybugs is believed to be affected by the composition and concentration of nutrients in phloem sap of the host plants.
    - Oliveira et al. (2014a) confirmed that nitrogen fertilisation and water stress can affect the offspring production of *F. virgata*.

Which part of the pineapple fruit is *F. virgata* associated with (e.g. fruit, bract, stem or crown remnant) and is it visually detectable?

MPI found no specific information on which parts of the pineapple fruit *F. virgata* prefers.

- As a sap-sucking insect, *F. virgata* can theoretically feed on any part of the host plant where its mouthparts can be inserted and where phloem sap is available.
    - For example, some studies on cotton found that *F. virgata* crawlers could infest all plant structures including leaves, petioles, stem, fruiting buds, flowers and open bolls (da Silva-Torres et al, 2013; Oliveira et al, 2014).
- However, many mealybug species are rarely found in direct sunlight and they like to conceal themselves. They tend to settle on the underside of leaves, inside the calyx of sepals, and in axils or under bark in the field.

As such, *F. virgata* is likely to be associated with every structure associated with pineapple fruit (e.g. the fruit, bract, stem or crown remnant), increasing difficulties for phytosanitary inspection.

Are different life stages of the *F. virgata* associated with different parts of the pineapple fruit?

No information was found to specify the life stages of *F. virgata* on pineapple fruit. Theoretically, however, all development life stages (except eggs and adult males) of *F. virgata* are believed to be associated with pineapple fruit because phloem sap is available.

- In the field, a study on *Acalypha macrophylla* in Egypt showed that the preferred oviposition sites were the lower surface of leaves and the junction of the petiole with the stem (Awadallah et al. 1979a). As such, eggs are likely not associated with decrowned pineapple fruit, but the possibility of eggs on fruit cannot be ruled out, because the crown may not always be fully removed.
- In the pineapple industry, the most common and important mealybug species are *Dysmicoccus brevipes* and *D. grassii*, which affect aerial roots, leaves, stems, fruit and crowns of pineapples (Sipes and Wang 2017).
- Adult males are able to fly and the first-instar nymphs are very mobile. Other life stages are less mobile when they are on suitable food sources. They may hide under the bract of pineapple fruit.
- Taking cold storage during transit into consideration, *F. virgata* adult females may be more commonly associated with pineapple fruits than other life stages. The viable interceptions at the New Zealand border by far are mainly female adults (LIMS 2022) despite that female adults are more detectable than other life stages. Also, Ata et al. (2019) observed only female adults present on shrub's leaves in their survey during

the winter in Egypt. Ammar et al. (1979) wrote that *F. virgata* probably overwinters as adult females.

Does *F. virgata* burrow into the fruit without obvious symptoms, hide under the pineapple bract OR exhibits latent/asymptomatic traits?

- There are no reports of *F. virgata* burrowing into the plant as a borer.
- Like most other mealybugs, *F. virgata* lives on the plant surface and feeds by inserting its mouthparts into the plant phloem. It may hide in protected parts of the pineapple surface, including bracts, reducing the likelihood of visual detection.

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8.4 *Planococcus minor* (Pacific mealybug)

Planococcus minor is a polyphagous mealybug that has been recorded on a wide range of plant hosts, including pineapple (*Ananas comosus*). It is widely distributed geographically and a commonly occurring species in regions where *Theobroma cacao* (cacao) is grown. Its feeding behaviour and excretion of honeydew affect the development of the plant and the productivity and marketability of the fruit.

8.4.1 *Taxonomic description*

Scientific name: *Planococcus minor* (Maskell, 1897)
Order: Hemiptera **Family:** Pseudococcidae
Other names: *Planococcus pacificus* Cox, *Pseudococcus minor*, *Planococcus psidii* Cox, *Pseudococcus calceolariae* var. *minor* Maskell, *Dactylopius calceolariae* var. *minor* Maskell (Cox 1989; García-Morales et al. 2016; CABI 2021); passionvine mealybug

Taxonomic notes:
The identification of *Planococcus* species is difficult. Some species are only recognizable by small differences such as the number of tubular ducts on the underside of their abdomen (Williams and Watson 1988). The identification of species is further complicated by the morphological variation that occurs as a result of the conditions under which individuals develop. For example, Cox (1983) demonstrated that *P. citricus* Ezzat & McConnell is a high temperature form of *P. citri*. The characteristics that distinguish species may be different for different sized individuals and are not easily distinguishable when they are immature (Venette and Davis 2004). Therefore, it is no surprise that since its description in 1897, *P. minor* has been synonymized with the nearly identical *P. citri* (Santa-Cecília et al. 2002). Molecular analyses have been conducted on *Planoccoccus* specimens from various parts of the world and the results indicate that the differentiation between *P. minor* and *P. citri* is valid (Rung et al. 2008). Morphological differentiation using Cox scores (i.e., matrix of characters scored using a point system) between *P. minor* and *P. citri* can only be made with females; and males can only be distinguished by molecular analyses (Stocks and Roda 2011). However, Rung et al. (2008) study suggest that morphological identification using Cox scores can be used to accurately identify *P. minor* females but it is not reliable to use for *P. citri* females.

8.4.2 *Hazard identification*

Planococcus minor is not known to be present in New Zealand.

- There is no entry of *Planococcus minor* in NZOR (2022), BiotaNZ (2022) or PPIN (2022).
- *Planococcus minor* is a regulated pest for New Zealand in ONZPR (2022).

Planococcus minor has the potential to establish a population and spread in New Zealand.

- It is a polyphagous species and many of its recorded hosts are present in New Zealand.
- The female has a high reproductive rate, is long-lived and can produce multiple generations in a year.
- It is reported in regions with similar climates to New Zealand.
- It is invasive and can establish a population when introduced to new areas.

- First-instar mealybugs (crawlers) can be dispersed long distances by wind.

Planococcus minor has the potential to cause harm to New Zealand.
- It has the potential to harm plants of economic importance to New Zealand.
- It has the potential to indirectly harm the New Zealand environment.
- It has potential to cause sociocultural impacts by affecting taonga.
- It has the potential to indirectly cause human health impacts by supporting populations of harmful ant species.

Planococcus minor is associated with pineapple fruit.
- *Planococcus minor* was recorded on pineapple by Williams (1982) and subsequently listed in Williams and Watson (1988) and Ben-Dov (1994).
- *Planococcus minor* has been intercepted twice on pineapple fruit at the New Zealand border.

Given the arguments and evidence above, MPI considers *Planococcus minor* to be a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

8.4.3 *Risk assessment*

8.4.3.1 Biology

Description
Mealybugs are small slow-moving insects with soft, segmented oval bodies which are covered with a white sticky powder (Mani and Shivaraju 2016). There are slight variations among the species, but mealybugs such as *Planococcus citri* and *P. ficus* generally have three larval instars for the female and four instars for the male (Gullan 2000; Wakgari and Giliomee 2005). Each of the instars resemble the previous except for an increase in size and the amount of wax secreted (Daane et al. 2012). Female adults are approximately 2–3.5 mm long, 1.5 mm in width and wingless. As they mature, they become less mobile. The females generally have a light-yellow body colour that may be obscured by a light dusting of white powdery wax (Roda et al. 2013). Elongated projections of denser wax can be found around the circumference of the body. Females are often accompanied by their ovisac, a larger and fluffier patch of wax which contains light yellow eggs and crawlers (i.e., first instar mealybugs). In heavy infestations, eggs, crawlers, immatures, and adult females can be found distributed on the same patch of wax (Stocks and Roda 2011). Males undergo a prepupal stage after the fourth instar and emerge as winged adults. The male is about 1.5 mm in length with long wings, a brown body and multisegmented antennae (Daane et al. 2012). Males do not feed and are very fragile and short-lived (Francis et al. 2012; Manners and Duff 2015).

Biology
The optimal temperature for *P. minor* development and reproduction is 25°C but it is able to develop and reproduce at temperatures between 20°C and 31°C (Francis et al. 2012). The low temperature threshold and the overwintering mechanisms of *P. minor* are unknown but closely related species such as *P. citri*, overwinters primarily as eggs on the upper roots, trunk and lower branches of the host plant (Roda et al., 2013).

Eggs appear brown, desiccated and fail to hatch when exposed for 15 days at 15°C or 35°C. The mean total duration of development of females was reported to be 49 d at 20 °C and approximately half that (27 days) at 29°C (Francis et al. 2012). Under laboratory conditions, the time to complete a single generation ranges from 31 to 50 days at 26°C (Martinez and Surís 1998) and Francis et al. (2012) reported 49 days at 20°C. The development time for males is longer than for females (Maity et al. 1998).

It is likely that the mode of reproduction of *P. minor* is sexual since Francis et al. (2012) demonstrated that in the absence of adult males, a virgin female did not produce eggs. In addition, there are reports of both females and males occurring in populations and no reports of only female populations (Sahoo and Ghosh 2001).

In warm climates, *P. minor* stays active and reproduces throughout the year (Ben-Dov 1994) and is able to complete up to 10 generations per year (Bastos et al. 2007). The pre-oviposition period is about 15 days at 20°C and approximately eight days at 29°C and the optimal temperature for egg production is 20°C (270 eggs) (Francis et al. 2012). Egg production in mealybugs is not only influenced by temperature but also by the number of matings and by food supply (Zaviezo et al. 2010; Waterworth et al. 2011). Therefore, egg production can range from 50 eggs to over 800 eggs per female (Daane et al. 2012). Eggs require as few as two to five days to hatch at 26°C and 69% RH (Martinez and Surís 1998). Females live longer than males. Females and male adults live approximately 34 days and around four days at 20°C, respectively (Francis et al. 2012).

Ecology

Mealybug nymphs and adult females have piercing–sucking mouthparts, which they insert into the plant's vascular tissue and which can remain in place through several moults, ingesting plant sap (Roda et al. 2013). The feeding preference of *P. minor* on pineapple plants is unknown but according to observations by Bastos et al. (2007) in cotton plants, *P. minor* prefer the growing parts of the plant, such as shoots and buds but are able to infest all parts of the plant, if there is no other option available.

In Brazil, the highest infestation rates of *P. minor* on cotton plantations were evident at times of low rainfall and high temperatures (Bastos et al. 2007). The lowest temperature tolerance and overwintering mechanism for *P. minor* is unknown. However, other *Planococcus* species such as *P. citri*, overwinter (but do not diapause) primarily as eggs on the upper roots, trunk and lower branches of the host plant. Other mealybug species overwinter in the soil or under the bark as late-instar nymphs or adult females (Roda et al. 2013).

Feeding of *Planococcus* spp. varies seasonally, and therefore, the plant locality where the mealybugs feed is variable (Becerra et al. 2006). For example, the location of *P. ficus* on grapevine varies according to the seasonal temperatures by moving from roots and trunk in winter to shoots, leaves and fruit in the spring to summer period (Becerra et al. 2006).

The population dynamics of *Planococcus* spp. are difficult to predict because plant host susceptibility can vary widely. For example, infestation levels of *P. citri* can fluctuate spatially, even on plants in close proximity, and can vary from one year to the next (Miller and Kosztarab 1976).

Geographical distribution

Planococcus minor is currently reported from at least 100 countries or regions (Cox 1989; Bastos et al. 2007; Aguiar 2009; Stocks and Roda 2011; Miller et al. 2014; Leathers 2016; CABI 2021). This mealybug is native of South Asia and it is known to be predominantly present in the South Pacific Islands (Williams and Watson 1988; Cox 1989) but has established in the Caribbeans, Central and South America, Europe, Africa and further in other parts of Oceania (Stocks and Roda 2011; Leathers 2016).

Most of *P. minor* occurrences are in places with lower Climate Matching Index (CMI) with New Zealand (0.4—0.6) Phillips et al. (2018). Few ocurrences of *P. minor* are reported in regions with similar climate to New Zealand (CMI: 0.7–0.9) (Table 7.7).

Table 7.7. Worldwide distribution of *Planococcus minor* (Cox 1989; García-Morales et al. 2016) EPPO 2020). Country/area/market in bold is included in the pineapple fruit for human consumption IHS project.

Continent/Region	**Country/area/market**
Africa	Ascension Island, Comoros, Madagascar, Mauritius, Seychelles
Asia	Bangladesh, Brit. Indian Ocean Terr., Brunei, Burma (=Myanmar), China (Hong Kong), Christmas Island, India, **Indonesia**, Kampuchea, **Malaysia**, Maldives, **The Philippines**, Singapore, **Sri Lanka**, **Taiwan, Thailand**, Vietnam
North America	Bermuda, Mexico, United States (Florida, California[1])
Central America and Caribbean	Barbuda, Bahamas, **Costa Rica**, Cuba, Dominica, Grenada, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, **Panama**, Saint Lucia, Trinidad and Tobago, United States Virgin Islands
South America	Argentina, Brazil, Colombia, **Ecuador**[2], Guyana, Suriname, Uruguay
Europe[3]	Portugal (Madeira)
Oceania	American Samoa, **Australia (Australian Capital Territory, New South Wales, Queensland, South Australia, Victoria)**, **Cook Islands**, **Fiji**, French Polynesia, Kiribati, **New Caledonia**, **Papua New Guinea**, **Samoa**, Salomon Islands, Tokelau, **Tonga**, **Vanuatu**, Wallis and Futuna Islands

[1] Ocurrence in Wistermann et al (2016) but contradicted by DFA (2016).

[2] Specimen collected in Ecuador previously thought to be *P. citri* but identified as part of the *P. minor* clade using Cox scores by Rung et al. (2008)

[3] Ocurrence in France by CABI (2021) is mistakenly recorded as *P. minor* instead of *P. citri* and *P. ficus* (Tóbiás et al 2010).

Hosts

Planococcus minor is a polyphagous mealybug that feeds on a wide variety of valuable plant hosts that range from wild to agricultural and ornamental plants exceeding 250 species in 80 families (Leathers 2016). However, recent literature suggests that earlier host records of *P. minor* might not necessarily be reliable in certain regions due to misidentification with another very similar species, *P. citri* that shares several common hosts (Viana de Souza et al. 2018). Although the host range of *P. minor* and *P. citri* overlap (both recorded feeding on cacao and citrus), the two species have different host preferences. For example, *P. minor* is commonly found in cacao and *P. citri* in citrus (Cox and Freeston 1985; Roda et al. 2013).

Many of *P. minor*'s known hosts are either present in New Zealand as ornamentals or agricultural crops, or belong to the same genera as native species (Table 2).

Table 2. Plant species or genera present in New Zealand that are reported as hosts of *Planococcus minor* (Venette and Davis 2004).

Plant species/genus	**Family**	**Common name**
Odontonema sp.	Acanthaceae	
Justicia carnea	Acanthaceae	Brazilian plume
Amaranthus sp.	Amaranthaceae	
Alocasia sp.	Araceae	
Xanthosoma sagittifolium	Araceae	arrowleaf elephant ear
Aralia sp.	Araliaceae	
Hedera helix	Araliaceae	ivy
Schefflera sp.	Araliaceae	
Asparagus plumosus	Asparagaceae	Common asparagus fern
Dracaena sp.	Asparagaceae	
Bidens pilosa	Asteraceae	black jack
Dahlia sp.	Asteraceae	dahlia
Helianthus sp.	Asteraceae	sunflower
Tagetes patula	Asteraceae	French marigold
Tithonia sp.	Asteraceae	
Impatiens balsamina	Balsaminaceae	garden balsam
Impatiens walleriana	Balsaminaceae	Busy Lizzie
Bignonia sp.*	Bignoniaceae	
Brassica oleraceae	Brassicaceae	broccoli and others
Raphanis sativus	Brassicaceae	radish
Tradescantia sp.	Commelinaceae	
Ipomoea sp.	Convolulaceae	
Corynocarpus sp.	Corynocarpaceae	
Citrullus lanatus	Cucurbitaceae	watermelon
Cucurbita maxima	Cucurbitaceae	squash
Cucurbita pepo	Cucurbitaceae	squash
Sechium edule	Cucurbitaceae	chayote (choko)
Cyperus rotundus	Cyperaceae	coco-grass
Aleurites moluccana	Euphorbiaceae	candlenut
Croton sp.	Euphorbiaceae	Croton
Euphorbia pulcherrima *	Euphorbiaceae	Poinsettia
Ricinus communis	Euphorbiaceae	castor oil plant
Acacia sp.*	Fabaceae	
Arachis hypogaea	Fabaceae	peanut
Erythrina sp.	Fabaceae	
Phaseolus lunatus	Fabaceae	luna bean
Wisteria sp.	Fabaceae	
Pelargonium sp.	Geraniaceae	
Gladiolus sp.	Iridaceae	
Ocimum basilicum	Lamiaceae	sweet basil
Salvia officinalis	Lamiaceae	sage
Persea americana	Lauraceae	avocado
Erythrina crista-galli *	Leguminosae	coral tree
Wisteria sp.*	Leguminosae	
Abutilon sp.	Malvaceae	

Hibiscus tiliaceus	Malvaceae	sea hibiscus
Pavonia sp.	Malvaceae	
Broussonetia papyrifera	Moraceae	paper mulberry
Morus sp.*	Moraceae	
Ficus carica	Marantaceae	fig
Psidium guajava	Myrtaceae	common guava
Jasminum sp.	Oleaceae	jasmine
Passiflora edulis	Passifloraceae	passionfruit
Saccharum officinarum	Poaceae	sugarcane
Zea mays	Poaceae	corn
Macadamia tetraphylla	Proteaceae	macadamia nut
Rosa chinensis	Rosaceae	China rose
Coffea arabica	Rubiaceae	Arabica coffee
Gardenia sp.*	Rubiaceae	Gardenia
Citrus limon	Rutaceae	lemon
*Citrus aurantium**	Rutaceae	Bitter orange
Citrus sinensis	Rutaceae	orange
Citrus paradisi	Rutaceae	grapefruit
Citrus grandis	Rutaceae	pomelo
Citrus reticulata	Rutaceae	mandarin
Capsicum annum	Solanaceae	bell pepper
Solanum lycopersicum	Solanaceae	tomato
Solanum melongela	Solanaceae	eggplant
Solanum torvum	Solanaceae	turkey berry
Solanum tuberosum	Solanaceae	potato
Stachytarpeta sp.	Verbenaceae	
Verbena sp.	Verbenaceae	
Vitis vinifera	Vitaceae	Grape

* There is a level of uncertainty on some of the reported hosts of *P. minor* given that *P. citri* has often been misidentified with *P. minor* in field observations according to Granara de Willink et al (2003).

8.4.3.2 Likelihood of entry

Planococcus minor is reported to be present in all markets considered in this IRA. The association of *P. minor* with pineapple was recorded by Williams (1982) and subsequently listed by Williams and Watson (1988) and Ben-Dov (1994). It is unclear to what extent this mealybug is associated with pineapple. *Planococcus minor* is a secondary pest of crops such as cacao and coffee and considered of no economic importance in neotropical regions where it has established (e.g., Caribbean) (Stocks and Roda 2011). However, it is reported to be a major pest in Taiwan on crops other than pineapple (Ho et al. 2007).

Planococcus minor is a highly intercepted mealybug in the United States of America (USA) (Venette and Davis 2004) and Australia (DAWE 2019). Interceptions of *P. minor* in USA have been associated primarily with international airline passengers (75%) and permit cargo (16%). Interceptions have been reported most frequently from plants in the genera *Nephelium* (19%), *Anona* (17%), *Sechium* (7%), *Syzygium* (6%), *Psidium* (5%) and *Musa* (4%) (Venette and Davis 2004).

Between 2000 and May 2022, *P. minor* live female adults have been intercepted twice at the New Zealand border on fresh pineapple fruit. One interception from Singapore (AN 19863)[58] and another one from Fiji (C2002/654)[59] via air cargo (LIMS 2022). No interceptions recorded as *Planococcus* sp. were found in LIMS (2022). Despite *P. minor* being intercepted on the pineapple fresh produce pathway, the number of detections is very low considering the amount of pineapple that has been imported in the past 20 years [147, 697 tons (t)] (MPI 2022). This suggests a weak association with the commodity; however, low interceptions records could also suggest that the existing control measures have managed the risk of entry of *P. minor*.

The likelihood of entry of *P. minor* will depend on the developmental stage associated with the pineapple fruit. Crawlers in general are susceptible to adverse abiotic and biotic environments (Magsig-Castillo et al. 2010) and adult winged males are fragile and short-lived (Francis et al 2012). Infield and packhouse activities will likely manage the risk of entry of these developmental stages. However, eggs and female adults could potentially be unnoticed and survive packhouse activities. A study on high pressure-washing on exported capsicum before packing revealed that not all live mealybugs were removed (58-84%) (Jamieson et al. 2010). Considering that the pineapple fruit has not a smooth, uniform surface as capsicums, we assume that the percentage of mealybug removal on pineapple fruit using high pressure-washing would likely to be lower.

Eggs can go unnoticed and can be difficult to control with infield treatments because they can be located in the cracks or underneath the pineapple bracts (Manners and Duff 2015) and thus not easily seen and protected from insecticides. In addition, *P. minor* is known to acquire resistance to several insecticides (Shukla and Tandon 1984; Thirumurugan and Gautan 2001). With eggs being an inconspicuous life stage of this insect, there is a possibility that eggs may be unnoticed during packhouses activities and survive commercial cleaning of fruit because of their waxy protective coating (Manners and Duff 2015).

Thermal development studies by Francis et al. (2012) demonstrated that *Planococcus minor* eggs appeared brown, desiccated and do not hatch when exposed to 15°C for a period of 45 days. Eggs on fresh pineapple produce are likely to survive the journey to New Zealand via air freight at room temperature, but the recommended cold storage conditions of pineapple in sea freight (7–13 °C) (Camelo 2004) will prevent eggs hatching and surviving. The survival of the eggs at these low temperatures will depend on shipping times. For example, the estimated shipping time from Central America and some Asian countries (>30 days) will likely affect the viability of the *P. minor* eggs but shipments from Australia could only take three days and this could increase the likelihood of eggs surviving (Freight 2022; Ports.com 2022). The cold tolerance and overwintering mechanisms of *P. minor* are currently unknown but interceptions of *P. minor* female adults on fresh pineapple at the New Zealand border, suggest that female adults are able to survive shipping temperatures as low as 7°C (Camelo 2004).

Uncertainty

Association with the commodity: There is no specific literature on the extent of the association of *P. minor* with pineapple fruit.

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[58] It is likely that this interception record is a result from human error. It is believed that mistakenly was reported coming from the offices of the exporting company DOLE which are based in Singapore instead of Phillipines, the country of origin of the fruit.

[59] Consignment reference number

Cold tolerance and overwintering mechanisms: the cold tolerance and overwintering mechanisms of *P. minor* are unknown, however the interception of live adult *P. minor* females on pineapples coming from Asia suggest that adults could survive temperatures as low as 7° C.

Interceptions at the border: It is unknown if the low interceptions records at the New Zealand border are a result of a weak association with the commodity, or that existing control measures have managed the risk of entry.

Given that:

- No information was found to indicate that indicates that *P. minor* is strongly associated with the commodity, suggesting pineapple is not a preferred plant host;
- There have been just two interceptions at the New Zealand border on pineapples since 2000, suggesting a weak association with pineapples. However, it is uncertain if the low interceptions records is because existing control measures has reduced the risk of entry;
- Eggs and first-instar mealybugs (crawlers) in general are inconspicuous life stages that could go unnoticed in packhouses and survive commercial cleaning and insecticide treatments;
- The cold tolerance and overwintering mechanisms of *P. minor* are unknown, but interception records at the New Zealand border on pineapples shipped from Asia suggests that adults could survive temperatures as low as 7°C;
- The viability of *P. minor* eggs will likely be negatively affected during sea freight coming from Asia or America, but likely to survive if coming from Australia or if transported via air freight;

MPI considers that the likelihood of *Planococcus minor* entering New Zealand associated with pineapple fruit is LOW with MODERATE uncertainty.

8.4.3.3 Likelihood of exposure

This assessment is made on the basis that P. minor *has entered New Zealand undetected.*

Imported fresh pineapple fruit is intended for human consumption, therefore, when the fruit arrives in New Zealand it will be distributed throughout New Zealand for wholesale or retail sale. Fresh pineapples produce large amounts of unavoidable waste. The thick skin is always removed, and the disposal of the fruit skin may aid the exposure of mealybugs. In New Zealand, organic waste that is bagged and goes to landfill is the most common method of disposing organic waste (Askarany and Franklin-Smith 2014) and it is unlikely to be a risk. However, there are other methods that could potentially aid the exposure of this insect such as animal feed, composting and direct disposal into the environment.

Fruit waste in New Zealand may be collected from unpacking areas (e.g., supermarket preparation rooms) and taken to rural areas where it is placed on the ground for eventual consumption by pigs or other farmed animals (MPI 2014). The movement of *P. minor* crawlers under the pile of discarded pineapple skins will be very difficult. However, the crawlers at the top of the pile can be uplifted and dispersed by the wind or by the feeding animals. The mealybugs at the edges of the pile can move to nearby weeds or grass.

However, *P. minor* can actively search for a suitable host only within a very limited area. The crawlers cannot fly and can only walk over short distances. Wider dispersal is wind-mediated and random. Hence, successful exposure depends on suitable hosts being very close to the waste, or to the mealy bugs' landing point after wind dispersal.

Composting is considered a low-risk method if it is done commercially. Waste in commercial compost is put into tunnels for a period of three to four days at temperatures of 55 °C or higher and these conditions are likely to kill *P. minor* eggs and immature stages (no eggs hatched at 35 °C) (Francis et al. 2012). Worm farming is also considered a low-risk method because it is recommended that organic waste is cut into small pieces (Angima et al. 2011) and it is a contained structure which will prevent the mealybug from wandering out into the environment.

Home composting increases the likelihood of exposure. A study conducted in Palmerston North found that 63% of a total of 72 households that do home composting used manufactured plastic bins for composting and the majority of others used an 'open' composting system, such as open compost piles and piles fenced with wire (Mensah 2017). Even though both home composting methods increase the likelihood of exposure of the mealybug to immediate hosts that are commonly found in New Zealand gardens (e.g., citrus and ornamentals), compost in plastic bins is less risk than open compost. In plastic bins, organic wasted is piled up inside the bin and usually the bins are black, which helps keep high temperatures inside the bin. Eggs could potentially remain viable and hatch inside a compost bin during winter temperatures in New Zealand as long as the temperatures inside the bin remain >15°C (Francis et al 2012). However, this is uncertain, given that it is unknown the lower temperature threshold of *P. minor*. Mealybugs'newly hatched first instar crawlers are unlikely to survive without a live host plant for more than a day (University of Minnesota Extension 2013). If crawlers wander out of the compost bin in search for food, they are highly susceptible to biotic and abiotic factors. During summer months, temperatures inside the compost bin could be agreeable to *P. minor* development (20 – 31 °C), however, crawlers would have to find a live suitable host fast (≤ 1 day) to avoid starvation or dehydration.

If a mealybug escapes a plastic bin or open compost, many suitable host plants are available at ground level and could be within the walking range of crawlers. For example, greenhouse experiment performed by Washburn and Frankie (1981) on the scale insect *Pulvinariella mesembryanthemi* (Coccidae) showed that the speed of walking of a crawler is 0.72 ± 0.22 mm/sec and studies by Greathead (1975) on the scale *Aulacaspis tegalensis* (Diapididae) showed that the speed of movement is upwards rather than sideways. Despite the ability of a crawlers to disperse, if no host is available nearby, the crawler is vulnerable to predation, dehydration or being washed away by the rain (Mendel et al. 1984).

Crawlers from other mealybug species can be wind-dispersed. Laboratory studies performed by Washburn and Washburn (1984) on *P. mesembryanthemi* showed that crawlers could be transported over 190 km in 24 hours at a wind speed of 8 km/h. However, to be uplifted and transported successfully by the wind over this distance, crawlers need to be at an appropriate height above the ground and be positioned at an appropriate direction on the plant or canopy (Washburn and Frankie 1981).

Direct disposal of pineapple fruit skin into the environment (e.g., by roadsides, parks, campsites) could potentially aid the exposure of the mealybug.

Uncertainty

Pineapple waste: Information regarding food waste in New Zealand is based on general data and there is no specific information on pineapple waste. Therefore it is assumed that the percentages of discarded pineapple fruit skin in New Zealand will be much lower.

Dispersal of crawlers: Information about the distance crawlers travel has been reported for other mealybug species. Therefore, there is no specific information about *Planococcus minor* or other *Planococcus* species. In addition, experiments were performed under laboratory conditions and its unknown how dispersal will be accomplished when crawlers face the adversities of the natural environment.

Given that:

- Pineapple skin that is bagged and sent to the landfill, commercial composting, worm farming and home composting in plastic bins are considered low-risk methods;
- Pineapple skin that is sent for animal feed or open composting could potentially expose the crawlers to the environment, because *P. minor* is a polyphagous species and many of its recorded hosts are present in New Zealand;
- The ability of *P.minor* to find a suitable host is limited because crawlers can only walk and search over short distances, are flightless and to be transported over long distances by passive wind dispersal a combination of conditions need to occur (i.e., right wind speed, angle position on the host, host location and survival to predation and environmental conditions);
- There is no specific information on the behaviour of *P. minor* crawlers. This assessment is based on information gathered on other mealybug species;
- Information about crawlers was based on laboratory or greenhouse experiments. It is uncertain how crawlers will survive the adversities of the environment;

MPI considers that the likelihood of exposure of *Planococcus minor* in New Zealand from pineapple fruit is VERY LOW with MODERATE uncertainty.

8.4.3.4 Likelihood of establishment

This assessment is made on the basis that P. minor *has been successfully exposed to a suitable host plant in the New Zealand environment.*

Planococcus minor is a polyphagous species and therefore there is a high probability that dispersing mealybugs in New Zealand will find a suitable host and expand to new habitats in surrounding areas (Venette and Davis 2004). Some of the reported plant hosts are present in New Zealand either as horticultural crops (e.g., avocado and citrus) ornamentals (e.g., *Dahlia* and *Schefflera*) and common weeds (e.g., *Tradescantia* sp., *Ricinus communis, Asparagus plumosus*) (Table 1).

Planococcus minor has a high reproductive rate (270 eggs or more) and under warm and humid conditions (26°C to 31°C) is able to produce multiple generations (i.e. 10 generations per year) (Sahoo et al. 1999).

It is likely that the mode of reproduction is sexual as evidenced by Francis et al. (2012). This means that to establish a *P. minor* population there is a significant barrier to overcome. Males (short-lived, fragile and without feeding mouthparts) are unlikely to enter New Zealand on the fresh produce pathway. Immature stages that are males must survive to maturity and mate with their siblings (which also must survive to maturity and may widely dispersed by wind on different locations) or their mother.

Most of the *P. minor* distribution records have a CMI between 0.4 – 0.6 (Phillips et al. 2018) indicating that this mealybug has mostly established in warm, humid conditions (Table 1). However, some distribution records are in regions with similar climates to New Zealand. For example, in Uruguay (CMI: 0.8–0.9), the region of Serra Gaúcha in Brazil (CMI: 0.8) and in several states of Australia (Australian Capital Territory, New South Wales, South Australia and Victoria; CMI: 0.7-0.9) (Morandi Filho et al. 2015) (Granara de Willink et al 1997; Granara de Willink and Claps 2003; IPCC 2021).

Likewise, Ecuador, Argentina and California (USA) have regions with similar climate to New Zealand (CMI: 0.6-0.9), but there is some uncertainty with the distribution records in these locations. A specimen collected in Ecuador in 2006, which was initially thought to be *P. citri*, was relocated to the *P. minor* clade using phylogenetic analysis and morphological results (Cox scores) (Rung et al. 2008). However no information was given on the location, host plant and if this specimen was collected in the environment or inside a greenhouse. For Argentina, the distribution records of *P. minor* in the regions Jujuy, Tucumán, Entre Ríos, Buenos Aires and Santa Cruz (CMI: 0.6-0.9) are uncertain. Granara de Willink and Claps (2003) acknowledge that their observations were field-based and they could have misidentified *P. citri* as *P. minor*. In California (CMI: 0.6–0.8), a technical report on table grapes mentions that *P. minor* is a serious pest of grapes (Wistermann et al 2016), but the presence of *P. minor* in California is uncertain. Stocks and Roda (2011) reports that a *P. minor* population was found in 2006 in a greenhouse which triggered a phytosanitary alert system. Subsequent molecular work indicated that the population was in fact *P. citri* and the alert was then retracted. In addition, a risk assessment by Leathers (2016) mentions that "*P. minor* has never been found in the environment in California".

Present mean annual temperature and mean maximum temperatures for many (but not all regions in New Zealand) in 2021, were "+0.51 °C to +1.20°C above the annual average (13.56°C) (NIWA 2022). The increasing temperatures projected for New Zealand due to climate change is 1.4 °C by 2090. These temperatures fall below the optimal reproductive and developmental temperatures for *P. minor* (20 - 31°C) presented by Francis et al. (2012), suggesting that *P. minor* is unlikely to establish in New Zealand. However, distribution records in regions with similar climate to New Zealand suggest that *P. minor* can develop and reproduce in temperatures lower than those reported by Francis et al. (2012).

Planococcus minor is known to be invasive and able to establish when introduced into new areas. For example, since its incursion in Australia (at least 60 years ago) (ALA 2022), *P. minor* has established in Queensland, South Australia, Australian Capital Territory, New South Wales, Victoria and the Northern territory (García-Morales et al. 2016).

The lack of a longer-range active dispersal mechanism may limit the rate at which mealybugs spread. Even though adult males are winged, they are fragile, do not feed and are short-lived (Francis et al. 2012; Manners and Duff 2015). Crawlers are the primary dispersal phase in the mealybug life cycle. They are capable of active dispersal by crawling and passive dispersal by hitchhiking on clothing of orchard workers, equipment, insects (e.g., ants) and birds or ballooning by wind currents (Leathers 2016). In Argentinian vineyards, the mealybug *P. ficus* developed to damaging population levels because practices such as mechanical harvesting had aided the movement among vineyards and regions (Daane et al. 2012). Nevertheless, long-distance movement of this mealybug is most likely a result of the movement of infested plants or fresh plant parts and agricultural commerce (Roda et al. 2013).

Uncertainty
Distribution in temperate regions: There is uncertainty on some of the distribution records in regions with similar climates to New Zealand.

Plant hosts: Given *P. minor* morphological similarity and reported misidentifications with *P.citri* due to plant host overlap, it is uncertain if all host can be attributed to *P. minor*.

Given that:

- It is likely that *P. minor* mode of reproduction is sexual and this is a significant barrier for establishment;
- *Planococcus minor* has a limited active long-range dispersal;
- *Planococcus minor* is a polyphagous species, and many of its recorded hosts are present in New Zealand. Therefore, it is highly likely that crawlers will find a suitable host;
- *Planococcus minor* has established in regions with similar climates to New Zealand;
- Has a high reproductive rate and able to produce multiple generations;
- Dispersal of crawlers can be done easily within the farms and across farms aided by agricultural equipment, farm workers, or movement of plant material;

MPI considers that the likelihood of *Planococcus minor* establishing in New Zealand is LOW with MODERATE uncertainty.

8.4.3.5 Impacts in New Zealand

This assessment is made on the assumption that P. minor *has successfully established in the New Zealand environment.*

Economic impacts
Although widely distributed, *P. minor* is not reported to be an economic pest in many countries (Roda et al. 2013). The economic impact of *P. minor* alone is difficult to assess because *P. minor* has similar host range and geographical distribution as other mealybugs (including *P. citri*) and often multiple species may occur on a plant host. For example, *P. minor* (recorded as *P. citri*), reportedly made up approximately 90% of a scale complex that included other species such as *Pseudococcus longispinus* (Targioni) and the soft scales *Coccus viridis* (Green) and *Saisettia coffeae* (Walker) on coffee in New Guinea and caused an estimated yield reduction of 70-75 percent (Williams and Watson 1988).

Many of *P. minor*'s plant hosts present in New Zealand contribute to the domestic and export revenue such as grapes (*Vitis vinifera*) (NZ$1857.9m), *Citrus* spp.(NZ$69.7m), avocado (*Persea americana*) (NZ$150.7m), watermelon (*Citrullus lanatus*) (NZ$24.7m), pumpkin (*Cucurbita maxima*) (NZ$16m), squash (*Cucurbita pepo*) (NZ$82.2m), pepper (*Capsicum annum*)(NZ$59.7m), tomato (*Solanum lycopersicum*) (NZ$143.6m), eggplant (*Solanum*

melongela) (NZ$12m), and potato (*Solanum tuberosum*) (NZ$962.3m) amongst others (Leathers 2016). All of these agricultural crops represent an approximate cumulative revenue of (NZ$3.14b) (Plant & Food Research 2020). However, no reports were found of economic impacts attributed to *P. mino*r for these plant hosts.
Mealybugs in general can cause both direct and indirect damage to plants. Direct damage occurs when the mealybug feeds on the vascular tissue of the plant. This results in leaf discolouration, distortion and dropping, and distortion and abortion of new shoots (Franco et al. 2009). When the plant is highly infested, the mealybug causes withering of the plant, stunted growth and subsequent death (Cox 1989). Damage on the fruits includes spotting at feeding sites which causes fruit discoloration, reduction of fruit growth rate, distortion of fruit, and development of cork tissue on fruit peel. Attacked fruit is considered of low quality and is often non-marketable (Ooi et al. 2002).

Indirect damage includes the production of honeydew and the transmission of viruses. Mealybugs secrete up to 90% of the ingested plant sap as carbohydrate-rich honeydew. This sugary honeydew provides a substrate for the growth of saprophytic sooty mould fungi. Sooty moulds form a black, powdery coating adhering to the leaves or fruit of plants, damaging plant surfaces and interfering with the plant's photosynthetic activity (Williams and Granara de Willink 1992). Although honeydew can be dissolved by light rain and will dry in warm temperatures, when mealybug populations are severe, honeydew can accumulate to form a hard, wax-like layer that covers the infested plant (Daane et al. 2012; Leathers 2016). The honeydew and sooty mould cause cosmetic defects and/or disfiguring of plants and/or their fruits, making plants and plants parts unsaleable (Roda et al. 2013; Leathers 2016).
Honeydew excretions from mealybugs are a major source of food for many ant and wasp species (MacIntyre and Hellstrom 2015). Ants protect mealybugs from predators and other natural enemies including parasitoids (Williams 2004). Disruption of biological control programmes for *P. ficus* as a result of injury to parasitic wasps by ants has been reported by Mgocheki and Addison (2009). Wasps feed on honeydew which otherwise will be food source for bees (MacIntyre and Hellstrom 2015).

Mealybugs, even at low population densities, can vector viruses that kill plants (Leathers 2016). *Planococcus minor* is known to be a vector of *Piper yellow mottle virus* (PYMoV) on black pepper (*Piper nigrum*) in Indonesia (Miftakhurohmah et al. 2022) and *Banana streak virus* on plantain fruit (*Musa* x *paradisiaca*) in Cuba (González-Arias et al. 2002). The transmission of viruses such as swollen shoot virus of cacao (*Theobroma cacao* L.) was initially thought to be vectored by *P. citri*. However, Cox (1989) claims that it is likely that the mealybug was misidentified and that the virus-transmission experiments actually involved *P. minor*. It is uncertain whether other viruses attributed to be vectored by *P. citri* in cacao (e.g., Ceylon cocoa virus) (Williams 2004) could be vectored by *P. minor*. Despite the ability of *P. minor* to vector viruses, none of the hosts mentioned above are of economic importance to New Zealand.

Planococcus minor is one of the mealybugs associated with grapes (*Vitis vinifera*) in Brazil together with *P. citri* (Morandi Filho 2008; Morandi Filho et al. 2015) and *P. ficus* (Daane et al. 2012). During a survey in 131 vineyards in the region of Bento Gonçalves City, *P. minor* was observed in six percent of grape clusters (50 grape clusters in total) in each site, compared to other species like *Dysmicoccus brevipes* which was present in 22.7% of grape clusters sampled (Morandi Filho et al 2015).

Other *Planococcus* species such as *P. ficus* (Engelbrecht and Kasdorf 1990) and *P. citri* (Cabaleiro and Segura 1997) are vectors of the Grapevine Leaf Roll associated Virus (GLRaV-3). To date, there is no evidence that *P. minor* is a vector of GLRaV-3.

Planococcus minor has been established in Australia at least from the 1960s (ALA 2022) and to date there has been no report of economic impacts to any of the known plant hosts. Similar case in Puerto Rico, where *P. minor* is widespread and no economic impact has been reported (Jenkins et al. 2014).

Programs to contain, eradicate and/or minimize the impact of mealybugs are likely to be costly (Bell et al. 2021) and include pesticide application and crop monitoring. In addition, existing controls (e.g., specific integrated pest management or organic systems) may be ineffective and compromised. In New Zealand since 1960s, there are programs established to control *Pseudococcus* mealybugs responsible for GLRAV-3, which is one of the most serious virus diseases affecting New Zealand grapevines (Bell et al. 2009; Bell et al. 2021). Even though the incursion of *P. minor* could increase to some extent the impact of mealybugs on crops such as grapes, current management strategies to control the impact of mealybugs would be applicable for *P. minor*.

Successful biological control programmes against two of the main mealybug pests in New Zealand vineyard have been reported (i.e. *Pseudococcus longispinus* and *P. calceolariae*) (Charles et al. 2010). This suggests that despite the presence of mealybugs in New Zealand in the last 100 years, biological control programmes with native and introduced species have not been compromised due to symbiotic relationship of mealybugs with ants.

An in-house MPI model predicted a low level of economic impact (between 10 and 100 million) over 20 years.

- Given that no information was found on the infestation level/yield loss on any important plant host important to New Zealand caused by *P. minor* but the mealybug is capable of causing damage, a 1% – 5% was assumed as a range of greatest level of impact that the mealybug can infest/damage a main known host. The model only considers the impact in the North Island, as it is the region where *P. minor* is most likely to establish in New Zealand given its worlwide distribution (Table 1). Plant host considered are grapes, avocado, citrus and potatoes, which are the main host of *P. minor* that are main agricultural crops in the North Island.
- The combined domestic and export value in New Zealand for avocado, citrus and potatoes are NZ$ 252.2 m , 71.6 m , 178.8 m, respectively (Plant & Food Research 2020, 2021) and the export revenue for grapes tables and wine is NZ$1857.9 (Plant & Food Research 2021). The planted area (ha) of each of these crops in the North Island (Plant & Food Research 2017) was used to calculate the proportion of production area to the whole of New Zealand (19.74%, 99.65%, 99.41, 50.4%) and to obtain the annual crop values for grapes, avocado, citrus and potatoes in the North Island which were NZ$366.75m, 251.32m, 71.18m and 90.12m, respectively. The greatest level of annual impact of each of these crops in the North Island is 1% – 5% of these values.
- The time to achieve the greatest impact was assumed to be 5 years given the limited dispersal capability of this mealybug.
- It was assumed that the time industries will take for full recovery was 1 year given that there are already effective control approaches for other mealybugs (Bell et al 2019; Bell et al., 2021).

The presence of this mealybug in New Zealand could represent an added impact for exporters because in other countries (e.g., USA), *P. minor* is considered a ‘regulated actionable pest’. This means that consignments could be destroyed, re-exported or fumigated at the exporter’s expense. Phytosanitary measures and compliance agreements (e.g., treatment schemes and inspection requirements) could be put in place, which would represent an additional cost to the producer (Roda et al. 2013). However, it was considered that this added impact is likely to be very low given the current effective controls approaches for other mealybugs. Therefore, the overall economic impact was considered to be low.

Uncertainty

Economic impacts: There is no information regarding the economic impact of *P. minor* on plant hosts that are present in New Zealand and impacts on other commodities are difficult to assess for a single mealybug because often *P. minor* interacts in the same host with a complex of other mealybugs.

Direct and indirect damage: There is no information about the damages of *P. minor* on plant hosts present in New Zealand. Therefore information was obtained from other *Planococcus* species.

Impacts on trade: It is unknown what would be the impact of trade by the potential incursion of *P. minor* in New Zealand.

Given that:

- There is no evidence of economic impacts attributed to *P. minor* on any of the horticultural crops of economic importance to New Zealand;
- Other countries/territories where *P. minor* has successfully established (e.g., Australia and Puerto Rico), have not reported any economic impacts;
- *Planococcus minor* transmits viruses to host plants that are not of economic importance to New Zealand;
- The attraction to ants due to the honeydew produced by *P. minor* is considered of negligible risk to biological control programmes in New Zealand because successful biological control programmes have been reported in New Zealand for mealybugs that have been established in the past 100 years;
- Additional management cost to producers because of the presence of *P. minor* is considered low because there has been management programmes to control mealybugs in New Zealand vineyards since the 1960s. These programmes are likely to control *P. minor* populations;
- Incursion of this mealybug could represent additional costs to producers due to phytosanitary measures and compliance agreements imposed by other countries where *P. minor* is a regulated pest;

MPI considers that the economic impact of *Planococcus minor* in New Zealand is LOW, with MODERATE uncertainty

Environmental impacts

The flowering plants genera *Schefflera* sp. and *Pelargonium* sp. and the New Zealand laurel, *Corynocarpus laevigatus*, are listed as hosts of *P. minor*. However, no information was found regarding the extent of damage caused by *P. minor* on these host plants. The risk of *P. minor* on these native species is considered very low because there are no reports of mealybugs that have already established in New Zealand (eg., *Pseudococcus calceolariae*) causing major damage to native species (Beever et al. 2007). In addition, New Zealand climate is not optimal for *P. minor* establishment.

The incursion of a new mealybug species to New Zealand could trigger new chemical treatment programs in horticulture and by residents who find infested plants rather unpleasant (Leathers 2016). The increase of pesticide application could result in the decline of native butterflies (Sands and New 2002), soil toxicity (Dalvi and Salunkhe 1975), runoff and water system contamination (APVMA 2008; NSWDPI 2012). However, increase in environmental impacts would likely to be negligible because current insectide treatments for mealybugs that are already present in New Zealand are likely to control *P. minor* (Charles 2004).

Uncertainty
Risk to native species: There is no information on impacts of *P. minor* on plant hosts that are native to New Zealand. It is uncertain if *P. minor* feeds on all *Schefflera* and *Pelargonium* species because they are listed as *Schefflera* sp and *Pelargonium* sp. by Venette and Davis (2004). Therefore it is unknown if *P. minor* will impact the New Zealand native species *Schefflera digitata* and *Pelargonium inodorum*.

Given that:

- There is no evidence of major damage caused to native species by exotic mealybugs in New Zealand and;
- The environmental conditions are not adequate for the establishment of *P. minor*;

MPI considers that the environmental impact of *Planococcus minor* in New Zealand is VERY LOW with MODERATE uncertainty

Human health impacts
There is no evidence of direct impacts of *Planococcus minor* on human health. The attraction of aggressive ants to the honeydew produced by mealybugs could potentially be an indirect human health impact. Some ants such as the Argentine ants are aggressive and bite when disturbed and some people have serious allergic reactions (Harris 2002). However, Argentine ants have a symbiotic association with the vine mealybug *Pseudococcus calceolariae* found in New Zealand (Hardiman 2018) and it is not known to cause a considerable human health impact on people working on vineyards. In addition, of all the ant species present in New Zealand, very few species are capable to inflict a painful sting and are not generally known to have tending behaviour in aboveground plant parts (Warwick 2007).
Given that:

- There are no reports of health impacts on people working in the field as a result of the attraction of aggressive ants by the honeydew excreted by other mealybugs found in New Zealand

MPI considers that the human health impact of *Planococcus minor* in New Zealand is NEGLIGIBLE with LOW uncertainty.

Sociocultural impacts
There is no information about damage on taonga species attributed to *P. minor*. The genera *Schefflera* sp. and *Pelargonium* sp. and species *Corynocarpus laevigatus* (known as ‘karaka’) are listed by (Leathers 2016). New Zealand native species such as *S. digita* (patatē) and *C. laevigatus* are taonga species that have medicinal properties or used as food source by Maori people to survive particularly before the arrival of Europeans (Maanaki-Whenua 2022).

These species are widespread in New Zealand and their conservation status is ‘not threatened’ (NZPCN 2002). There are no reports of mealybugs in New Zealand (that have established for a long time) causing major damage to taonga species (Beever et al., 2007). Root crops such as *Ipomoea batatas* (sweet potato or ‘Kūmara’), *Solanum tuberosum* (potato) and *Colocasia esculenta* (taro) are listed as hosts of *P. minor* (Leathers 2016). These crops are considered staple food (potatoes) and taonga by Māori people (Kūmara) and considered kai rangatira (food for important people) (taro) by the Pasifika communities (McFarlane 2007; Furey 2008; McVinnie 2008). There is no information available about impacts on these crops by *P. minor*, however, other mealybugs that have established in New Zealand for a long time (such as *Pseudococcus longispinus*) is not known to cause any impact on taro.

The presence of sooty mould on New Zealand gardens is considered a nuisance because it is unsightly or because the honeydew is deposited on automobiles, outdoor furniture or anything that is placed under a mealybug infested tree (Windbield-Rojas and Messenger-Sikes 2020).

Uncertainty

Risk to taonga or staple foods: There is no information regarding the impacts of *P. minor* on New Zealand taonga species or staple foods, therefore this assessment is based on the information available from other mealybug species established in New Zealand.

Given that:

- There is no evidence of *P. minor* affecting species that are considered taonga or staple foods for Maori or Pasifika communities in New Zealand;
- It is not known of any other mealybug species that have established in New Zealand, having major damage that would compromise the cultivation of root crops that are considered of importance by Maori people and Pasifika communities;

MPI considers that the sociocultural health impact of *Planococcus minor* in New Zealand is VERY LOW with MODERATE uncertainty。

8.4.3.6 Overall impact to New Zealand

MPI considers the overall impact of *P. minor* on the New Zealand economy, environment, health and society is LOW with MODERATE uncertainty.

8.4.3.7 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is LOW with MODERATE uncertainty,
- assuming entry, the likelihood of exposure is VERY LOW with MODERATE uncertainty,
- assuming successful exposure, the likelihood of establishment is LOW with MODERATE uncertainty, and
- the overall impact on the New Zealand economy, environment, human health, and society is considered to be LOW with MODERATE uncertainty,

MPI considers the overall level of assessed risk to New Zealand from *Planococcus minor* on pineapple fruit is VERY LOW with MODERATE uncertainty.

8.4.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *Planococcus minor* association with pineapple fruit been observed?
There is no reference in the literature regarding the stage of ripeness or the pineapple varieties *Planococcus minor* is associated with.

Which part(s) of the pineapple fruit is *Planococcus minor* associated with (e.g., fruit, bract, stem or crown remnant) and is it detectable by visual detection?
There is no specific information regarding the part of the pineapple *P. minor* is associated with. However, other *Planococcus* species are known to be found on the base of leaves, twigs, bark, flowers and fruit. Therefore, it is assumed that *P. minor* will have similar behaviour.

Are different life stages of *Planococcus minor* associated with different parts of the pineapple fruit?
There is no specific information about the parts of the pineapple fruit where different life stages of *P. minor* are found. In other crops, such as cotton, *P. minor* crawlers, wander around the plant toward actively growing plant parts before settling to feed. The female adult becomes more sessile and can be found in similar places as the crawlers.

Does *Planococcus minor* burrow into the fruit without obvious symptoms, or hide under the pineapple bract?
Mealybugs immature stages and eggs are inconspicuous and easily to go unnoticed in pineapples because they can hide under bracts and crevices of the fruit.

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8.5 Pseudococcus jackbeardsleyi (Jack Beardsley mealybug)

Pseudococcus jackbeardsleyi is a polyphagous mealybug that feeds on the sap of hosts from over 50 plant families. This mealybug can infest most above-ground plant parts, including leaves, stems and fruit. It is present in many warmer parts of the world, in particular the Americas and Asia and is commonly detected in on nursery stock (plants for planting), ornamentals and fresh produce in various ports of entry around the world.

8.5.1 *Taxonomic description*

Scientific name: *Pseudococcus jackbeardsleyi* Gimpel and Miller 1996
Order: Hemiptera **Family:** Pseudococcidae
Other names: Jack Beardsley mealybug

Taxonomic notes:
Pseudococcus jackbeardsleyi was first described by Gimpel and Miller in 1996, from specimens collected in 1921. Before it was described, *P. jackbeardsleyi* was often misidentified as the morphologically similar *P. elisae. Pseudococcus elisae* has a more restricted host range and geographical distribution.

8.5.2 *Hazard identification*

Pseudococcus jackbeardsleyi is not present in New Zealand.

- There is no entry of *Pseudococcus jackbeardsleyi* in NZOR (2022) or BiotaNZ (2022).
- *Pseudococcus jackbeardsleyi* is listed as not present in New Zealand in PPIN (2022).
- *Pseudococcus jackbeardsleyi* is a regulated pest for New Zealand and has unwanted status in ONZPR (2022).

Pseudococcus jackbeardsleyi has the potential to become established in New Zealand and spread.

- The geographic distribution of *P. jackbeardsleyi* spans across many countries (Gimpel and Miller 1996), and the climate in some of these regions is similar to some parts of New Zealand.
- *Pseudococcus jackbeardsleyi* has a wide host range (Williams 2004; García-Morales et al. 2016) and some hosts (e.g. tomato, potato and citrus) are commonly grown in many areas of New Zealand.
- *Pseudococcus jackbeardsleyi* feeds on different plant parts such as leaves, stems and fruits (Gimpel and Miller 1996; Williams 2004).

Pseudococcus jackbeardsleyi has the potential to cause harm to New Zealand.

- *Pseudococcus jackbeardsleyi* has the potential to harm economically important plants (e.g. capsicum, tomato, potato and citrus) in New Zealand by damaging their appearance.
- *Pseudococcus jackbeardsleyi* has the potential to expand its host range to include some native plants because it has host species in the same genera in its realised geographic range.

- *Pseudococcus jackbeardsleyi* has the potential to affect culturally significant plants such as sweet potato (kūmara) and plants that are grown by home gardeners.

Pseudococcus jackbeardsleyi is associated with pineapple fruit.

- Pineapple is a host of *P. jackbeardsleyi* (Gimpel and Miller 1996; Culik et al. 2007), and the mealybug may be found on all plant parts of its hosts including fruit (Gimpel and Miller 1996).
- *Pseudococcus jackbeardsleyi* has been intercepted on pineapples at the New Zealand border (LIMS 2022).
- Mealybug species associated with pineapples are typically more prevalent on mature plants and fruit than immature plants or suckers that are yet to start fruiting (Bartholomew and Malézieux 1994), however, the level of fruit maturity was not clearly defined.

MPI considers *Pseudococcus jackbeardsleyi* a hazard on pineapple fruit imported to New Zealand.

8.5.3 *Risk assessment*

8.5.3.1 Biology

Hosts and geographical distribution

Pseudococcus jackbeardsleyi is a polyphagous pest which has been reported from 158 plant species in 54 plant families (García-Morales et al. 2016). Some economically important hosts include capsicum, tomato, potato, citrus and pineapple (Williams 2004; Culik et al. 2007; García-Morales et al. 2016). *Pseudococcus jackbeardsleyi* feeds on sap from the stems, fruits and leaves of its hosts (Gimpel and Miller 1996; Williams 2004; Mani et al. 2013). It is mostly distributed in tropical areas (Gimpel and Miller 1996; Matile-Ferrero 2006; Germain et al. 2008; Muniappan et al. 2009; Germain 2013; Germain et al. 2014). The geographic distribution of *P. jackbeardsleyi* is shown in Table 1.

Table 1: Geographic distribution of *Pseudococcus jackbeardsleyi*. Distribution is based on García Morales et al. (2016) except where a different reference is cited. Markets in this IRA are in bold.

Continent/Region	Country/area/market
Africa	Cote d'Ivoire, Réunion, St. Helena, Seychelles
Asia	Brunei, Cambodia, China (Hainan, Xinjiang), India (Kerala, Tamilnadu), **Indonesia** (Java, East Nusa Tenggara, West Papua), Laos, **Malaysia**, Maldives, **The Philippines**, Singapore, Singapore, **Sri Lanka**, **Taiwan**, **Thailand**, Vietnam
Europe	N/A
North America and the Caribbean Islands	Aruba, Bahamas, Barbados, Belize, **Costa Rica**, Cuba, Dominican Republic, El Salvador, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, Martinique, Mexico, **Panama**, Puerto Rico and Vieques Island, St. Martin, St. Barthelemy, Trinidad and Tobago, USA (Hawaii, Florida, Texas), U. S. Virgin Islands
Oceania	**Australia** (Queensland) (Queensland Government 2020), Papua New Guinea, Federated States of Micronesia, French Polynesia, Kiribati, Niue (McKenzie et al. 2001), Tuvalu

Continent/Region	Country/area/market
South America	Brazil (Espírito Santo, Pernambuco, Rio Grande do Sul), Colombia, **Ecuador** (Galapagos Islands), Peru, Venezuela

General biology

The feeding behaviour and general biology of *P. jackbeardsleyi* is typical of other mealybugs (Williams 2004; CABI 2022). There are few published reports on the biology of *P. jackbeardsleyi* specifically, so some information is general to mealybugs. Mealybugs have five male instars and four female instars (including adults). *Pseudococcus jackbeardsleyi* lays about 300 to 500 eggs in a waxy cotton-like material (ovisac) on the host plant (Undhawutti et al. 2011). The process of making the ovisac and laying eggs may take 1–2 weeks (Undhawutti et al. 2011) but it is not clear if the adult female lays only one set of eggs over the course of its life. The eggs frequently hatch within 7–10 days (Undhawutti et al. 2011; Wang 2015). The first instars (crawlers) are the most mobile stage of all mealybugs. Using their well developed legs, they are able to crawl out of the ovisac towards a favourable feeding site on the host plant (Williams 2004; Mau and Kessig 2022). Other life stages are less mobile (Mau and Kessig 2022). The male pupa is black and covered in multiple wax layers (Wang (2015). Although *P. jackbeardsleyi* adult males have not been specifically described, male mealybugs are generally small, winged, lacking functional mouth parts, and alive for less than a day (Williams 2004; CABI 2022). Adult *P. jackbeardsleyi* females are the most commonly encountered lifestage (Sartiami et al. 2016; Pacheco Silva et al. 2019). They can be found in mixed colonies with other mealybugs, e.g. *Paracoccus marginatus* (Sartiami et al. 2016). Adult *P. jackbeardsleyi* females are occasionally tended by ants (e.g. *Brachymyrmex* spp. and *Crematogaster* spp.) which feed on the honeydew produced by the mealybugs (Williams 2004; Kondo et al. 2008). Depending on climatic conditions, about eight or nine generations of the pest can occur in a year (CABI 2022). The life span of *P. jackbeardsleyi* under natural conditions is not known but it takes ≤ 35 days to grow from eggs to adults in the laboratory (Shao et al. 2013; Wang 2015). Since males are reported it is assumed that *P. jackbeardsleyi* reproduces sexually however it is not known whether there are also asexually reproducing forms.

The optimum temperature required for growth and development of *P. jackbeardsleyi* in the laboratory is 25°C (Zhan et al. 2016; Piyaphongkul et al. 2018; Nurkomar et al. 2021) while the minimum and maximum lethal temperatures for nymphs and adults are 5°C and 56°C respectively (Piyaphongkul et al. 2018). *Pseudococcus jackbeardsleyi* nymphs, like the nymphs of other mealbugs, can disperse naturally by walking across short distances (Williams 2004). Longer distance dispersal can take place by wind or phoresy (Gimpel and Miller 1996; Williams 2004), but long range dispersal (invasion) usually occurs via human-mediated movement of infested host plant material (Gimpel and Miller 1996).

Symptoms

Pineapple is a known host of *P. jackbeardsleyi*, (Gimpel and Miller 1996; Culik et al. 2007) however it is not known to cause any particular damage to the plant. The lack of reports of damage to pineapple by *P. jackbeardsleyi* is partly attributed to suppression by natural enemies (Culik et al. 2007). Heavy infestions of *P. jackbeardsleyi* on other plants are generally obvious because they often form colonies or exist in mixed colonies with other mealybugs (Pacheco Silva et al. 2019). Even after removal of the mealybugs and their ovisacs from heavily infested fruits, their honeydew by-products develop sooty moulds which may remain on the fruits (Pacheco Silva et al. 2019).

8.5.3.2 Likelihood of entry

Pseudococcus jackbeardsleyi has a wide range of hosts and is mostly distributed in tropical regions (Table 1). It is reported from 10 out of the 17 markets within the scope of this IRA project, including Costa Rica, Ecuador, Indonesia, Malaysia, Panama, Papua New Guinea, the Philippines, Sri Lanka, Taiwan and Thailand (Gimpel and Miller 1996; Williams 2004; García-Morales et al. 2016). Most of the pineapple fruit currently imported to New Zealand are from the Philippines and Ecuador (QuanCargo 2021). While this mealybug is known to be associated with pineapple, most invasions have been associated with other plant hosts. *P. jackbeardsleyi* has been observed on pineapple plants in Brazil, Costa Rica, Cuba, Domincan Republic and Puerto Rico (Gimpel and Miller 1996; Williams 2004; Culik et al. 2007).

Mealybugs are generally more prevalent on mature pineapple plants and fruits (Bartholomew and Malézieux 1994) but the level of fruit maturity was not clearly defined. There are three records of the mealybug being intercepted at the New Zealand border on pineapples from the Philippines between 2000 and 2020 (LIMS 2022). *P. jackbeardsleyi* is often intercepted on pineaples in China (Zhan et al. 2016). It is possible that the interceptions of *Pseudococcus* mealybugs on pineapples at Italy's border (EPPO 2022) were *P. jackbeardsleyi* but this is not confirmed. Adult *P. jackbeardsleyi* females are 3–4 mm long and 2 mm wide with long tail filaments (Gimpel and Miller 1996; Undhawutti et al. 2011). The first instars are tiny (0.7–1.2 mm long), more mobile (Undhawutti et al. 2011), and capable of hiding in the bracts, exterior grooves or crown remains of pineapples. The first instars of *P. jackbeardsleyi* are more likely to be missed at border inspections than the adults. The eggs and nymphs of pseudococcid mealybugs are frequently intercepted on pineapples at the New Zealand border (LIMS 2022). Since pseudococcid mealybugs are morphogically indistinguishable at the egg and nymphal stages (Williams 2004), it is likely that some of Pseudococcidae interceptions on pineapples at the New Zealand border were *P. jackbeardsleyi*.

Thermal acclimation experiments by Piyaphongkul et al. (2018) showed that *P. jackbeardsleyi* mealybugs can survive at temperatures below 13°C but are not likely to retain their muscular control or develop. The temperature requirement (7°C–13°C) during shipping may not be sufficient to stop the mealybug entering New Zealand if it can continue its development at normal room temperature when it arrives. Additionally, pineaples fruits imported by air cargo may not undergo the required temperature (7°C–13°C), and even if they do, it may only be for hours rather than days or weeks as is the case by sea ships. This may also explain the live *P. jackbeardsleyi* mealybugs that has been intercepted on pineapples at the New Zealand border (LIMS 2022). *P. jackbeardsleyi* is susceptible to irradiation, chemical and heat treatment, partly because it is on the exterior of the fruit (Ma et al. 2014; Wang 2015; Hofmeyr et al. 2016).

Uncertainty

There is moderate uncertainty about whether *P. jackbeardsleyi* could arrive on the commodity. Thorough cleaning is likely to reduce abundance of the mealybugs on the commodity especially when they occur in a colony. Thorough cleaning using high water pressure reduces the mealybugs on capsicums but does not eliminate them (Jamieson et al. 2010).

Pseudococcus jackbeardsleyi can survive at temperatures below 13°C (Piyaphongkul et al. 2018), but no information was found about the length of time it can survive at such temperatures. Since the mealybug can lose muscular control at temperatures close to 13°C (Piyaphongkul et al. 2018), it is not clear if it will still be fit enough to survive in the New Zealand environment, especially if the cold transit period is long (two to three weeks).

Given that:

- the mealybug is associated with the exterior of the pineapple fruit,
- the first instars of the mealybugs may be missed during border inspections if they hide under pineapple bracts,
- the mealybug can survive short transits to New Zealand, especially if the commodity is brought in by air cargo.

but considering:

- no information was found to associate the mealybug with pineapple fruits apart from interception data.
- that basic pre-export cleaning may reduce the mealybugs' abundance on the commodity,
- the mealybug is unlikely to remain viable after long transits in cold temperatures,

MPI considers the likelihood of *P. jackbeardsleyi* entering New Zealand associated with pineapple fruit is LOW, with MODERATE uncertainty.

8.5.3.3 Likelihood of exposure

This assessment is made on the assumption that Pseudococcus jackbeardsleyi *has entered New Zealand undetected. Exposure is considered to be the transfer of a pest or disease from an imported commodity or inanimate object, to a host or environment suitable for the completion of development or production of offspring.*

Imported fresh pineapple fruit is intended for human consumption, therefore, when the fruit arrives in New Zealand it will be distributed throughout New Zealand for wholesale or retail sale. Fresh pineapple fruit generates substantial amounts of unavoidable waste; the thick rind is always removed and disposed of, and the fruit is also sometimes cored (see waste analysis section 2.3.1). The disposal of whole fruit (e.g. culled/unsold fruit, uneaten fruit remains) is common during wholesale, retail and by consumers. This suggests that *P. jackbeardsleyi* may have a higher likelihood of exposure when associated with fresh pineapple fruit than when it is associated with other kinds of fresh produce that are generally eaten whole.

In New Zealand the most common method of disposal of organic waste is bagged into landfill (Askarany and Franklin-Smith 2014); this is unlikely to be a risk. However, there are other disposal methods that could increase the exposure likelihood of the mealybug, such as feeding out to animals, home composting and direct disposal into the environment. Fruit waste may be collected from unpacking areas (e.g., supermarket preparation rooms) and taken to rural areas where it is placed on the ground for eventual consumption by pigs or other farm animals (MPI 2014). The waste materials may also be used in worm farming. Worm farming is considered a low-risk method of organic waste disposal because organic waste is often cut into small pieces (Angima et al. 2011) and the worm farm bins are often covered.

Composting is considered a low-risk method if it is done commercially. Waste in commercial compost is put into tunnels for a period of three to four days at temperatures of 55 °C or higher and these conditions are likely to kill all stages of *P. jackbeardsleyi* since no lifestages survive at 49 °C or higher for more than two hours (Ma et al. 2014). Home composting increases the likelihood of exposure. A study conducted in Palmerston North found that 63%

of a total of 72 households that do home composting used manufactured plastic bins for composting and the majority of others used an ‘open’ composting system, such as open compost piles and piles fenced with wire (Mensah 2017). Even though both home composting methods increase the likelihood of exposure of the mealybug to immediate hosts that are commonly found in New Zealand gardens (e.g., citrus and ornamentals), compost in plastic bins is less likely to result in successful exposure than in open compost. In plastic bins, organic waste is piled up inside the bin and usually the bins are black, which helps keep high temperatures inside the bin. Plastic bins have holes for aeration on the outside close to the ground. For a mealybug to escape the compost bin, the compost bin needs to be almost empty. If a mealybug escapes a plastic bin or open compost, many suitable host plants are available at ground level and could be within the walking range of crawlers.

Pseudococcus jackbeardsleyi is a polyphagous species that is able to feed on most plant parts (Gimpel and Miller 1996), potentially allowing it to persist in the environment when infested pineapple fruit parts are discarded. Although the first instars of *P. jackbeardsleyi*, like other mealybugs, are more mobile than the three succeeding life stages (Williams 2004), all the nymphs and adult females have well developed legs (Gimpel and Miller 1996) and can move over very short distances to find an appropriate feeding site on host plants (Williams 2004). Additionally, *P. jackbeardsleyi* can be dispersed onto other suitable hosts by wind when infested host leaves are blown away (Williams 2004). Its polyphagous nature means the mealybug has an increased likelihood of encountering a new host that is suitable by chance. The use of pumpkins and sprouting potatoes to culture *P. jackbeardsleyi* in the laboratory (Undhawutti et al. 2011; Pumnuan and Insung 2016; Zhan et al. 2016; Piyaphongkul et al. 2018) suggests that the pest can easily survive on available plant materials when infested pineapple fruit parts are discarded in the environment.

Uncertainty

Information regarding food waste in New Zealand is based on general data and there is no specific information on pineapple waste. Therefore, it is assumed that the percentages of pineapple fruit skin which are not disposed in the landfill in New Zealand will be much lower.

While *P. jackbeardsleyi* can easily feed on a wide variety of plant species, the presence of secondary metabolites (e.g. alkaloids and acetogenins) in some plant stems and leaves may have negative impacts on the mealybug’s survival (Pacheco Silva et al. 2019). The relatively colder climate of New Zealand might be a limiting factor in the survival of *P. jackbeardsleyi* and its exposure to suitable hosts since the pest is more prevalent in tropical areas (see Table 1). It is not clear if the mealybug can develop or recover after being paralysed by the required low temperatures for shipping. Thus it is uncertain if it can be exposed to the environment.

Given that:

- the mealybug has a wide variety of hosts and it feeds on the stems, fruits and leaves of its hosts;
- the mealybug can actively crawl to a new feeding site and can be blown by wind to a suitable host;

but considering:

- the mealybug is unlikely to survive commercial composting, and
- cold temperatures and plant secondary metabolites can impede the mealybugs’s survival;

MPI considers the likelihood of exposure of *P. jackbeardsleyi* in New Zealand from pineapple fruit is VERY LOW, with MODERATE uncertainty.

8.5.3.4 Likelihood of establishment

This assessment is made on the basis that Pseudococcus jackbeardsleyi *has been successfully exposed to a suitable host plant in the New Zealand environment.*

Pseudococcus jackbeardsleyi has over 150 reported plant hosts (García-Morales et al. 2016) and the majority of these hosts are economically significant plants. Some of the known hosts occur in New Zealand as commercially cultivated crops (e.g. capsicum, potatoes and tomatoes) and/or backyard plants (e.g. citrus) in many home gardens. *Pseudococcus jackbeardsleyi* feeds on the stems, leaves and fruits of its host plants (Gimpel and Miller 1996). *Lantana camara* is a known host of the mealybug (Gimpel and Miller 1996) and occurs in New Zealand. The unusually wide range of host plants strongly suggests that *P. jackbeardsleyi* will find new hosts in New Zealand. Availability of hosts will likely favour the establishment of *P. jackbeardsleyi*.

Pseudococcus jackbeardsleyi is distributed across a wide geographical range (Table 1). However, most of the countries where *P. jackbeardsleyi* exist have tropical climates. The northern parts of New Zealand have a warmer and more humid climate, which is typical of countries where *P. jackbeardsleyi* occurs. We assess whether climatic conditions are similar to New Zealand using the composite match index (Phillips 2018). The CMI values range from 0.2 to 1. If a country has CMI of ≥ 0.7, its climate is similar to the climate of all of New Zealand. While the ranges of CMI values in most of the countries where *P. jackbeardsleyi* occurs are less than 0.6, it also occurs in other places like Taiwan (0.4–0.7), the warmer regions of USA (0.5–0.7), and Mexico (0.3–0.8), which demonstrates its potential to establish a population in the northern parts of the North Island. The few odd records from Canada (Gimpel and Miller 1996) and China (Wang et al. 2018) were associated with indoor or greenhouse plants. *P. jackbeardsleyi* has not become established in those regions. The predicted increasing range of insect pest occurrence as a result of climate change (Skendžić et al. 2021) may increase the potential of *P. jackbeardsleyi* to establish a population in New Zealand.

Established populations of mealybugs can spread to non-infested hosts when crawlers attached to plant parts are blown by wind to a suitable host sites (Williams 2004). This suggests that *P. jackbeardsleyi* could spread if it becomes established in New Zealand. However, *P. jackbeardsleyi* is unlikely to spread beyond the northern part of the North Island, which has a warmer climate than the rest of New Zealand. Although *P. jackbeardsleyi* has been recorded in the warmer parts of USA (Gimpel and Miller 1996) for about 30 years or more, it is yet reach the colder parts of USA. Temperature might be a factor limiting its spread. The detection of *P. jackbeardsleyi* in a flower greenhouse market in China (Wang et al. 2018) suggests that the mealybug could possibly spread through the trade of greenhouse plants if it establishes a population in New Zealand.

Uncertainty

It is not clear if *P. jackbeardsleyi*'s co-occurrence with other mealybugs can enable its establishment in New Zealand. For example, *Planococcus minor* occurs in mixed colonies with *P. jackbeardsleyi* (Sartiami et al. 2016), but it is not clear if *P. jackbeardsleyi* competes with such mealybugs or benefits from their presence.

New Zealand has two of *P. jackbeardsleyi*'s five natural enemies, which may limit its population size and spread. These are one insect (*Cryptolaemus montrouzieri*) (Mani et al. 2013) and one fungus (*Lecanicillium lecanii*) (Ginting et al. 2020).

Given that:

- hosts are widely available for the establishment of *P. jackbeardsleyi*;

but considering:

- the climate is relatively unsuitable for the mealybug's establishment,
- existence of natural enemies may impede spread and population size of the mealybug;

MPI considers the likelihood of *Pseudococcus jackbeardsleyi* establishing in New Zealand is VERY LOW, with MODERATE uncertainty.

8.5.3.5 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is LOW with MODERATE uncertainty,
- assuming entry, the likelihood of exposure is VERY LOW with MODERATE uncertainty,
- assuming successful exposure, the likelihood of establishment is VERY LOW with MODERATE uncertainty,

The combined likelihood for entry, exposure and establishment is NEGLIGIBLE. Therefore, MPI considers the overall level of assessed risk to New Zealand from *Pseudococcus jackbeardsleyi* on pineapple fruit is NEGLIGIBLE, with MODERATE uncertainty. This is based on the methodology provided in the 'Guidelines for Risk Analysis in Plant Biosecurity 1.0'

8.5.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *Pseudococcus jackbeardsleyi* association with pineapple fruit been observed?
No information was found to suggest that *P. jackbeardsleyi* is associated with a particular stage of ripeness or variety of pineapple fruits.

Which parts of the pineapple fruit is *Pseudococcus jackbeardsleyi* associated with (e.g. fruit, bract, stem or crown remnant) and is it detectable by visual detection?
No information was found linking *P. jackbeardsleyi* to any specific part of pineapple fruit, but it is clearly associated with fruit (LIMS 2022). It is known to feed on stems, leaves and fruits of its host plants, therefore, it will likely be associated with all exterior parts of pineapple fruit.The mealybug is detectable by visual inspection but the first three instars are likely to be missed because they are smaller and can hide under the pineapple bracts.

Are different lifestages of the *Pseudococcus jackbeardsleyi* associated with different parts of the pineapple fruit?

No information was found about specific life stages of *Pseudococcus jackbeardsleyi* associating with particular parts of the pineapple fruit. All post-egg stages of the mealybug have well developed legs and can move around the fruit.

Does *Pseudococcus jackbeardsleyi* burrow into the fruit without obvious symptoms, hide under the pineapple bract OR exhibit latent/asymptomatic traits?
Pseudococcus jackbeardsleyi feeds and lives on the exterior parts of its hosts. The first three instars are small and can easily hide under the pineapple bracts, grooves and crown remains. The adult females are relatively obvious. The cotton-like ovisac with eggs is quite obvious.

8.5.5 *References*

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9 Pest risk assessments on insects: Lepidotera, Cosmopterigidae (cosmet moths)

9.1 *Anatrachyntis rileyi* (pink scavenger caterpillar)

Anatrachyntis rileyi is generally regarded as a scavenger that feeds on dead plant material, however it can also feed on healthy plant tissue. It has tropical and subtropical distribution but has also established in some temperate regions. Larvae are mainly associated with the flower parts of the pineapple plant but occasionally damages the fruit surface by boring into the fruit. This affects the fruit shelf life and marketability.

9.1.1 *Taxonomic description*

Scientific name: *Anatrachyntis rileyi* (Walshingham, 1882)
Order: Lepidoptera **Family:** Cosmopterigidae
Other scientific names: *Batrachedra rileyi* Walsingham, 1882; *Pyroderces rileyi* (Walsingham, 1882) ; *Sathrobrota rileyi* (Walsingham, 1882); *Batrachedra stigmatophora* Walsingham, 1897; *Pyroderces stigmatophora* (Walsingham, 1897); *Anatranchyntis stigmatophora* (Walsingham, 1897) (Synonymy from Zimmerman 1978).

Other common names: scavenger bollworm, pink budmoth, pink cornworm

Taxonomic notes:
There is no uniformity in the use of the scientific name across the literature. The genus *Anatrachyntis* has been accepted by European authors (Koster and Sinev 2003; Heckford and Sterling 2004), while the genus *Pyroderces* is still commonly used in America (Cubillo and Guzmán 2003; Roque-Alberto 2006; Lee and Brown 2009).

Larvae of *A. rileyi* larvae are morphologically very similar to those of *A. badia* (Adamsky et al 2006) and adults of *A. rileyi* have nearly identical wings as *A. simplex* (Halbert 2015). Historically these similarities have led to widespread misidentifications, particularly in publications in the first half of the 20th century (Zimmerman 1978, Halbert 2015). Examination of genital structures is recommended for accurate species determination (Dawidowicz and Rozwałka 2017).

9.1.2 *Hazard identification*

Anatrachyntis rileyi is not known to be present in New Zealand.

- There is no entry for *Anatrachyntis rileyi* in NZOR (2022).
- There is no entry for *Anatrachyntis rileyi* in BiotaNZ (2022).
- There is no entry for *Anatrachyntis rileyi* in PPIN (2022).
- *Anatrachyntis rileyi* is a regulated and unwanted pest for New Zealand (ONZPR 2022).

Anatrachyntis rileyi has the potential to establish and spread in New Zealand.

- Many of the host plants of this moth are cultivated or found growing wild in New Zealand (BiotaNZ 2022).
- Climate is unlikely to be a barrier for establishment, given that the species has been reported from places with similar climate to New Zealand (Douglas et al 1962; Arbogast and van Byrd 1986; Herbison-Evans and Crossley 2002).

- *Anatrachyntis rileyi* has established in cooler regions than New Zealand, where larvae have overwintered in temperatures as low as -3°C, and emerged when temperatures are more suitable for development (Douglas et al 1962)

- *Anatrachyntis rileyi* has the potential to cause harm to New Zealand.
    - *Anatrachyntis rileyi* has the potential to cause harm to corn and citrus plantations (Douglas et al 1962; Grafton-Cardwell et al 2017).
    - *Anatrachyntis rileyi* has the potential to cause harm to taonga species such as taro (*Colocasia esculenta*) (Cock and Burris 2013).

Anatrachyntis rileyi is associated with pineapple fruit.

- *Anatrachyntis rileyi* larvae usually feed on the remains of petals, stamens and style at the bottom of the blossom cup but a few larvae may bore into the fruit when it is close to ripe, causing injury (Linford 1939).
- *Anatrachyntis* rileyi larvae have been intercepted on multiple occasions on pineapple fruits at the New Zealand border (AQ 2022; LIMS 2022)

Given the arguments and evidence above, MPI considers *Anatrachyntis rileyi* to be a hazard on decrowned *Ananas comosus* (pineapple) fruit (as described in the commodity description) imported to New Zealand.

9.1.3 *Risk assessment*

9.1.3.1 Biology

Description

Anatrachyntis rileyi eggs are small, about 0.5 mm with a pearly white colour when deposited. Gradually the eggs become opaque, then yellowish and when the eggs are almost ready to emerge, reddish spots appear and the head of the larvae can be seen (Herford 1934; Douglas et al 1962).

The newly hatched larvae are translucent white with a pale brown head. After 24 hours a pink colour appears over the entire larvae (Douglas et al 1962; Herbison-Evans and Crossley 2022). After a few days the first moult occurs and over the subsequent larval moults, there is little change in the appearance of the larvae, except an increase in size. The larvae has four moults, having in total five instars (Douglas et al 1962). The fully developed larvae is 6 to 8 mm long (Busck 1917; Saunders et al 1998).

The pupa is smooth, light yellowish, about 4–5 mm long and 1.5 mm wide (Busck 1917; Herford 1934; Douglas et al 1962). The pupa is usually surrounded by a cocoon, constructed among the web and frass where the larva has fed (Herford 1934).

Development and reproduction

Development and reproduction is favoured by high temperatures and low humidity (Henry 2001; Cubillo and Guzmán 2003). The life cycle duration (egg to adult) is commonly around 25–28 days when adults are confined in cages (Douglas et al 1962). Larval development in temperate climates, with temperature extremes (e.g. -3 to 34°C in USA), can have an average length as low as 21.8 days during the summer or more than six months with an overwintering larval stage (Douglas et al 1962; Garraway et al 2007).

In laboratory conditions (26–33°C; 75–95% RH; 12.5 h daylight), eggs were laid two days after adult emergence. The egg stage lasted three to four days, and the larval stage 26–28 days. The pupation period was five to seven days (Garraway et al 2007) but can be 13 days under field conditions (Herford 1934). The life cycle (egg to adult) is approximately 37 days in the laboratory (Garraway et al 2007). The life span is approximately eight days in the field (Herford 1934) and 5–18 days under enclosed conditions (Douglas et al 1962).

Anatrachyntis rileyi overwinters as larvae and the time of emergence varies from year to year. In Mississippi, USA (33.45°N) the hibernating larvae pupates in late April or early May (Douglas et al 1962).

Eggs are laid singly or in groups of up to 3 or 4, often together (Chittenden 1916; Herford 1934). Enclosed females deposited up to 147 eggs during their lifetime (Douglas et al 1962).

Ecology & behaviour

Anatrachyntis rileyi is generally regarded as a scavenger, feeding mostly on dead vegetable matter (Swezey 1909; Chittenden 1916, Taniguchi and Wright 2003). However, *A. rileyi* also feeds on healthy plant material (Linford 1939; Starks et al 1966; Zimmerman 1978; Hughes and Moorte 2011) and according to Zimmerman (1978), the larva is a predator of scale insects.

In pineapple fields in Hawaii, *A. rileyi* larvae can complete their development on dead stumps and associated leaves, typical of old or abandoned ratoon fields or healthy plants with almost no trace of dead organic material without the need to feed on the fruit (Herford 1934). However, according to Linford (1939) and Zimmerman (1978), a few larvae may bore into the fruit from the blossom cup when the fruit is almost ripe, or be found on the surface of the fruit eating the floral remains.

Anatrachyntis rileyi has been found attacking host plants after they have been injured by other insects, suggesting that it is an opportunistic and secondary feeder (Swezey 1909; Busck 1917; Douglas et al 1962).

Moisture conditions play an important role in the feeding behaviour of the caterpillar. In banana, *A. rileyi* feeds preferentially on old floral parts because the moisture level is reduced and as a result the latex content of the flowers (which may act as a barrier) it is also reduced (Garraway et al 2007).

Rainfall can affect the survival of the larvae, especially the young larvae which is very small (<0.5 mm). Because the larvae is mostly found in the floral parts of the host plant, when there is heavy rain, the floral parts get flooded for extended periods of time causing the larvae to drown (Garraway et al 2007).

The oviposition preference of *A. rileyi* in pineapple plants is not known but in corn eggs were found on both green and dry silk of the ear and in banana eggs were found on the sticky stigma of the flower. Experiments by Douglas et al (1962) and Garraway et al (2007) show that females can deposit eggs on any available surface (e.g., saucer, crevices of cork, twine, cloth, and paper) either singly or several end to end and rarely touching (Douglas et al 1962).

Oviposition occurs mainly close to the flowering stage, but it can be continued for a considerable period of time, since Herford (1934) observed very young larvae on almost fully grown pineapple fruits.

Larvae of *A. rileyi* have been reported not only as scavengers in dead plant material but also as specialized predators of scale insects (Van Duyn and Murphey 1971; Zimmerman 1978; Pierce 1995). In the Galapagos, Ecuador, *A. rileyi* larvae were found in stems of the white mangrove, *Laguncularia racemosa* (Combretaceae) feeding on eggs and nymphs of the cottony cushion scale *Icerya purchasi* (Roque-Alberto 2006, as *Pyroderces rileyi*).

Anatrachyntis rileyi interacts freely with ants and mealybugs on young pineapple fruits. The African big-headed ant *Pheidole megacephala* (present in New Zealand) has been observed supplementing the silk web produced by *A. rileyi* with soil, to form a communal covering that shelters ants, mealybugs and *A. rileyi* larvae. However, when *A. rileyi* larvae are disturbed and leaves its normal location, there is evidence of the same ants functioning as predators (Linford 1934).

In Hawaii, the larvae is preyed by various wasps such as *Polistes aurifer* Sauss, *P. hebraus* Fab. and *Pachodynerus simplicornis* Sauss (Illingworth 1928a). However, due to *A. rileyi* secretive habits, preference for shaded conditions and their practice to construct dense silk webs, natural enemies can only reach a small portion of the population (Linford 1939).

Adults are weak flyers, especially in daylight. They can be seen fluttering above the pineapple leaves but without a sustained flight. Wind is probably the most effective method to transfer the moth from one area to another (Linford 1939). The period of most activity is during twilight hours (Cubillo and Guzman 2003).

Damage & visibility

Anatrachyntis rileyi is considered a pest of secondary importance in crops such as pineapple, sugarcane, banana, cotton and citrus and on various other plants (Busck 1917; Arbogast and van Byrd 1986; Cubillo and Guzmán; Grafton-Cardwell et al 2017). However, it has been reported to be a serious pest of corn (Douglas et al 1962; Saito 1992) (Table 9.1).

Table 9.1 Damage caused by *Anatrachyntis rileyi* on plant hosts other than pineapple (Swezey 1909; Busck 1917; Douglas et al 1962; Garraway et al 2007; Grafton-Cardwell et al 2017).

Plant Host	Plant Part	Damage
Zea mays (corn)	Healthy cob, kernels, silk, and husk.	The larvae feed on the silks but when the husks are dry, it starts feeding on the kernels (at grain fill stage) close to maturity. The larvae tunnel the cob at the tips, between the row of kernels or through the kernels.
Musa paradisiaca (banana)	Dead flower, young and mature fruit	Feeds on dead flowers residues but in rare occasions it may bore into the flower and reach the fruit. It can also eat through the skin of the ripened fruit and eat the fruit inside.
Saccharum officinarum (sugarcane)	Dead leaves, previously injured canes.	Feeds beneath the leaf sheaths of dead cane and previously bored cane sticks.
Gossypium hirsutum (cotton)	Damaged and healthy cotton bolls and cotton seeds	Feeds on rotting parts of the boll but occasionally seen feeding in healthy bolls.

Citrus limon, *Citrus sinensis* (lemon and orange)	Dry or rotten fruit, ripe fruits, dead floral parts.	Larvae is mainly a scavenger but occasionally is found eating the rind of ripe oranges, near the stem end or on the sides of fruit in a cluster. In heavy infestation may result in fruit drop or decayed fruit during storage.

In pineapple, *Anatrachyntis rileyi* larvae feed mainly on the remains of petals, stamens and the style at the bottom of the blossom cup (Linford 1939). From there, the larvae create tunnels extending inward toward the young fruit. Infestation is usually confined to very young fruit, and the larvae appear to do very little damage to the fruit. However, a few larvae can be present when the fruit is close to ripe, causing injury (Linford 1939).

The tunnels created by the larvae into the fruit allow the entrance of pathogenic microorganisms (i.e. *Penicillium*) (Linford 1939; Zimmerman 1978). These pathogens create a firm dark-brown rot of limited extent (Linford 1939). This rot increases the visibility of *A. rileyi* feeding injury. However, visibility could be difficult if the larvae had recently burrowed into the fruit, given the lack of colour contrast between the larvae and the fruit internal tissue (Linford 1939). According to Herford (1934) the breakdown of fruit as a result of *A. rileyi* infestation is very rare since he observed a large percentage of healthy ripe fruits in the field, with the presence of web in the crown, from a previous infestation.

The larvae can also be found in the eyes (e.g., rough spiny marking on the pineapple’s surface) of the fruit where they feed upon dead stamens, pistils, and the outer calyx cavities and at the basal area of the fruit (Zimmerman 1978) without causing significant damage to the fruit or plant (Taniguchi and Wright 2003). The larvae frequently gnaw the crown of the fruit, removing the fine layer of dead cuticle on the underside of the leaves (Herford 1934; Zimmerman 1978). While feeding on the pineapple fruit surface and crown, the larvae creates a web from various sorts of litter (including faecal frass) which causes an objectionable appearance (Illingworth 1928b; Zimmerman 1978).

An outbreak of wilt in ratoon fields has been attributed to the presence of *A. rileyi* in the field. The plants wilt, the fruits die and shrivel to form dry black fibrous “mummies”, which can remain firmly attached to the plant for a long period. These provide ideal shelter and nourishment for the larvae. However, according to Herford (1934), there is no evidence to indicate that *A. rileyi* is responsible for the condition of the plants.

Pineapple variety susceptibility

Anatrachyntis rileyi larvae was found feeding on Cayenne and Hilo varieties (types of smooth Cayenne selected in Hawaii) with a preference for the Cayenne variety (Linford 1939). In South Africa, *A. rileyi* is a minor pest on the variety ‘Queen’(Rabie and Mbatha 2019) which is also known as ‘Common Rough” in Australia, as ‘Nanas Moris’ in Malaysia, ‘Sarikei’ in Sarawak and ‘Phuket’, ‘Rough Mcgregor’, ‘Ripley Queen’, ‘Alexandra’ and ‘Victoria’ in other parts of the world (TFNET 2016).

Hosts

Anatrachyntis rileyi has been reported from numerous hosts (Table 9.2), however the real extent of the host range is uncertain due to misidentification with *A. badia* in particular.

Table 9.2 *Anatrachyntis rileyi* host plants

Family	Species	Common name	Reference
Arecaceae	*Cocos nucifera*	coconut	Cock and Burris 2013; CABI 2019
	Mauritia flexuosa	Moriche palm	Cock and Burris 2013
	Roystonea oleracea	Caribbean royal palm	Cock and Burris 2013
Araceae	*Colocasia esculenta*	taro	Cock and Burris 2013
Asphodelaceae	*Aloe vera*	aloe	Swezey 1909
Bromeliaceae	*Ananas comosus*	pineapple	Linford 1939; CABI 2019
Combretaceae	*Laguncularia racemosa*	white mangrove	Roque-Alberto 2006
Crassulaceae	*Rochea* sp. (*Crassula* sp.)	crassula	Cock and Burris 2013
Euphorbiaceae	*Ricinus communis*	castor oil plant	Garraway et al 2017
Fabaceae	*Vigna unguiculata*	cowpea	Chittensen 1916
		twining bean vine	Swezey 1909
	Samanea saman	monkey pod tree	Zimmerman 1978
	Tamarindus indica	tamarind	Zimmerman 1978
	Vicia faba	broad bean	Oshaiba et al 1983
Lamiaceae	*Hyptis* sp.	bushmint	Cock and Burris 2013
Malvaceae	*Gossypium hirsutum*	Cotton	Busck 1917; Hinds 1928; Herbison-Evans and Crossley 2022
	Abelmoschus esculentus	Okra	Oshaiba et al 1983; Garraway et al 2007
Musaceae	*Musa x paradisiaca*	Banana	Garraway et al 2007
Pandanaceae	*Pandanus* sp.	Pandan	Swezey 1909
Poaceae	*Saccharum officinarum*	Sugarcane	Swezey 1909
	Zea mays	Corn	Douglas et al 1962; CABI 2019
	Sorghum bicolor	Sorghum	Chittenden 1916
	Panicum torridum	Torrid panic grass	Zimmerman 1978
	Oryza sativa	Rice	Ikenaga et al 2000
Rosaceae	*Prunus dulcis*	Almond	King and Saunders 1984
	Prunus armeniaca	Apricot	Garraway et al 2007
	Malus domestica	Apple	Garraway et al 2007
	Prunus persica	Peach	Garraway et al 2007
Rubiaceae	*Coffea arabica*	Coffee	Cock and Burris 2013
Rutaceae	*Citrus limon*	Lemon	Herbison-Evans and Crossley 2022
	Citrus sinensis	Orange	Hughes and Moore 2011
Sapindaceae	*Sapindus oahuensis*	Oahu soapberry	Zimmerman 1978
Solanaceae	*Capsicum annuum*	Bell pepper	King and Saunders 1984
	Solanum melongena	Eggplant/Aubergine	Cock and Burris 2013
Verbenaceae	*Lantana* sp.	Lantana	Swezey 1909

Geographical distribution

The geographical distribution of *A. rileyi* is uncertain and it may be wider than that presented in Table 3. Some authors report its presence in the Antilles, South America (Bippus 2020), West Indies (Busck 1917), Asia Minor, Indochinese Peninsula (Riedl 1969), and the Caribbean (Cock and Burris 2013). It is unclear whether the authors refer to all countries of these particular regions, therefore a conservative approach was taken and only those countries that are specifically mentioned in the literature were included in Table 9.3.

Table 9.3 Geographic distribution of *Anatrachyntis rileyi* and the Climate Matching Index range (by continent) to (all) New Zealand climate. Markets included within the scope of this import risk analysis are marked in bold.

Continent	Country/area/market	CMI	Reference
Central America & Caribbean	El Salvador, **Costa Rica (Limón)**, Honduras, Virgin Islands, Trinidad and Tobago, Jamaica	0.4–0.6	Wilson 1923; King and Saunders 1984; Rodriguez 1996; Henry 1999; Cock and Burris 2013
North America	Mexico, United States of America (Georgia, Arkansas, Tennessee, North Carolina, South Carolina, Mississippi, Louisiana, Washington D.C, Florida, Texas, Arizona, California)	0.4–0.8	Chittenden 1916; Stark et al 1966; King and Saunders 1984; Arbogast and van Byrd 1986; Adamski et al 2006; Grafton-Cardwell et al 2017
South America	**The Galapagos Islands (Ecuador),** Peru, Colombia, Argentina, Brasil	0.4–0.9	Hinds 1928; Da Costa-Lima 1945; Arbogast and van Byrd 1986; Roque-Alberto 2006; CABI 2019.
Africa	Egypt, South Africa (Kwazulu Natal), Mauritius, Ivory Coast	0.4–0.7	Oshaiba et al 1983; Py et al 1987; Rabie and Mbatha 2019; Bippus 2020
Asia	**Thailand (Phra Phutthabat), Philippines**, **Indonesia**, India, Iraq, Afghanistan, Japan, Turkey	0.4–0.9	Riedl 1969; Saito 1992; Riedl 1994; Ikenaga et al 2000
Oceania	**Australia (Queensland, New South Wales),** Hawaii	0.4–0.9	Swezey 1909; Bippus 2020; Herbison-Evans and Crossley 2022
Europe	Spain (Canary Islands)	0.8	Falck and Karsholt 2019

9.1.3.2 Likelihood of entry

Anatrachyntis rileyi is present in pineapple exporting markets that fall within the scope of this Import Risk Assessment (IRA): Costa Rica, The Galapagos Islands (Ecuador), Thailand, Philippines, Indonesia, Australia (Riedl 1969; Saito 1992; Herbison-Evans and Crossley 2002; Rodriguez 1996; Roque-Alberto 2006).

Despite *Anatrachyntis rileyi* being mainly a scavenger, there are circumstances in which it can be associated with pineapple fruit (as described in the commodity description). Newly hatched larvae are mainly present inside the floral blossom cup where they feed on the remains of petals, stamens and the style and build inward tunnels. At this stage they appear not to cause damage to the fruit. However, occasionally, the larvae bore into the ripening fruit, causing injury (Linford 1939).

No information was found on the oviposition preference of *A. rileyi* on pineapple plants. On other plant hosts, such as corn and banana, it prefers to oviposit on the green dry silk or the sticky stigma of the flower, respectively (Douglas et al 1962; Garraway et al 2007). It is uncertain if *A. rileyi* could deposit eggs on the surface of the pineapple fruit. However, to date, there are no records of eggs intercepted in the New Zealand border (LIMS 2022).

Anatrachyntis rileyi has certain level of tolerance to organophosphate pesticides (Cubillo and Guzmán 2003). In banana plantations, the pesticide Dursban (1% chlorpyrifos) was used to impregnate the polyethylene bags that cover the banana bunches. According to Cubillo and Guzmán (2003), this pesticide did not affect oviposition and larval development in banana plantations (Cubillo and Guzmán 2003). Therefore, this suggests that some control measures might not be effective on managing *A. rileyi* populations in the field.

Detectability of *A. rileyi* in the field will depend on the developmental stage. Adults are likely to be detected during in-field activities because when disturbed they are seen flying at the top of the pineapple plant (Linford 1939). Mature larvae are likely to be noticed in the field because while feeding they create a noticeably unpleasant web made of soil and fecal frass on the surface of the fruit and crown (Illingworth 1928b). In addition, after the crown is removed, it is likely that old entry points to the fruit will show a brown rot due to the entrance of opportunistic pathogens (Linford 1939). However, young larvae that recently bored into the fruit would be difficult to detect after crown removal because rot formation from pathogens would be non-existent or not yet formed and tunnels may not be seen with the bare eye in the field. Similarly, eggs could be difficult to detect due to the complex surface (e.g. bracts and crevices) and colouring of the pineapple fruit.

The larvae overwinter and can survive temperatures as low as -3°C in Washington and Arkansas (Garraway et al 2007). This suggests that if the larva is inside the pineapple fruit or has recently hatched it can survive storage and transport on sea cargo (7 °C) (Camelo 2004). From those interceptions where *A. rileyi* larvae where alive and identified to species level, there have been 35 larvae counts on 26 interceptions on pineapple fruit coming from the Philippines via sea cargo in the past 20 years (LIMS 2022; AQ 2022). In a period of three consecutive years (2018–2020), 23 *A. rileyi* larvae have been intercepted (LIMS 2022; AQ 2022).

Given that:

- *Anatrachyntis rileyi* eggs and larvae are associated with pineapple fruit (per commodity description).
- *Anatrachyntis rileyi* larvae can show resistance to some types of pesticides.
- Some developmental stages, such as eggs and young larvae, could be undetected during field and packhouse activities.
- *Anatrachyntis rileyi* can overwinter and further develop when climatic conditions are suitable.
- There have been interceptions of live *A. rileyi* larvae at the New Zealand border on pineapple fruit.

the likelihood of *Anatrachyntis rileyi* entering New Zealand associated with pineapple fruit is considered to be HIGH with LOW uncertainty

9.1.3.3 Likelihood of exposure

This assessment is made on the basis that A. rileyi *has entered New Zealand undetected.*

Imported fresh pineapple fruit is intended for human consumption, therefore, when the fruit arrives in New Zealand it will be distributed throughout the country for wholesale or retail sale. Fresh pineapple fruit generates large amounts of unavoidable waste and this waste can be disposed in different ways.

In New Zealand, organic waste that is bagged and goes to landfill is the most common method of organic waste disposal (Askarany and Franklin-Smith 2014). This method is considered low risk as it is unlikely to facilitate successful exposure. Similarly, commercial composting is considered a low risk method. Waste is placed into tunnels for a period of three to four days at temperatures of 55 °C or higher (WasteMINZ 2009) and these conditions are likely to kill *A. rileyi* larvae. However, there are other disposal methods that could facilitate successful exposure, such as feeding waste out to animals, home composting and direct disposal into the environment.

Fruit waste that is taken to rural areas and placed on the ground for eventual consumption by farmed animals (Goodman-Smith 2018), open compost either in farmed areas or households or deposited by roadsides, parks and campsites, increases the likelihood of exposure. Once in the open environment, *A. rileyi* larvae are likely to seek concealed areas due to their cryptic habits, thus protecting themselves from biotic (e.g. natural enemies) or abiotic factors (e.g., rainfall) (Linford 1939; Garraway et al 2007). Given its scavenger nature and capacity to complete its life cycle on dead material, it is highly likely the larvae (or adult) would be successfully exposed to a host or situation suitable for it to complete its lifecycle. In addition, plant hosts, such as species from the Poaceae family (i.e. grasses), fruit trees (i.e. *Citrus*) or vegetables (e.g. *Capsicum*), in rural areas, roadsides and households will increase the likelihood of exposure.

Worm farming and home composting in plastic bins could be considered a risk only when the contained structure is opened. The larvae could complete its life cycle feeding on organic waste and when it reaches adulthood it could fly away if the contained structure is opened. Adults are weak flyers (Linford 1939) and would likely settle on a nearby host plant which could be fruit trees (e.g., *Citrus* sp or *Prunus* sp.) that are commonly found in New Zealand gardens. However, with the aid of wind, the adult could be exposed to other hosts at a longer range. In contrast, is unlikely the larvae would move away, given its cryptic behaviour (Linford 1939).

The upper temperature threshold for *A. rileyi* is not known. Studies by Garraway et al (2007) show that *A. rileyi* can develop at temperatures reaching 33°C but it is unknown if higher temperatures such as those inside a compost bin during the summer season would reduce *A. rileyi* survival. Nevertheless, temperatures inside a compost bin during winter could be suitable for *A. rileyi* development.

Uncertainty

Pineapple waste: Information regarding food waste disposal methods in New Zealand is based on general data and there is no specific information on pineapple waste. In addition, the information may not be up to date.

Temperature thresholds: No information was found on upper temperature thresholds for *A. rileyi*. Therefore, it is unknown if *A. rileyi* could survive under a home composting scenario during summer temperatures.

Given that:

- *Anatrachyntis rileyi* may survive and develop on pineapple fruit waste.
- There are waste disposal methods that could facilitate the exposure of *A. rileyi* to a host or environment suitable for the completion of its development.
- Known host plants of this species are widespread and common in New Zealand.
- Some waste disposal methods would limit the exposure of *A. rileyi* to the environment because they are under contained structures.
- Despite adults being weak flyers, wind can aid the exposure of *A. rileyi* to other host found in longer distances.

the likelihood of exposure of *Anatrachyntis rileyi* in New Zealand from pineapple fruit is considered to be MODERATE with MODERATE uncertainty

9.1.3.4 Likelihood of establishment

This assessment is made on the basis that A. rileyi *has been successfully exposed to a suitable host plant in the New Zealand environment.*

Host plant availability will not be a barrier for *A. rileyi* establishment. Many of *A. rileyi* host plants are cultivated or found wild in many regions in New Zealand, either in suburban or rural areas. For example, maize (*Zea mays* L.) is widely grown in the rural North Island for animal feed (Millner and Roskruge 2013). Other plant hosts such as apricot (*Prunus armeniaca* L.), apples (*Malus domestica* B.), peach (*Prunus persica* L.), lemon (*Citrus limon* L.) are cultivated or present commonly in gardens across New Zealand (BiotaNZ 2022). In addition, host plants such as *Lantana* sp. are considered weeds and are commonly found in the Northland region (NRC 2022). There is some uncertainty on the extent of host plants of *A. rileyi* due to misidentifications with other *Anatrachyntis* species.

The ability of *A.rileyi* to feed as a scavenger and opportunistic feeder (Douglas et al 1962; Tanigushi and Wright 2003) increases the likelihood of establishment because the caterpillar does not rely on locating healthy plants to survive. However, it is uncertain if *A. rileyi* is a scavenger-host specific species, which will limit the food sources in the environment.

Anatrachyntis rileyi is mostly established in warm tropical and subtropical climates, However, it has established in few countries that have similar climate to New Zealand, such as Argentina (CMI: 0.7–0.9), USA (e.g., Washington D.C) (CMI: 0.8) (Arbogast and van Byrd 1986) and Australia (e.g., New South Wales) (CMI: 0.7–0.9) (Herbison-Evans and Crossley 2002). which have similar climate to New Zealand.

The larvae are able to overwinter and survive harsh conditions for periods up to six months, emerging when conditions are more suitable for development and reproduction (Douglas et al 1962; Cubillo and Guzmán 2003).

Sexual reproduction is a barrier to establishment. Mated female adults are unlikely to enter New Zealand because they are easily disturbed during in-field and packhouse activities. Therefore, to establish a population, larvae of both sexes would need to be in close proximity and to survive until adulthood. This could occur if several larvae are present in the same pineapple waste material when disposed in the environment. In a scenario where both sexes are not in close proximity, it is unlikely they will find each other, given that adults are weak flyers and have a short life span in the field (8 days) (Herford 1934; Lindford 1939). However, pheromones could help overcome this barrier. According to Garraway et al (2007), no pheromone has been isolated from *A. rileyi*, but pheromone baits for other *Anatrachyntis* species proved successful to attract *A. rileyi* moths.

Interception records at the New Zealand border show that *A. rileyi* has been intercepted on pineapple and other fresh produce (e.g. watermelon and squash) more than 70 times in the last 20 years (LIMS 2022; AQ 2022) and to date there is no evidence of its present in New Zealand (NZOR) and hence its establishment.

Anatrachyntis rileyi larvae and adults could be subject to abiotic factors (i.e.rainfall) and biotic factors (i.e. predation) that would limit the likelihood of establishment. Rainfall increases the mortality of young larvae by drowning (Garraway et al 2007) and larvae could be preyed on by ants (Linford 1934).

Present and future projected temperatures in New Zealand are likely to improve the suitability of the New Zealand environment for *A. rileyi*. The mean annual temperature and mean maximum temperatures for many (but not all regions in New Zealand) in 2021, were +0.51 °C to +1.20 °C above the annual average (13.56 °C) (NIWA 2021). The temperature increase projected for New Zealand due to climate change is 1.4 °C by 2090. These temperatures fall within the temperature of establishment of *A. rileyi* in colder states of United States of America (-3 – 33°C) (Garraway et al 2007).

Uncertainty

Host plant range: The plant host range of *A. rileyi* is uncertain due to potential misidentifications with other *Anatrachyntis* species, particularly *A. badia*.

Given that:

- *Anatrachyntis rileyi* is mostly established in warm tropical and subtropical climates.
- Sexual reproduction is a barrier for establishment.
- *Anatrachyntis rileyi* has been intercepted frequently in pineapples and other fresh produce but its not known to be present and hence established in New Zealand.
- Host plant availability will not be a barrier for establishment.
- *Anatrachyntis rileyi* is a predator and a scavenger species which increases its feeding choices.
- The larvae can overwinter and resume development when conditions are suitable for development.

the likelihood of *Anatrachyntis rileyi* establishing in New Zealand is considered to be LOW, with LOW uncertainty

9.1.3.5 Impacts in New Zealand

This assessment is made on the assumption that A. rileyi *has successfully established in the New Zealand environment.*

Economic impacts

Anatrachyntis rileyi is mostly regarded as a scavenger species (Roque-Alberto 2006; Garraway 2007; Hughes and Moore 2011; Herbison-Evans and Crossley 2022) feeding on a variety of plant materials. However, it can also damage healthy plants (Douglas et al 1962; Stark et al 1966).

Anatrachyntis rileyi is considered a seasonal, secondary pest, with limited distribution in tropical crops such as pineapple and banana (Petty et al 2002; Cubillo and Guzman 2003;

Taniguchi and Wright 2003). However, it is considered an important pest of field and stored corn in some parts of the world (e.g., Thailand and Mississippi, USA) (Douglas et al 1962; Saito 1992).

Larvae of *A. rileyi* are reported to cause an annual loss in corn production of about 2% in the southeastern states of USA (i.e., Alabama, Florida, Georgia, North Carolina and South Carolina) (Stark et al 1966). The current pest status of *A. rileyi* in corn crops is uncertain, given the most recent reports of economic damage found were from the 1990s. A study by Xinzhi et al (2012) mentioned that few *A. rileyi* larvae were collected during a two year study (2007–2008) in the state of Georgia, USA, compared to sap beetles (*Carpophilus* spp.) which were found abundantly damaging the corn kernels. This suggests that *A. rileyi* is not regarded as a major pest of corn in recent times.

In New Zealand, corn is used mostly for animal consumption (Millner and Roskruge 2013; AFIC 2021) and represents a total domestic revenue of NZ$389m (Robertson and Hurren 2022). Besides corn, *A. rileyi* feeds on other host plants of economic importance to New Zealand (Table 9.4), representing an approximate cumulative revenue of NZ$1.4b (Plant & Food Research 2020).

Table 9.4 Domestic and export revenue of *Anatrachyntis rileyi* host plants that are of economic importance to New Zealand (Plant & Food Research 2020).

Host plant	**Domestic revenue (NZ$ million)**	**Export revenue (NZ$ million)**	**Total revenue (NZ$ million)**
Corn (Zea mays)	389	-	389
Apricot (*Prunus armeniaca*)	3.7	7.8	11.5
Apple (*Malus domestica*)	-	847.9	847.9
Peach (*Prunus persica*)	11	0.3	11.3
Lemon (*Citrus limon*)	10.8	7.2	18
Orange (*Citrus sinensis*)	16.6	1	17.6
Bell Pepper (*Capsicum annuum*)	-	24.7	24.7
Eggplant (*Solanum melongena)*	12	-	12
Total cumulative revenue ($ billion)			**1.4**

Other than corn, no information was found on percentage of yield loss or annual losses of host plants of economic importance to New Zealand. According to Grafton-Cardwell et al (2017), *A. rileyi* (as *Pyroderces rileyi*), occurs sporadically in California, USA in orange and lemon trees. It is considered a scavenger caterpillar feeding on dry or decaying fruit clusters, dead floral parts and sooty mould. However, the larvae may feed on the rind of oranges and even though is usually superficial and not causing much damage, during heavy infestations it may result in fruit drop, or decaying fruit during storage.

Most of the impacts on tropical host plants are aesthetic, thus affecting the marketability of the fruit. For example, in bananas, 45% of fruit rejections by the United Kingdom market were due to in-between finger scarring. This occurs when faecal frass left by *A. rileyi*, causes a scar between fingers (Garraway et al 2007). According to Henry (2001), 22,628 kg of fruit was lost in Jamaica due to between-finger scar which was 2% of the total production in 1997. In pineapples, the larva creates a web with soil and faecal material giving the fruit an unpleasant appearance (Illingworth 1928b). However, occasionally, the larvae can feed on the fruit of both crops (Linford 1939; Zimmerman 1978), allowing the entrance of secondary pathogens that cause fruit rot (Zimmerman 1978).

Anatrachyntis rileyi can complete its life cycle without the need to feed on the ripening fruit. According to Herford (1934), a large percentage of healthy ripe pineapple fruits were produced despite evidence of high infestations of *A. rileyi*.

Anatrachyntis rileyi has been regarded as an opportunistic species in cotton and sugarcane (Swezey 1909; Busck 1917). Larvae were found feeding in places where the leaves were dirty and sticky after being attacked by aphids or leafhoppers or on sugar canes that were previously damaged by other lepidopoteran species (Swezey 1909).

Anatrachyntis rileyi can be dispersed to longer distances by wind or by movement of detritus or plant material by people working on farms or households.

An in-house MPI model predicted a low level of economic impact over 20 years.

- Stark et al (1966) and Henry (2001) report an annual yield loss of 2% on corn and bananas, respectively. This value was used to calculate the greatest level of annual impact that *A. rileyi* can damage important agricultural crops in New Zealand listed in Table 4.
- The model considers the impact of *A. rileyi* in all of New Zealand given that the area planted by regions is clustered into groups (e.g., summerfruit covers apricot, cherries, nectarines, peaches and plums) (Plant & Food Research 2020).
- The time to achieve the greatest impact was assumed to be 5 years given that population buildup would likely to be slow in more temperate regions.
- It was assumed that the time industries will take for full recovery was 1 year given that *A. rileyi* is considered a seasonal pest, with restricted distribution in regions where temperatures are more favourable for development (Cubillo and Guzmán 2003).

The model predicted a low level of economic impact, however, it is considered that the impact is very low because the annual loss of 2% was obtained from crops that are mostly grown in warmer regions than those found in New Zealand e.g Jamaica and southern states of USA such as Georgia and Florida). In addition, the annual yield loss of 2% was calculated on agricultural crops with the assumption that they are grown in all of New Zealand to portray a very pessimistic scenario. However, it is likely that the greatest level of annual impact is lower given that crops such as corn and citrus are mostly grown in the North Island.

Uncertainty

Pest status on corn: *Anatrachyntis rileyi* was regarded as an important pest of corn in the 1960s in temperate climates of United States. No information was found on the impacts of *A. rileyi* on corn in recent years. Therefore, it is uncertain if this species is still considered a major pest in corn and if economic impacts could be lower than those reported earlier in the literature.

Host plants: There is a level of uncertainty on *A. rileyi* host plant range due to misidentifications with similar species such as *A. badia* and *A. simplex.*

Given that:

- *Anatrachyntis rileyi* is mainly regarded as a scavenger species but can occasionally feed on healthy plants.
- *Anatrachyntis rileyi* is considered a seasonal pest with a limited distribution and a secondary pest of no economic importance in some crops, but a major pest in field and stored corn.
- *Anatrachyntis rileyi* can complete its life cycle on dead plant material and does not rely on healthy fruits to complete its life cycle.

- *Anatrachyntis rileyi* is considered an opportunistic species, found feeding in previously injured sugarcane and cotton plants.
- *Anatrachyntis rileyi* can be easily dispersed by wind and movement of dead and healthy plant material by humans.

the economic impact of *Anatrachyntis rileyi* in New Zealand is considered to be VERY LOW, with MODERATE uncertainty.

Environmental impacts
No evidence was found on impacts associated with *A. rileyi* or other *Anatrachyntis* species on New Zealand native plant species.

There is evidence that *A. rileyi* larvae is a predator of scale insects (Pierce 1995; Roque-Alberto 2006). New Zealand has native scales (Henderson 2011) but it is uncertain if *A. rileyi* could feed on them because the degree of specialization of *A. rileyi* predator-prey relationship is not known. It is unlikely *A. rileyi* will cause major impacts on New Zealand native scales given that its infestation is seasonal ans restricted due to the larvae limited dispersal capabilities.

Uncertainty:
Native scale predation: It is uncertain if *A. rileyi* could feed on native scales because no information was found on the predator-prey specificity of this species.

Given that:

- No evidence was found on impacts associated with *A. rileyi* and other *Anatrachyntis* species on New Zealand native plant species.
- *Anatrachyntis rileyi* is a predator of scales but unlikely to cause impacts on New Zealand native scales given its infestation is seasonal and restricted due to its limited dispersal capabilities.

the environmental impact of *Anatrachyntis rileyi* in New Zealand is considered to be VERY LOW with MODERATE uncertainty

Human health impacts
No evidence was found on human health impacts associated with *A. rileyi* or other *Anatrachyntis* species that could represent a risk to New Zealand.

Given that:

- No evidence was found on human health impacts associated with *A. rileyi* or other *Anatrachyntis* species.

the human health impact of *Anatrachyntis rileyi* in New Zealand is considered to be NEGLIGIBLE with LOW uncertainty

Sociocultural impacts
The root tuber, taro (*Colocasia esculenta*), a cherished root crop amongst Pasifika and Asian community is listed as a *A. rileyi* host plant. However, no information was found on the impacts of *A. rileyi* on this species, suggesting that it is a pest of secondary importance.

Taro is a widely distributed crop in Northland and Auckland regions. It is grown mainly in gardens and in some marae for its cultural and nutritional value and is commonly a minor summer crop, specifically for its leaves. Until recently taro has been grown commercially under glasshouse conditions (Parshotam 2018). It is uncertain if taro is a host of *A. rileyi* given that there have been misidentifications, specifically in early literature from Hawaii with the species *A. badia* (Zimmerman 1978). Given that *A. rileyi* is considered mainly a scavenger species, occasionally feeding on healthy fruits during high infestations in the summer months (Herford 1934), it is unlikely it will have a major negative impact on crop production in those regions were taro is widely planted.

Uncertainty

Impacts on taro: Taro is listed as a host of *A. rileyi* but no information was found on impacts of this species or other *Anatrachyntis* species, therefore it is uncertain if *A. rileyi* is considered an important pest in other parts of the world.

Taro as a host plant: It is uncertain if taro is a host plant of *A. rileyi* given misidentifications in early publications in Hawaii with *A. badia*.

Given that:

- No information was found on the impacts of *A. rileyi* and other *Anatrachyntis* species on taro, suggesting that it is a pest of secondary importance.
- *Anatrachyntis rileyi* is considered mainly a scavenger species and occasionally feeding on the fruit of healthy plants, it is unlikely to cause a major negative impact on taro plantations in New Zealand.

the sociocultural impact of *Anatrachyntis rileyi* in New Zealand is considered to be VERY LOW with MODERATE uncertainty

9.1.3.6 Overall impact to New Zealand

The overall impact of *Anatrachyntis rileyi* on the New Zealand economy, environment, health and society is considered to be VERY LOW with MODERATE uncertainty

9.1.3.7 Overall risk to New Zealand

Based on the assessments of likelihood and consequences above, that:

- the likelihood of entry is HIGH
- assuming entry, the likelihood of exposure is MODERATE
- assuming successful exposure, the likelihood of establishment is MODERATE
- the overall impact on the New Zealand economy, environment, human health, and society is considered to be VERY LOW

the overall level of assessed risk to New Zealand from *Anatrachyntis rileyi* on pineapple fruit is considered to be VERY LOW with MODERATE uncertainty.

9.1.4 *Specific considerations*

On which pineapple variety (or varieties) and at what stage of ripeness has *Anatrachyntis rileyi* association with pineapple fruit been observed?

Anatrachyntis rileyi usually infests very young pineapple fruits causing little to no damage to the fruit. However, occasionally, larvae can cause injury when the fruit is close to ripe.

Anatrachyntis rileyi was found feeding on Cayenne and Hilo varieties in Hawaii and the Queen variety in South Africa.

Which part(s) of the pineapple fruit is *Anatrachyntis rileyi* associated with (e.g. fruit, bract, stem or crown remnant) and is it detectable by visual detection?

Anatrachyntis rileyi can be found inside the fruit and on the surface (eyes of the fruit) feeding on dead floral remains. The presence of *A.rileyi* can be detected by the brown rot created by opportunistic pathogens that enter after the larvae bores into the fruit. However, if the larvae enters the fruit close to the time when the crown was removed, it would be difficult to detect the injury and hence the larvae.

Newly emerged larvae on the surface of the fruit can be undetected because they can hide and find refuge on the complex fruit surface.

Are different lifestages of the *Anatrachyntis rileyi* associated with different parts of the pineapple fruit?

Larvae can be found inside the floral parts, inside and outside the pineapple fruit. Eggs are deposited mainly in the blossom cup of the young fruit but it is uncertain if the female deposits eggs on the surface of the ripening fruit.

Does *Anatrachyntis rileyi* burrows into the fruit without obvious symptoms or hides under the pineapple bract?

A. rileyi can burrow into the fruit without causing obvious symptoms (especially when it recently burrows into the fruit) or hide under the bract when the larvae is very young.

9.1.5 *References*

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10 Vector analysis

Insect vector analyses were carried out for two insect species (Table 10.1) that are present in at least one pineapple exporting market and are associated with pineapple fruit. The two species are recorded from New Zealand but are considered in these analyses because they are known to vector various pathogens, some of which are not reported from New Zealand.

Table 10.1 The two vector species considered in this analysis.

Scientific name	Common name	Pest group	Order: Family
Planococcus citri	citrus mealybug	mealybug	Hemiptera: Pseudococcidae
Pseudococcus longispinus	long-tailed mealybug	mealybug	Hemiptera: Pseudococcidae

Generally, the risk posed by vectors is low. This is because successful introduction of the pathogen requires the vector to: i) acquire the pathogen from its host (either pineapple or another plant host); ii) remain infectious during transit and after arrival in New Zealand and then iii) successfully transmit the pathogen to another plant host suitable for the pathogen's establishment. Plant viruses can be transmitted by insects in various ways. These have been classified as non-persistent, semi-persistent, and persistent, depending on the length of the period the vector can harbor infectious particles, which can range from minutes to hours (non-persistent) to days (semi-persistent) and to life-time and even inheritance by the insect progeny (persistent) (Hohn 2007).

It is assumed that the entry of pineapple pathogens via vectors is possible, no matter if the pathogen is transmitted in a non-persistent, semi-persistent or persistent manner. Vector-transmitted pineapple pathogens are considered to pose a risk if they have other plant hosts available in New Zealand. However, pineapple specific pathogens are assumed to pose a negligible risk, since their likelihood of establishment and spread is considered negligible (refer to Annex 3). In New Zealand, there is only a recent, small, and localised commercial production of pineapples (Northland) ii. the risk posed by vectors is generally considered to be low.

Vector-transmitted non-pineapple specific pathogens are considered to have a lower likelihood of entry compared to pineapple pathogens. This is because the successful entry of non-pineapple pathogens requires an extra step, i.e. the insect vector must successfully acquire the pathogen from a non-pineapple host, move to pineapple, and remain associated with the commodity before successfully locating a suitable host in New Zealand. Non-pineapple specific pathogens that are transmitted in a semi-persistent or persistent manner by the vector may be able to enter New Zealand, while those transmitted in non-persistent manner are extremely unlikely to do so. In fact, pathogens need to be retained by the vector long enough to be exposed to suitable hosts, and it takes longer than one day for the commodity to arrive in New Zealand.

When assessing the risk of vectors associated with fresh produce, it is usually assumed that commercial plantations are grown as monocultures and that vectors are unlikely to be in contact with plant species other than the commodity being assessed. Therefore, vector analysis is usually limited to considering vectored pathogens that are associated with the commodity. However, the different pineapple exporting markets involved in this risk assessment may have different agricultural practices (e.g. companion planting, close distancing between pineapple and other plant crops and multi-cropping). These alternative agricultural practices increase the risk of vectors being in contact with other plants that are potentially infected with pathogens not associated with pineapple. To allow for this possibility, high priority viruses and viroids (Table 10.2) are also considered in this analysis. This list of pathogens[60] is compiled from the MPI high priority pest and disease (HPP) list and the list of Sector Risk Organisms (SRO) as listed/described by each Government Industry Agreement (GIA).

Table 10.2 HPP/SRO list - Pathogens considered in this analysis regardless of their association to pineapple. This list is compiled from the MPI high priority pest and disease (HPP) list and the list of Sector Risk Organisms (SRO) as listed/described by each Government Industry Agreement (GIA) partner in either their draft Operational Agreement, Biosecurity Plan or Website.

Scientific name	**Family:Genus**
Avocado sunblotch viroid	*Avsunviroidae*:*Avsunviroid*
Blueberry scorch virus	*Quinvirinae*:*Carlavirus*
Broad bean wilt virus	*Comovirinae*:*Fabavirus*
Capsicum chlorosis orthotospovirus	*Tospoviridae*:*Orthotospovirus*
Clover yellow mosaic virus	*Alphaflexiviridae*:*Potexvirus*
Cucumber green mottle mosaic virus	*Virgoviridae*:*Tobamovirus*
Cucurbit yellow stunting disorder virus	*Closteroviridae*:*Crinivirus*
Grapevine pinot gris virus	*Betaflexiviridae*:*Trichovirus*
Grapevine red blotch virus = Grapevine red blotch-associated virus	*Geminiviridae*:*Grablovirus*
High Plains wheat mosaic emaravirus = High plains virus	*Fimoviridae:Emaravirus*
Hop stunt viroid	*Pospiviroidae*:*Hostuviroid*
Little cherry virus 2	*Closteroviridae*:*Ampelovirus*
Maize dwarf mosaic virus	*Potyviridae*:*Potyvirus*
Pea early-browning virus	*Virgaviridae*:Tobravirus
Pea enation mosaic virus[1]	Please see footnote
Peach rosette mosaic virus	*Comovirinae*:*Nepovirus*
Pelargonium Zonate Spot Virus	*Bromoviridae:Anulavirus*
Pepino Mosaic Virus	*Alphaflexiviridae*:*Potexvirus*
Plum pox virus	*Potyviridae:Potyvirus*
Potato mop-top virus	*Virgaviridae:Pomovirus*
Potato spindle tuber viroid	*Pospiviroidae*:*Pospiviroid*
Potato Virus H	*Quinvirinae*:*Carlavirus*
Potato virus Y	*Potyviridae*:*Potyvirus*
Squash leaf curl virus	*Geminiviridae*:*Begomovirus*
Tomato apical stunt viroid	*Pospiviroidae*:*Pospiviroid*
Tomato Brown Rugose Fruit Virus	*Virgoviridae*:*Tobamovirus*
Tomato Chlorosis Virus	*Closteroviridae*:*Crinivirus*
Tomato infectious chlorosis virus	*Closteroviridae*:*Crinivirus*
Tomato leaf curl New Delhi virus	*Geminiviridae*:*Begomovirus*
Tomato leaf curl purple vein virus	*Geminiviridae*:*Begomovirus*

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[60] Only viruses and viroids from the MPI priority pest and disease list and the list of Sector Risk Organisms are considered.

[1] Pea enation mosaic virus is regulated in ONZPR (2022). Neither Pea enation mosaic virus 1 (Solemoviridae:Enamovirus) nor Pea enation mosaic virus 2 (Tombusviridae:Umbravirus) is known to be present in New Zealand (PPIN; Veerakone et al. 2015).

Tomato mottle virus	*Geminiviridae*:*Begomovirus*
Tomato ringspot virus = Peach yellow bud mosaic disease, yellow bud mosaic	*Comovirinae*:*Nepovirus*
Tomato torrado virus	*Secoviridae*:*Torradovirus*
Tomato yellow leaf curl virus	*Geminiviridae*:*Begomovirus*

Therefore, the criteria for an insect vector to be considered as a hazard on any market pathway in the analysis are:

- The insect transmits at least one pathogen in the HPP/SRO list OR one pineapple pathogen that is not present in New Zealand AND is regulated[61] /can impact other plant hosts important to New Zealand.
- For pathogens in the HPP or SRO list not associated with pineapple, the insect transmits the risk pathogen in a persistent or semi-persistent manner, AND
- both the insect vector and the pathogen are present in the same pineapple exporting market.

10.1 Summary of the analysis

The two vector species assessed in this analysis are not considered to be hazards.

Planococcus citri is not considered to be a hazard in this analysis, given that:

- *Planococcus citri* can transmit one pineapple pathogen, *Pineapple bacilliform comosus virus* (PBCoV), BUT no evidence could be found that PBCoV can affect plant species other than pineapple.
- *Planococcus citri* is not known to transmit any pathogen in the HPP/SRO list in a persistent or semi-persistent manner.

Pseudococcus longispinus is not considered to be a hazard in this analysis, given that:

- *Pseudococcus longispinus* may transmit one pineapple pathogen, *Pineapple mealybug wilt-associated virus* 2 (PMWaV-2), BUT no clear evidence could be found that PMWaV-2 can affect plant species other than pineapple.
- *Pseudococcus longispinus* is not known to transmit any pathogen in the HPP/SRO list in a persistent or semi-persistent manner.

10.2 Vector analysis

10.2.1 *Planococcus citri (Hemiptera: Pseudococcidae)*

Pineapple exporting markets status:
Planococcus citri is present in Australia, Cook Islands, Costa Rica, Ecuador, Indonesia, Malaysia, Papua New Guinea, Philippines, Samoa, Sri Lanka, Taiwan, Thailand, Tonga (CABI 2022b).

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[61] Strains of pathogens that are not recorded in New Zealand, and with no defined entity (a named subspecies, pathovar, haplotype etc.), are not considered hazards in this analysis. The criteria for regulating taxa below species level require that:

- There is a defined entity (a named subspecies, pathovar, haplotype etc) which is not known to be present in New Zealand.
- The entity is biologically distinct (for example host range, pathogenicity or vector relationships). Genetic differences alone are not sufficient.
- There is an increased risk to New Zealand posed by the entity. Need a reference to these criteria.

It is reported as absent in Fiji (unconfirmed presence record (s)), New Caledonia (unconfirmed presence record (s)), Panama, Vanuatu (CABI 2022b). However, *P. citri* may be present in Fiji, because it has been intercepted at the New Zealand border on commodities coming from Fiji.

New Zealand status:

- *Planococcus citri* is present in New Zealand (NZOR 2022).
- *Planococcus citri* is listed as a 'Potential vector' in ONZPR (2022).

Plant hosts:
Planococcus citri is highly polyphagous, with hosts of over 200 plant species belonging to 82 families. Many plants of economic importance are hosts of the pest, such as citrus, bananas and taro (CABI 2022b).

Plant parts affected:
Nymphs and adults of *P. citri* can be found on fruits, growing points, leaves, inflorescence, roots and stems (CABI 2022b). At the New Zealand border, *P. citri* has been intercepted and identified on non decrowned pineapple fruits, twice from Fiji (Asure Quality data), and once on pineapple fruits from French Polynesia in 1991 (LIMS 1986-2021).

Vectored organisms:
Planococcus citri is reported to vector PBCoV (Gambley et al. 2008). *Planococcus citri* is also known to vector viruses causing Banana streak disease (BSD), Banana streak OL virus (BSOLV) (synomym Banana streak badnavirus (Meyer et al. 2008)) (CABI 2022b), Banana streak GF virus (BSGFV), Banana streak MY virus (BSMYV), Banana streak VN virus (BSVNV) (DAWR 2019). *Planococcus citri* is also known to vector *Cacao Mild Mosaic Virus* (CaMMV) (Puig et al. 2021), *Cacao swollen shoot virus* (CSSV), *Cucumber mosaic virus* (CMV) (CABI 2022b), Commelina yellow mottle virus (ComYMV) (DAWR 2019), *Dioscorea bacilliform virus* (DBV) (CABI 2022b), DBALV (DAWR 2019), *Schefflera ringspot virus* (SRV) (CABI 2022b), *Grapevine virus A* (GVA), *Grapevine virus B* (GVB) (Herrbach et al. 2017), *Grapevine leafroll-associated virus* (GLRaV), *Grapevine leafroll-associated virus 1* (GLRaV-1), *Grapevine leafroll-associated virus 3* (GLRaV-3) (Bertin et al. 2016), *Citrus mosaic disease* (a synonym for *Citrus yellow mosaic virus,* CiYMV) (Reddy et al. 2010; Ahlawat and Pant 2003) and *Piper yellow mottle virus* (PYMV or PYMoV), KTSV, *Taro bacilliform virus* (TaBV), *Sugarcane bacilliform MO virus* (SCBMOV) and *Sugarcane bacilliform IM virus* (SCBIMV) indirectly, via original Sugarcane bacilliform virus (SCBV) (DAWR 2019).

***Pineapple bacilliform comosus virus* (PBCoV)** is a *Badnavirus* also referred to as *Pineapple bacilliform CO virus* (Sether et al. 2012) (recognised by ICTV). PBCoV affects pineapple (Gambley et al. 2008). *Planococcus citri* is reported to vector PBCoV (DAWR 2019) because the mealy bug was experimentally used to vector PBCoV (Gambley et al. 2008). This is here assumed to be sufficient evidence that *P. citri* can naturally vector PBCoV. PBCoV is not listed in ONZPR (2022). PBCoV is not known to be present in New Zealand (not recorded in Veerakone et al. 2015, PPIN 2022, or NZOR 2022). No evidence was found that PBCoV can affect plant species other than pineapple.

Pineapple bacilliform comosus virus (PBCoV) is one of two currently recognised Pineapple bacilliform virus species (the other being *Pineapple bacilliform ER virus* (PBERV)) (ICTV 2022, EPPO 2022). "Pineapple bacilliform virus" is regulated in ONZPR (2022). Pineapple bacilliform virus (PBV) (not listed by ICTV, but referred to as such by Collins and Carter (1954) is present in Australia (Wakman et al. 1995; Thomson et al. 1996), where it is ubiquitous (Gambley et al. 2008), and Sri Lanka (Kularathne et al. 2005). No evidence was found that PBV can affect plant species other than pineapple.

No evidence was found that any of the pathogens vectored by *P. citri* other than PBCoV affect pineapple (see Search section just before References).

None of the pathogens vectored by *P. citri* are in the HPP/SRO list (Table 2).

Hazard identification conclusion:
Planococcus citri is not considered to be a hazard in this analysis, given that:

- *Planococcus citri* can transmit one pineapple pathogen, PBCoV, BUT no evidence could be found that PBCoV can affect plant species other than pineapple.
- *Planococcus citri* is not known to transmit any pathogen in the HPP/SRO list in a persistent or semi-persistent manner.

10.2.2 *Pseudococcus longispinus (Hemiptera: Pseudococcidae)*

Pineapple exporting markets status:
Pseudococcus longispinus is present in Australia, Cook Islands, Costa Rica, Fiji, Indonesia, Malaysia, New Caledonia, Panama, Papua New Guinea, Philippines, Sri Lanka, Taiwan, Vanuatu (CABI 2022c).
It is absent in Ecuador, Samoa, Thailand, Tonga (CABI 2022c).

New Zealand status:

- *Pseudococcus longispinus* is present in New Zealand (NZOR 2022).
- *Pseudococcus longispinus* is listed as a ‘Potential vector’ in New Zealand (ONZPR 2022).

Plant hosts:
Pseudococcus longispinus is highly polyphagous and has been recorded on over 100 host plants belonging to 78 plant families. Host plants include many plants of economic importance, such as citrus, pear and grapevine (CABI 2022c).

Plant parts affected:
Pseudococcus longispinus feeds externally on fruits, growing points, inflorescence, leaves and stems (CABI 2022c). At the New Zealand border, *P. longispinus* has been intercepted and identified on non decrowned pineapple fruits. Between 1986 and 2021, it was intercepted six times on pineapples from the Philippines and USA (LIMS). three of these interceptions took place between 2000 and 2020, as one additional interception from the Philippines (Asure Quality data).

Vectored organisms:
Pseudococcus longispinus is reported to acquire and transmit PMWaV-2 (Hu et al. 2009). *Pseudococcus longispinus* also vectors *Grapevine leafroll-associated virus* (GLRaV) (CABI 2022c), *Grapevine leafroll-associated virus 1* (Bertin et al. 2010), *Grapevine leafroll-associated virus 3* (CABI 2022c), *Grapevine leafroll-associated virus 4* (Golino et al. 2002), *Grapevine leafroll-associated virus 9* (Tsai et al. 2010), *Grapevine virus A* (GVA) (Notte et al. 1997), *Grapevine virus B* (GVB) (Kuniyuki et al. 2006) and *Cacao swollen shoot virus* (CSSV) (CABI 2022c). In the Solomon Islands and other islands in the south-west Pacific region, *P. longispinus* is a vector of the smaller of two bacilliform viruses associated with

‘bobone’ disease in taro and *Xanthosoma* sp. (CABI 2022c), Taro bacilliform virus (TaBV) (Gollifer et al. 1977). *Pseudococcus longispinus* can also transmit viruses associated to stem-pitting in grapevines (CABI 2022c). Palma-Jiménez et al. (2019) report that *P. longispinus* can transmit Banana streak OL virus (BSOLV) (synomym Banana streak badnavirus (Meyer et al. 2008)) and *Banana Streak virus* (BSV) (Palma-Jiménez et al. 2019), citing (Kubiriba et al. 2001; Meyer et al. 2008). However, these viral associations are not reported in either Kubirba et al. (2001) or Meyer et al. 2008 and we conclude that Palma-Jimenez et al.(2019) reported them in error.

Pineapple mealybug wilt-associated virus 2 (PMWaV-2) is an *Ampelovirus* (recognised by ICTV 2022). *Pseudococcus longispinus* is reported to vector PMWaV-2(Hu et al. 2009), also cited by (DAWR 2019). However, there is high uncertainty about the association between the mealybug and the virus. In fact, there is only one paper reporting this association (Hu et al. 2009). Moreover, Hu et al. (2009) refer to *P. longispinus* only once *as* “longtailed mealybug”, reporting that *P. longispinus* is not as efficient as a vector as the grey pineapple mealybug (*Dysmicoccus neobrevipes*), without providing any further information on the transmission of PMWaV-2 by *P. longispinus*. PMWaV-2 is under consideration for Regulation in ONZPR (2022). PMWaV-2 is not known to be present in New Zealand (not recorded in Veerakone et al. 2015, PPIN 2022, or NZOR 2022).

No evidence could be found that PMWaV-2 can affect plant species other than pineapple. PMWaV-2 is one of three currently recognised species of Pineapple mealybug wilt-associated virus species (PMWaV-1, PMWaV-2, PMWaV-3) (ICTV 2022). “Pineapple mealybug wilt-associated virus”, PMWaV, is under consideration to be listed as regulated and unwanted in ONZPR (2022). PMWaV, as well as *P. longispinus*, is present in Australia, Indonesia, Malaysia, Philippines, and Taiwan (CABI 2022c). One PhD thesis suggests that the Vassi grass *Paspalum urvillei* (L.) may act as a host of PMWaV (Gunasinghe 1989). Gunasinghe (1989) was erroneously cited to report that *Andropogon insularis* may also act as a host (CABI 2022a). Under the assumption that PMWaV can affect any *Paspalum* species, PMWaV may impact one New Zealand native, threatened, and nationally vulnerable species, *Paspalum orbiculare* (NZPCN 2022).
However, there is high uncertainty about the vector relationship between *P. longispinus* and PMWaV, the biological distinction between PMWaV and PMWaV-2, and the association of PMWaV with *P. urvillei*, due to the paucity and quality of the supporting evidence. Moreover, no evidence could be found that *P. longispinus* feeds on *Paspalum.*

No evidence could be found that any of the pathogens vectored by *P. longispinus*, other than PMWaV-2, will affect pineapple and the likelihood of the virus being exposed to cultivated pineapple in New Zealand via the Fresh Produce Pathway is considered NEGLIGIBLE.

None of the pathogens vectored by *P. longispinus* are in the HPP/SRO list (Table 2).

Hazard identification conclusion:
Pseudococcus longispinus is not considered to be a hazard in this analysis, given that:

- *Pseudococcus longispinus* may transmit one pineapple pathogen, PMWaV-2, BUT no clear evidence could be found that PMWaV-2 can affect plant species other than pineapple and the likelihood of the virus being exposed to cultivated pineapple in New Zealand via the Fresh Produce Pathway is considered NEGLIGIBLE.

- *Pseudococcus longispinus* is not known to transmit any pathogen in the HPP/SRO list in a persistent or semi-persistent manner.

Searches

- Vector species – vectored organisms/plant hosts: CPC 2022, Scalenet 2022, Google/Google scholar search: Scientific and common name vector species and ICTV AND HPP/SRO vectored organism/plant host name, first 50 results (to 9/08/2022).
- *Ananas comosus* – vectored organisms association: CPC 2022, Google/Google scholar search: *Ananas comosus* OR pineapple AND vectored organism name, first 50 results (to 9/08/2022).
- Alternative host – vectored organisms association: CPC 2022, Google/Google scholar search: host AND vectored organism name, first 50 results (to 9/08/2022).

10.3 References

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Appendix 1. Summary of taxa excluded at hazard identification

The following table shows the groups and species identified at the hazard identification stage as not requiring further assessment and not requiring measures over and above basic measures, and the rationale for exclusion.

Pest scientific name	Rationale for exclusion
Amoebozoa	
Protosteliopsis fimicola	The species is present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021).
Arachnid	
Acalvolia sp.	No evidence found for association with pineapple fruit (Google/Google Scholar: Acalvolia pineapple). The genus Acalvolia comprises of only one known species *A. squamata* that it is associated with house dust and bird nests. A new species was found on leaves in association with nymphs of the citrus whitefly infected by fungus *Aschersonia aleyrodis*. Apparently, it feeds on this fungus (mycophagous).
Amblyseius sp.	*Amblyseius* belong to the Phytoseeidae family which mostly comprises predatory mites that are commonly used as biological controls. This mite feeds on pollen, fungi, nematodes, other mites, scale insects and debris. There are reports of being found in pineapple plantations, however not feeding on the plants. There are several *Amblyseius* species recorded as present in New Zealand (PPIN 2022). As the mites associated with pineapple have not been identified to species level it cannot be determined whether they are already present in New Zealand or not and cannot be assessed further.
Araneae	Family name, addressed through more detailed associations
Brachytydeus sp.	There is no record of this genus present in NZ. Other than the three interception on pineapple (AssureQuality 2021), no other evidence of association with pineapple was found in the literature (Google/google scholar: Brachytydeus pineapple/Ananas comosus).
Brevipalpus sp.	None of the species listed in the flat mites of the world database have pineapple as a recorded host (Beard et al. 2012). A species that is associated with pineapple could also not be defied by google and google scholar searches 'Brevipalpus' and 'pineapple', and 'brevipalpus' and 'ananas'.
Calvolia sp.	This genus is not present in New Zealand (NZOR 2021). No evidence found for association with pineapple fruit (Google/Google scholar: Calvolia pineapple) and is therefore not considered to be associated with the commodity.
Clubiona sp.	Spiders are likely to be detected or removed during commercial production process due to their size and high mobility.
Cosmolaelaps sp.	*Cosmolaelaps* sp. is listed as present in New Zealand (PPIN 2022). Members of this genus are known to be predatory mites. There are reports of detections at the border of adult and eggs on pineapple consignment from Ecuador, as well as adults from pineapple coming from the Philippines. However as these have not been identified to species it is uncertain whether the taxa associated with pineapple are the same as those recorded from New Zealand and cannot be assessed further.

Crossopriza lyoni	Spiders are likely to be detected or removed during commercial production process due to their size and high mobility.
Cunaxa sp.	There has been one interception of the mite on pineapples from the Philippines. However, this genus of mite does not appear to be associated directly with fruit, but rather is a predator of other mites and pests (and all results found related to this behaviour) (Gerson 2008). Therefore, the interception is likely a hitchhiker incident rather than a true association with the commodity.
Cunaxidae	It is a family of mite. The risk of this family is assumed to be covered by species assessments.
Cunaxoides sp.	Predatory mites that are likely hitchhikers rather than truly associated with the commodity.
Daidalotarsonemus sp.	No evidence was found of the genus being associated with pineapple (Google/Google scholar: Daidalotarsonemus pineapple).
Dermatophagoides farinae	The species is present in New Zealand (NZOR 2021) and is not listed in ONZPR (2021). This species is a house dust mite, no specific association with pineapples.
Dictyna sp.	Spiders are likely to be detected or removed during commercial production process due to their size and high mobility.
Dictynidae	Spiders are likely to be detected or removed during commercial production process due to their size and high mobility.
Dolichotetranychus sp.	Assumed to be covered by the other species assessed.
Dolichotetranychus floridanus	*Dolichotetranychus floridanus* is not listed in NZOR (2021) and is regulated ONZPR (2021). This species is reported from exporting counties and is associated with pineapple (Beard et al. 2012). It was excluded from the previous pineapple hazard ID because the only reported host is pineapple and therefore exposure and establishment is unlikely. This conclusion remains and therefore this species does not require further assessment.
Dolichotetranychus sp. nr. *vandergooti*	See *D. vandergooti* assessment. This does not appear to be an accepted name.
Dolichotetranychus vandergooti	The species is not listed in NZOR (2021) or ONZPR (2021). According to the DAFF (2012a) for decrowned pineapple fruit the mite feeds on leaves and is not associated with decrowned pineapples. The 2012 Australian IRA for decrowned pineapple fruit from Malaysia states that the species is not considered to be associated with the decrowned pineapple pathway.
Eutetranychus orientalis	This species is not listed in NZOR (2021) and is regulated ONZPR (2021). The association with pineapple is based on a reference from South Africa (Meyer 1987 cited in Migeon and Dorkeld (2021), but full-text is not accessible). The feeding location of the mite on pineapples could not be found. Based on the feeding of the mite on other hosts, it feeds on plant leaves (CABI 2021) particularly the upper surfaces (Singh and Raghuraman 2011). Information on the mites effects on pineapples is lacking, however based on its behaviour on other hosts, it is likely that the mite feeds on leaves and therefore would not be associated with decrowned pineapples. No evidence was found that the species is found on pineapple fruits. No record of it being intercepted on pineapple arriving at the New Zealand border.

Fungitarsonemus sp.	There is one interception of the genus on pineapple from the Philippines. No other evidence of an association with pineapple was found via a google/google scholar search using appropriate search terms. As not specify to species level, there is no sufficient information for a PRA.
Gaeolaelaps aculeifer	The species is not listed in NZOR (2021) and is non-regulated (ONZPR 2021). This is a soil-dwelling generalist predatory mite (Ajvad et al. 2018; Park et al. 2021). There are no records of this pest associated with pineapple plantation (Google and Google Scholar: 'Gaeolaelaps aculeifer' and pineapple). It is not known if this species is found in the exporting markets.
Galumna sp.	Three species from this genus are reported present in New Zealand (NZOR 2021). No evidence was found that this genus may be associated with pineapple fruit. Members of the genus are mostly collected in soil samples, debris, bark of trees, moss (Saxena and Rao 2015).
Gamasellodes sp.	Intercepted in a pineapple consignment coming from the Philippines. There is no record of this genus present in New Zealand. This genus is known to be soil-dwelling mites and interest has increased for their potential as biocontrol agents for root pests. Other than the interception, no evidence was found of the species associated with pineapple fruit (Google/Google Scholar: Gamasellodes pineapple/Ananas cosmosus). Given that no association with the commodity is documented, was not assessed further.
Hemicheyletia sp.	There is one interception of this genus on pineapple from Fiji. One report of this genus on pineapple leaves was found (Fain et al. 2002). No evidence of the genus on fruit was found. Evidence was found that 75% of the cheyletid mites are predatory to other arthropods and the rest are parasitic to mammals and birds (Ray and Hoy 2018). Therefore, unlikely that this genus has a true association with the commodity. As not specify to species level, there is not sufficient information for a PRA.
Hexabdella sp.	Although they may be associated with plants, these are predatory mites. Therefore, the interceptions are likely due to the mites hitchhiking rather than a true association with the fruit. No results were found in a google and google scholar search of Hexabdella and pineapple. As not specify to species level, there is no sufficient information for a PRA.
Lasioseius sp.	This genus is not known to present in New Zealand. Although this genus has been intercepted in different pineapple consignments coming from the Philippines and Ecuador it is excluded as contaminated pest. This genus contains species that are found on rotting organic substances, under bark, in forest litter, moss, soil, nests of mammals and birds, sored products, fungi and hay. No evidence was found on its association with pineapple (CAB Abstract/Google Scholar).
Lauritzenia sp.	Two species present in New Zealand (NZOR 2021). No evidence found for association with pineapples. This is a soil-dweller mite. Very limited information and no association with fruits was found.
Liebstadia sp.	Two species of the genus present in New Zealand (NZOR 2021). No evidence found for association with pineapples. Species of this genus have been collected in litter, lichen, moss and soil. No indication that these mites are associated with pineapple fruit.
Linyphiidae	Spiders are likely to be detected or removed during commercial production process due to their size and high mobility.

Lorryia sp.	There is one interception of this genus on pineapples arriving in New Zealand. No evidence was found of the genus associated with pineapple in Google/Google scholar searches using relevant search terms. References found were related to the genus associated with citrus (Aguilar-Piedra 2001). Also no evidence was found of the genus being an important economic pest. Feeding on pollen, cleaning citrus trees of sooty mould and predation of citrus mite pests was found (Aguilar-Piedra 2001).
Loxosceles sp.	Spiders are likely to be detected or removed during commercial production process due to their size and high mobility.
Lupaeus sp.	The genus is not known to be present in NZ (NZOR 2021). Although there is one interception on pineapple in at the New Zealand border (AssureQuality 2021), no other evidence found on association with pineapple (search in Google Scholar, CABI (2021) and EPPO (2021))
Macquarioppia striata	Present in New Zealand according to NZOR (2021). A marine mite of New Zealand subantarctic Islands. It is not associated with pineapple fruits.
Magnobates sp.	*Magnobates flagellifer is* present in New Zealand (NZOR 2021). No evidence of this genus being associated with pineapple fruit.
Metapronematus sp.	No evidence of association with pineapple was found, except two interceptions on pineapples from the Philippines. Reports of the genus on citrus, clover, *Schefflera* sp., and moths was found but nothing for pineapple plants using appropriate search terms (Aguilar-Piedra 2001). This genus is not known to present in New Zealand. However, due to a lack of information and no specific species found to be associated in literature search, further assessment cannot be conducted.
Neocunaxoides sp.	*Neocunaxoides andrei* and *Neocunaxoides* sp. nr. *Rykei* has been intercepted on pineapple in New Zealand for one time. No other evidence suggest that N. andrei and *Neocunaxoides* sp. nr. *Rykei* is associated with pineapple (literature search in Google Scholar, CABI (2021) and EPPO (2021)). N. andrei is reported to be assoiated with soil and a biological control agent of root-knot nematode. Not much information can be found on these mites.
Neoramia sp.	Spiders are likely to be detected or removed during commercial production process due to their size and high mobility.
Neoseiulus barkeri	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021). The mite is not known to be a vector of disease.
Nyssus coloripes	Spiders are likely to be detected or removed during commercial production process due to their size and high mobility.
Oligonychus litchii	This species is not listed in NZOR (2021) and is regulated in ONZPR (2021). *Oligonychus litchii* feeds on sap by sucking near veins on a leaf, before spreading to the entire leaf as population density increases (Department of Agriculture 2019). No evidence was found of the species being associated with pineapple fruit (Google/Google Scholar: Oligonychus litchii pineapple).
Oribatida sp.	Species within this suborder are present in New Zealand (NZOR 2021). No evidence found for association with pineapple fruit.
Oribatulidae	Some species of this family are present in New Zealand (NZOR 2021). No evidence found associating this family with pineapples, likely to be associated with soil or decaying plant material.
Oulenzia bakeri	This species appears to be a synonym of *Oulenziella bakeri*, and is non-regulated. This species is a fungus feeder (Fan et al. 2015) and no evidence was found of it being associated with pineapple fruits.

Panonychus citri	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Proprioseiopsis ovatus	The species is not listed in NZOR (2021) or ONZPR (2021). This species is abundant in weeds, in lower vegetation. In Spain, specimens were found not on the leaves or fruits and the authors think that the mite was collected from the trunks, close to the soil, humus, litter and grasses similar to other species of this genus (Faraji et al. 2008). No evidence found in literature of association with pineapple fruit (Google/Google Scholar: Proprioseiopsis ovatus pineapple).
Prostigmata	Assumed to be covered by species assessments.
Psylloglyphus sp.	*Psylloglyphus parapsyllus* present in New Zealand (NZOR 2021) and this genus is not listed in ONZPR (2021). No evidence found associating this genus with pineapple fruit.
Pulaeus sp.	Exception from the one interception record at the New Zealand border (AssureQuality 2021), no other evidence found indicating association with pineapple (Google scholar, CABI (2021) and EPPO (2021)).
Ramusella sp.	No evidence was found of the genus being associated with pineapple (Google/Google scholar: Ramusella pineapple/Ananas comosus). Members of the genus are found associated with soil and decomposing plant material (Hugo-Coetzee 2016).
Rhizoglyphus setosus	There is one report on the association with pineapple and it is unclear which part of the pineapple it is associated with. This species is not reported to feed on or be associated with any other fruits. It is primarily associated with plant bulbs. Feeds on saprophytic and plant pathogenic fungi. There appears to be a single report of this species being associated with mealy bugs on pineapple from Fiji (Zhang et al. 2004). It is unclear how the mites are associated with the mealy bugs, or what part of the pineapple plant it is associated with. It was concluded that there was insufficient evidence of an association with the commodity to assess further.
Rhizoglyphus sp.	Rhizoglyphyus phylloxerae is reported to be associated with pineapple root system and Rhizoglyphus setosus is reported to be associated with "pineapple"(Goff 1987) but the specific plant part is not mentioned. No evidence of other species under this genus being associated with pineapple. No evidence found for association with pineapple fruit.
Scheloribates sp.	Several species in this genus are reported present in New Zealand (NZOR 2021). No evidence found for association with pineapple fruit (Google search: Scheloribates pineapple *Ananas comosus*).
Schizotetranychus asparagi	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). There is limited information available on this species. Its host range is very narrow (the species is noted for damaging ornamental asparagus and young pineapple plants; edible asparagus is a recorded host but the impacts on it are uncertain) and there is limited potential for the mite to find a host plant. There is no evidence this mite is likely to be a major pest.
Scytodes sp.	Spiders are likely to be detected or removed during commercial production process due to their size and high mobility.
Steneotarsonemus ananas	The species is not listed in NZOR (2021) or ONZPR (2021). Due to host specificity with pineapple, it is unlikely that it would establish in New Zealand.

Steneotarsonemus comosus	The species is not listed in NZOR (2021) but is regulated ONZPR (2021). The only record found describing host and feeding, was from pineapple crown leaves (Ochoa Pérez 1989). No evidence was found of the mite associated with pineapple fruit or with other hosts (Google/Google Scholar: Steneotarsonemus comosus pineapple). Therefore it is not considered associated with the commodity.
Steneotarsonemus sp.	Assumed to be covered by species assessments.
Tarsonemidae	Assumed to be covered by species assessments.
Tarsonemus bilobatus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). There is one interception of the mite on pineapple. However, no association with pineapple was found in the literature (Google/Google Scholar: *Tarsonemus bilobatus* pineapple/*Ananas comosus*). Therefore, the species is not considered to be associated with the commodity.
Tarsonemus confusus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). There have been five interceptions of the mite at the New Zealand border (AssureQuality 2021). However, it is a primarily fungivorous species (Lindquist 1986) and present on some ornamentals (e.g. African violet, azalea, cissus, Cyclamen, Gloxinia, ivy and Pilea) in greenhouses in Europe and tomatoes in North America, but have rarely caused primary damage to its host plants (Zhang 2003). Therefore, it is likely that the mites were associated with fungi on the pineapples rather than the pineapples themselves. No evidence was found of the mite being associated with pineapples in a Google/Google scholar search using appropriate search terms.
Tarsonemus sp.	Assumed to be covered by species assessments.
Tetranychus sp.	No evidence was found of *Tetranychus* species being associated with pineapple. None of the species listed in the spider mite database had pineapple as a host (Migeon and Dorkeld 2021). No interception of the genus on pineapples is listed in the AQ database. There is one interception from 1992 in the LIMS data, but was not identify to species level. No evidence was found of an association with pineapple (Google/Google Scholar: Tetranychus pineapple/Tetranychus Ananas comosus).
Thyreophagus entomophagus	This species is reported present in New Zealand (NZOR 2021) but the subspecies *Thyreophagus entomophagus italicus* is listed in ONZPR as regulated. The was no evidence found that this species is associated with pineapple fruit (Google search: Thyreophagus entomophagus pineapple) as is a stored product pest. This species is also commonly found in debris in beehives.
Thyreophagus sp.	Species of this genus are reported in New Zealand (NZOR 2021). No evidence found for association with pineapple fruit (Google search: Thyreophagus pineapple *Ananas comosus*).
Tydeidae	Assumed to be covered in the species assessments.
Tydeus sp.	Although there are interceptions of the genus on pineapples (which were not identified to species level), no other evidence was found of an association of the genus with the commodity (Google/Google Scholar: Tydeus pineapple). No evidence was found of the genus being important economic pests, and there is evidence that these are predatory mites that feed on fungi, pollen and other small arthropods. Some may be plant feeders, but no evidence was found of this causing damage. Very little information on this genus and little understanding of their feeding habits.

Tyrophagus curvipenis	The species is present in New Zealand (NZOR 2021; PPIN 2021), but is not listed in ONZPR (2021).
Tyrophagus javensis	The species is not reported present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). This species is mostly found in stored products and decaying organic matter (Fan and Zhang 2007). It has been intercepted in pineapples in New Zealand but there is no evidence that they are associated with the fruit in the field (Google search: Tyrophagus javensis pineapple ananas comosus).
Tyrophagus putrescentiae	Present in New Zealand (NZOR 2021; PPIN 2021) and is non-regulated (ONZPR 2021).
Tyrophagus robertsonae	Species is reported present in New Zealand in NZOR (2021). It is non-regulated in ONZPR (2021).
Xenotarsonemus sp.	There is one interception from a 2005 from pineapples in the Philippines. No literature was found (Google/Google Scholar searches: Xenotarsonemus pineapple/ananas) of an association with pineapple. Given that no association with the commodity was found, no further assessment required.
Zygoribatula sp.	Some species in this genus reported present in New Zealand (NZOR 2021). No evidence found for association with pineapple fruit (Google search: Zygoribatula pineapple ananas comosus).
Bacteria	
Acetobacter aceti	BiotaNZ (2022) stated *A. aceti* was present in New Zealand but has added a statement beneath that record which says “Acetobacter aceti was declared to be not a New Organism by the EPA on 22 September 2016. Isolate ICMP 1669 was initially thought to be from New Zealand but its origin is unknown”. There are no New Zealand isolates recorded in the NZFungi collections. NZOR (2021) states it is present but may have based this on information pre-Sept 2016. There is no record in PPIN (2021) and it is listed as regulated (ONZPR 2021). Excluded from further assessment on the basis of insufficient evidence of it being a plant pathogen. *Acetobacter aceti* was originally thought to be one of the organisms responsible for pink disease in post-harvest pineapple processed for canning (Kado 2003). Organisms in the genus *Tatumella* have subsequently been found to be responsible (Brady et al. 2010). *Acetobacter aceti* is known to be ubiquitous in the environment, usually in association with any sugar fermentation process in nature. It is found in symbiotic relationships with many plants like tea, coffee, mango, pineapple and bananas, also rotting apples, wine and canal water. Found in flowers, fruits, vegetables, honeybees and may also be found in soil (UCDavis 2018a). General searches through Google Scholar, Google and CAB Abstracts show it is used industrially for the making of acetic acid and vinegars, including from pineapple waste (Praveena et al. 2021). 2021).
Acetobacter liquefaciens	*Acetobacter liquifaciens* is absent from New Zealand (NZOR 2021), but is not listed in ONZPR (2021). The species has been associated with pink disease of pineapple which occurs during canning. As with other species that have been associated with this disease and excluded (*Gluconobacter oxydans*) this is excluded based on lack of information that it would be able to establish in New Zealand, based on it only being reported from *Ananas comosus*. If the host range were to expand, it may need to be reassessed.

Acetobacter pasteurianus	*Acetobacter pasteurianus* is reported as absent from New Zealand (NZOR 2021) and it is listed as regulated (ONZPR 2021). Excluded from further assessment on the basis of insufficient evidence of it being pathogenic to plants of environmental or economic concern to New Zealand. If evidence to the contrary is found then *A. pasteurianus* will need to be reassessed. It is one of a few Acetobacters that causes marbling disease in pineapple (Rohrbach and Apt 1993). This bacterium is endophytic and exists on sugar-rich substrates such as flowers, fruits and vegetables. Acetobacters are also found on naturally spoiled fruits. They can occur on the skins of grapes and survive the fermentation process thus spoiling wines (UCDavis 2018b). General searches through Google Scholar, Google and CAB Abstracts show *A. pasteurianus* is used in making wine vinegars, cellulose and acetic acid production.
Acetobacter sp.	Assumed to be captured by species assessments.
Bacillus subtilis	*Bacillus subtilus* is present in New Zealand (NZOR 2021) and is non-regulated (ONZRP 2021). It is a ubiquitous bacterium found in soil, water and plant residues. Most of the information found to do with the species and pineapple was fermenting and isolations from juice (google, google scholar). No evidence was found suggesting that the *B. subtilus* associated with pineapple represents a strain not present in New Zealand.
Brevibacillus borstelensis	Present in New Zealand (BiotaNZ 2022),but is not listed in ONZPR (2021). BiotaNZ states that a culture of the species from New Zealand is held in a private collection. No evidence was found that the isolates from pineapple represent a strain not present in New Zealand.
Dickeya chrysanthemi	Although *Dickeya chrysanthemi* is listed as present in New Zealand (NZOR 2021), this is no longer considered to be correct. *Dickeya* sp. have been associated with bacterial heart rot of pineapple. However, *D. chrysanthemi* has not been specifically confirmed to be causative agent of this disease (Kaneshiro et al. 2008; Peckham et al. 2010; Sueno et al. 2014; Aeny et al. 2020).
Dickeya paradisiaca	This species was found to not be associated with the commodity. It was found that the host association had been mis-represented in the literature. The references could be traced back to one primary reference, that when checked was found to not list *D. paradisiaca* in association with pineapple. No other reference to the bacterium associated with pineapple was found.
Dickeya sp.	Assumed to be covered by species assessments.
Enterobacter sp.	The Enterobacter species found associated with pineapple was *E. agglomerns* (Rohrbach and Pfeiffer 1976). This is a synonym of *P. agglomerans* which has been assessed and is present in New Zealand.
Gluconobacter oxydans	*Gluconobacter oxydans* is reported as uncertain from New Zealand (BiotaNZ 2022) and it is listed as regulated (ONZPR 2021). There is a note in BiotaNZ: 'Cultures are held in private New Zealand collections. But unverified.'. However, no evidence was found of the bacterium being isolated from New Zealand. Excluded from further assessment on the basis of insufficient evidence of it being pathogenic to plants of environmental, economic or cultural concern to New Zealand. All other reports found as part of Google and Google Scholar searches related to its industrial applications. If evidence to the contrary is found then *G. oxydans* will need to be reassessed.

Gluconobacter sp.	Assumed to be covered by the assessed species as the paper found referring to *Gluconobacter* and pineapple identified it as *G. oxydans* (Rohrbach and Pfeiffer 1976).
Klebsiella pneumoniae	Present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). No evidence that the isolates from pineapple represent strains not present in New Zealand.
Klebsiella sp.	Assumed to be covered by the species assessment
Pantoea agglomerans	The species is present in New Zealand (BiotaNZ 2022) and is non-regulated (ONZPR 2021).
Pectobacterium carotovorum	The species is present in New Zealand (BiotaNZ 2022) and is non-regulated (ONZPR 2021).
Pseudomonas sp.	Assumed to be covered by species assessments.
Pseudomonas ananas	The species is not listed in BiotaNZ (2022) and has a regulatory status of 'not assessed' in ONZPR (2021). Very limited literature was available for this species. All of the literature that was found, refers to an association with pineapple fruits (apart from the synonym from the Malaysian document *Pseudomonas syringae* pv. *Antirrhini*, which is reported from snap dragon (Hendson et al. 1992). However, this synonym wasn't found in other sources. Of the limited papers all related to the species causing disease on pineapple (Serrano 1934; Ministry of Agriculture and Agro-based industry Malaysia 2004). It is reported that the disease is rare in Malaysia, with only 1% of the fruits at a cannery affected (IPPC 2004). The hosts listed in the IPPC (2004) are pineapple, snapdragon and Penstemons. None of these are significant to NZ (and the snapdragon hosts is dubious based on that synonym not being used in other sources). Given the host range, it is unlikely that the bacterium would establish/cause impacts in NZ. May need to be reassessed if the host range expands or the pineapple industry in New Zealand increases in size. Based on the synonym Bacterium ananas and the DAFF (2012a) for pineapple from Malaysia, this may be a synonym of *Pantoea ananatis* which is being assessed further.
Pseudomonas marginalis	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). There are collections of the species from New Zealand. One pathovar of *P. marginalis* (P. m. pv. pastinacae) is not present in New Zealand (NZFungi 2021) and is regulated (ONZPR 2021). However, no evidence was found of this pathovar being associated with pineapples. Therefore, no evidence found that isolates from pineapple represent a strain not present in New Zealand.
Pseudomonas syringae pv. *antirrhini*	This organism is associated with leaf and stem lesions of pineapple. Given that the crown is not included in the commodity description, leaf/stem pathogens do not require further assessment. Beyond the listing in the pest list sent by the Philippines, and the AMAF (2020) list no evidence was found of the species being associated with pineapple (google/google scholar). In IPPC (2004), it is described that *P. s.* pv. *antirrhini* is a synonym of *P. ananas*, which does affect fruit. However, no other evidence was found that this is a valid synonym (Bull et al. 2010; DAFF 2012b; BiotaNZ 2022). The other consideration is that other than snapdragon (*Antirrhinum majus*) was the only host identified (BiotaNZ 2022), which although are present in New Zealand, are not of economic, cultural, social or environmental significance.
Ralstonia pseudosolanacearum	No evidence was found of *Ralstonia* species being associated with pineapple (Google/Google Scholar: Ralstonia pineapple/Ralstonia Ananas).

Tatumella citrea	The species is not listed in NZOR (2021), PPIN (2021) or ONZPR (2021). The species was initially thought to cause pink disease on pineapple as *Pantoea citrea*, but the strains have been allocated separate species status.
Tatumella morbirosei	Along with strains of *T. ptyseos*, *T. morbirosei* are reported causing pink disease of pineapple (Brady et al. 2010; Bull et al. 2012). This causes the release of a pink pigment during the canning process, in otherwise healthy looking fruit (Kado 2003). No evidence was found of the pathogen affecting any other host Google scholar/Google searches (including *Pantoea citrea*, which used to be considered the causative agent of pink disease). Given that pineapples are not commonly grown in New Zealand, this pathogen is unlikely to exposure or establish. This may need to be reassessed if pineapple become a more significant crop.
Collembola	
Seira sp.	No literature available associating *Seira* sp. with pineapples (Google search: Seira Poduromorpha pineapple ananas comosus). Only interception records available, and none identified to species level. *Seira septapartita* is already present in New Zealand (NZOR 2021).
Diseases of Unknown Aetiology	
glassy spoilage	Now considered to be caused by yeast species, likely *Fusarium subglutinans* (Rohrbach and Johnson 2003). This fungus is one of the other scientific names of *Gibberella subglutinans* in ONZPR (2021), which is non-regulated.
terminal mottle	This is caused by an unconfirmed virus or toxin (APS 2021). Given the unconfirmed nature of the disease, there is insufficient information to assess further.
Triad rot	The causative agent is unknown. No information available on this disorder. Based on the unknown nature of the disease and the lack of information, there is insufficient information to conduct an assessment.
Y-center rot	The causative agent is unknown there is no information available on this disorder and therefore insufficient information to assess further.
Fungus	
Acremonium polychromum	Not present in New Zealand (NZOR 2021) and is regulated (ONZPR 2021). This fungus has been isolated from the leaf of pineapple in Sierra Leone and dead herbaceous stems in Costa Rica. The fungus *Gliomastix murorum* var *polychroma* is a synonym and it is reported to be common in dead plant tissues (Dickinson 1968; Granados-Montero et al. 2018). No evidence found for association with pineapple fruit (Google/scholar search: Acremonium polychromum pineapple ananas comosus).
Acrostalagmus annulatus	*Acrostalagmus annulatus* and synonym *Stilbella annulata* are not reported present in New Zealand (NZOR 2021) and are not listed in ONZPR (2021). Literature found describes this species as a saprophytic fungi associated with dead and decaying plant material, no evidence found of association with pineapple fruit (Google/scholar search: Acrostalagmus annulatus Stibella annulata pineapple ananas comosus).
Alternaria alternata	This fungus is present in New Zealand. Strains not present in New Zealand are regulated (ONZPR 2021). Reported causing leaf spot on pineapple (CABI 2021). Infection of fruit appears to be primarily association with wounding during processing (Troncoso-Rojas and Tiznado-Hernández 2014). Such fruit is not expected to meet the commodity description and therefore this species was not assessed further.

Antennularia sp.	The only report of this fungus associated with pineapples is an import risk analysis for the importation of pineapples from Malaysia (DAFF 2001). It appears to be only associated with the leaves of pineapple (Singh 1980).
Armillaria mellea	The fungus is listed as 'recorded in error' in NZOR (2021) and is regulated in ONZPR (2021). This fungus is not known to infect fruit. It affects leaves, stems but mainly roots (CABI 2021). As such, it is not associated with the commodity.
Aspergillus sp.	The primary *Aspergillus* species associated with pineapple were identified as *A. flavus* and *A. niger*. Aspergillus flavus appears to be present in New Zealand (PPIN 2021; NZOR 2022). This species has been isolated from decayed pineapple fruits. *Aspergillus flavus* var. *parvisclerotigenus* is absent from New Zealand (NZOR 2021), however, the fungus is from tropical soil in Thailand and its aflatoxin productivity, no evidence of an association with pineapple was found (Google/Google Scholar: Aspergillus flavus var. parvisclerotigenus pineapple/Ananas cosmosus). *Aspergillus niger* is present in New Zealand (NZFungi 2021) and non-regualted (ONZPR 2021). *Aspergillus fumigatus* is also reported in association with pineapple, but this species is present in New Zealand (NZOR 2021). No other associations with pineapple found within this genus.
Aspergillus flavus	The species is present in New Zealand (NZOR 2021). The regulatory status is not assessed in ONZPR. The fungus has been associated with post harvest rot and decay of pineapples (Sarma 2014; APS; Rohrbach and Johnson 2003).
Aspergillus fumigatus	The species is reported present in New Zealand (NZOR 2021; PPIN 2021) and not listed in ONZPR (2021).
Aspergillus japonicus	The species is not present in New Zealand (NZOR 2021) and not listed in ONZPR (2021). This fungus has been reported in Panama being present in soil samples. This fungus has been isolated from rotten pineapple fruit in Nigeria. The GBIF.org (2021) reports this fungus present in other exporting markets but presence should be taken carefully as some are specimens kept in Museums, or DNA accessions (Piepenbring 2006). No literature was found of the species causing disease of pineapples (Google/google scholar search: Aspergillus japonicus pineapple), rather it appears to be used in the processing of pineapple juice and waste.
Aspergillus niger	Present in New Zealand (NZOR 2021; PPIN 2021) and non-regulated (ONZPR 2021).
Asterina aliena	Not reported present in New Zealand (NZOR 2021) and is not listed in ONZPR (2021). This fungus has been reported in association with the leaves of pineapple (Crane et al. 1997) but no evidence was found for association with pineapple fruit. Given that no association with the commodity was identified, the species was not assessed further.
Asterinella stuhlmanni	The species is not listed in NZOR (2021) or ONZPR (2021). This fungus is reported to affect the leaves of pineapples, causing leaf spot symptoms (Ministry of Agriculture and Agro-based industry Malaysia 2004). No evidence was found of the species associated with pineapple fruit (Google/Google Scholar: Asterinella stuhlmanni pineapple).
Athelia rolfsii	Present in New Zealand (NZOR 2021; PPIN 2021) and non-regulated (ONZPR 2021).
Beltrania rhombica	Present in New Zealand (NZOR 2021; PPIN 2021) and not listed in ONZPR (2021). *Beltrania indica* is a synonym.

Blakeslea trispora	Species is not present in New Zealand (NZOR 2021) and is regulated (ONZPR 2021). This species has been reported on pineapple from Nigeria but there are no specification on what part. This fungus is mainly found on waste by product of some fruits and is particular useful to produce carotenoids (HerbIMI 2022). No further association with pineapple was found (Google/scholar search: Blakeslea trispora pineapple ananas comosus). Given that no association with the commodity was determined, the species was not assessed further.
Blakeslea trispora	The species is listed as intercepted at the border (NZOR 2021) and is regulated (ONZPR 2021). No evidence was found that the species is associated with pineapple (Google: Google Scholar: Blakeslea trispora pineapple/Ananas comosus; Farr and Rossman (2021)). Some google results suggest that it grows on pineapple waste.
Brachysporium ananassae	The species is not listed in (NZOR 2021) or (ONZPR 2021). This fungus has been reported in Taiwan present in dead pineapple leaves (Sawada 1959). Therefore, it is not associated with the commodity.
Brachysporium sp.	This genus was assessed in DAFF (2001). It was concluded that it was associated with the leaves and caused leaf spot. Google and Google scholar searches found examples of other *Brachysporum* sp. being associated with leaf spot disease. As we are not considering pineapples with crowns, it does not appear to be associated with the commodity. No further assessment is required.
Calothyriella ananassae	The species is not listed in NZOR (2021) or ONZPR (2021). This fungus occurs on the leaves of pineapples. There is not much information in the literature about this fungus other than a list provided by the Australian Government where it mentions this fungus was not included because the pineapple is decrowned.
Candida sake	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). No evidence was found that the pineapple isolates represent strains not present in New Zealand.
Candida sp.	Assumed to be covered by species assessments.
Capnodium sp.	Some species in this genus are present in New Zealand (NZOR 2021) and some species are regulated (ONZPR 2021). Sooty mould that may cause secondary infection of pineapple leaves if mealybugs are present (Rohrbach and Johnson 2003). There is very little literature available for this genus, and it is unclear what species may be associated with pineapple fruit and there is unlikely to be enough information available to conduct a full assessment.
Ceratocystis fimbriata	This species is reported present in New Zealand (NZOR 2021; PPIN 2021). The Ipomoea strain is non-regulated, while strains that are not present in New Zealand are regulated (ONZPR 2021). The association of the fungus with pineapple is unconfirmed and is likely the result of erroneous reports (EPPO 2021). Given that the species is not confirmed to be associated with the commodity, this is not assessed further. If new information becomes available, this may need to be reassessed.
Ceratosphaeria sp.	No evidence found of association of this genus with pineapple fruit. There is a report of this genus on the leaves of pineapple in Venezuela (Urtiaga 1986), but not with the fruit part.

Cercospora sp.	Members of the genus are not associated with pineapple fruit. There is one disease associated specifically with the leaves of pineapple called the Cercospora spot of pineapple. It is characterized by necrotic spots in the leaves. It was detected in Brazil and is not recorded in any of the exporting markets (Ponte and Castro 1976). However, there are other species of *Cercospora* that attack other commercially important crops and that are present in some of the exporting markets (but are not reported to be associated with pineapple).
Cladosporium cladosporioides	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). *Cladosporium cladosporioides* f.sp. *pisicola* has been raised to species level and is now *Cladosporium pisicola*, it is not associated with pineapple.
Cladosporium oxysporum	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). No evidence was found of strains that may not be present in New Zealand.
Cladosporium perangustum	The species is present in New Zealand (NZOR 2021) and is not listed in ONZPR (2021). No evidence was found of strains that may not be present in New Zealand.
Cladosporium sp.	Assumed to be covered by species assessments.
Cladosporium sphaerospermum	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). No evidence was found of strains that may not be present in New Zealand.
Clonostachys rosea	Species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Clonostachys rosea f. *rosea*	Species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Clonostachys sp.	Species in this genus are present in New Zealand (NZOR 2021). No species found to be specifically associated with pineapple fruit.
Cochliobolus geniculatus	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Collariella gracilis	Species not listed in NZOR, ONZPR or PPIN (2021). This species has been reported on pineapple from Thailand but there are no specification from what part of the plant (HerbIMI 2022), however no other information is given. No evidence found of association of this species with pineapple fruits (Google/scholar search: Collariella gracilis pineapple ananas comosus). Given that no evidence of association with the commodity was found, the species was not assessed further.
Collariella gracilis	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence that the species is associated with pineapple (Google/Google Scholar: *Collariella gracilis* pineapple/*Ananas comosus*).
Colletotrichum gloeosporioides	Species is present in New Zealand (NZOR 2021) and its regulatory status is not assessed (ONZPR 2021).
Colletotrichum sp.	Some species within this genus are present in New Zealand (NZOR 2021) and some species are regulated (ONZPR 2021). *Colletotrichum capsici* is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021), therefore is not a hazard. *Colletotrichum ananas* is associated with pineapples, is not reported present in New Zealand (NZOR 2021), not listed in ONZPR (2021). It is not reported in exporting markets, therefore is not a hazard.

Colletotrichum truncatum	Species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Coniella fragariae	Present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021). No evidence was found of strains that may not be in New Zealand.
Coniothyrium sp.	A search of 'coniothyrium' and 'ananas' in Farr and Rossman (2021) returned two results: Coniothyrium fuckelii and Coniothyrium sp. *Coniothyrium fuckelii* is present in New Zealand (NZOR 2021). The second result is on genus level. Although it is associated with pineapple, its distribution shown in Farr and Rossman (2021) is only Cambodia, Florida and South Africa.
Corynespora cassiicola	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Curvularia sp.	Multiple species of *Curvularia* have been identified association with pineapple (Farr and Rossman 2021). The majority of the reports are of them causing pineapple leaf disease (Zhong et al. 2016; Farr and Rossman 2021). There is one report of the species *C. eragrostidis* causing post-harvest rot of pineapple in Brazil (Ferreira et al. 2014). This is the only report of this disease, and although it is a cosmopolitan fungus, such symptoms have not been observed in pineapples in exporting markets (or elsewhere). Curvularia eragrostidis was assessed in a PRA exclusion note.
Curvularia australiensis	This species is present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021).
Curvularia clavata	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Cylindrocarpon effusum	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021).The fungus is associated with the base and root of the pineapple. The two records are based in Mauritius, there is no evidence so far that this fungus is found in any of the exporting markets using the google search terms 'Cylindrocarpon AND Ananas' or using the Farr and Rossman (2021) database. Therefore, there is no evidence of the species being associated with the commodity.
Daldinia sp.	*Daldinia eschscholtzii* (not known to present in New Zealand (NZOR 2021) and not listed in ONZPR (2021) appears to be associated with the peduncle of pineapples and was assessed further. No evidence found of other species of *Daldinia* being associated with pineapple fruits.
Dictyoarthrinium quadratum	*D. sacchari* is not present in New Zealand (NZOR 2021) and is regulated (ONZPR 2021). This species is a saprophytic fungus and is not reported to be associated with pineapple fruit. This fungus occurs on mature leaves, not on crown leaves (Department of Agriculture 2019) and is therefore not associated with the commodity.
Dictyothyrina ananasicola	The species is not listed in NZOR (2021) or ONZPR (2021). The current information are recorded from databases in which the fungus was detected on leaves of pineapple (Sarbhoy et al. 1971). There is little information about the fungus in the literature therefore at this point it is not known its complete distribution. Given that no association with the commodity was determined, it was not assessed further.
Diplodia sp.	Species within this genus are present in New Zealand (NZOR 2021) and many species are regulated (ONZPR 2021). *Lasiodiplodia theobromae* (syn. *Diplodia ananassea*) is present in New Zealand (NZOR 2021) and is non-regulated. No evidence found for other species in this genus being associated with pineapples.

Dothiorella sp.	Species within this genus are present in New Zealand (NZOR 2021) and some species are regulated (ONZPR 2021). No evidence found for association of a specific Dothiorella species with pineapple (Google/scholar search: Dothiorella pineapple ananas comosus).
Echidnodes bromeliacearum	Not reported present in New Zealand (NZOR 2021) and is not assessed in ONZPR (2021). Synonym is *Lembosia bromeliacearum* (EPPO 2021). While the fungus has been reported in association with pineapples (DAFF 2001) it is unclear if it is associated with the pineapple fruit and there is not enough information available to conduct further assessment. No evidence was found of the species associated with pineapple fruit (google/scholar search: Echidnodes bromeliacearum). This fungus has been observed on the leaves of other Bromeliads. The disease appears as elliptical leaf spots, either upper or lower, and light brown on the corresponding opposite sides. Spots may coalesce (El-Gholl et al. 1988). Therefore, it is assumed that the species affects pineapple leaves and is not associated with the commodity.
Ellisiodothis sp.	The genus does not appear to be associated with pineapple fruit. There is one record of this genus associated with pineapple, although it is not known what part of the plant is affected. The publication is from Fiji, it could possibly be assumed that this fungus is present in Fiji but not completely certain (Wright 2003; Pacific Islands Pest List Database 2022).
Elsinoe perseae	The only source that indicates an association of *E. perseae* with pineapple is from USDA fungal database (Farr and Rossman 2021), and the reference from USDA is Mendes (1998). However, this reference does not specify which pineapple plant part the fungus is associated with. No further association with pineapple was found in literature searches (Google/Google Scholar: Elsinoe perseae pineapple/ Ananas cosmosus). Therefore, is not considered to be associated with the commodity.
Epicoccum nigrum	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021) under the synonym *Epicoccum purpurcens*.
Erysiphe cichoracearum	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021) under the synonym *Epicoccum cichoracearum*.
Fusarium affine	The species is not listed in NZOR (2021) or ONZPR (2021).This fungus is responsible of root rot in pineapple, not associated with the fruit or the base of the fruit (Gonsalves and Ferreira 1994). Therefore, the species is not associated with the commodity.
Fusarium ananatum	This fungus infects fruitlets causing them to remain green or delay its maturity. Internal browning is observed in the center of the affected fruitlet and the rot ocassionally spread to the fruit core (Barral et al. 2020). No evidence was found that this species infects any other hosts except for pineapple. Exposure, establishment and impacts are unlikely in New Zealand due to lack of host availability.

Fusarium chlamydosporum	There was only a single report of this species being associated with pineapples, and was based off of morphological identification. It may be possible that this association was not of *F. chlamydosporum*, but of another similar (possibly undescribed) fusarium species. *Fusarium chlamydosporum* is also considered a species complex and the fungus may be a new species in this complex. There is not enough evidence of this fungus species being associated with pineapples for a full PRA to be justified. This fungus causes discoloration of the fruitlet and water-soaked appearance. On the leaves, rotting at the base, necrotic spot, dry rot on the roots and wilting were observed. Reported hosts of *F. chlamydosporum* include *Agaricus bisporus*, *Pennisetum glaucum*, *Sorghum bicolor*, *Morus* sp., *Pinus haplepsis*, *Helianthus* sp., tobacco, kangaroo paw, rooibos tea plants, okra, *Lycium barbarum*, *Musa sampientum*, *Colocasia esculenta.*
Fusarium guttiforme	No evidence found that this *Fusarium* species infects any other hosts except for pineapple. Exposure, establishment and impacts are unlikely in New Zealand due to lack of host availability. Presence in exporting markets is uncertain, but appears to be unlikely. It affects all parts of the plant. *Fusarium guttiforme* is the asexual state, however the sexual state is part of the Gibberella fujikuroi complex, and this sexual state has not been associated with fusariosis in pineapple. It is characterized gummosis on the plant and fruits. On the fruits, the gummosis occurs mainly on the floral cavity deteriorating the quality of the fruit.
Fusarium polyphialidicum	There is not enough evidence of this fungus species being associated with pineapples for a full PRA to be justified.
Fusarium temperatum	This fungus is present in New Zealand (NZOR 2021), but is not listed in ONZPR (2021). No evidence was found that the pineapple isolate represents a strain that is not present in New Zealand.
Gibberella fujikuroi	This is a species complex. Some synonyms are not present in New Zealand and are regulated (ONZPR 2021). The preferred name, *Fusarium fujikuroi*, is reported present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Gibberella sacchari	Synonym of *Fusarium sacchari*, which is present in New Zealand and is non-regulated
Gliomastix luzulae	Species is present in New Zealand (NZOR 2021) and is not listed in ONZPR (2021). Preferred name is *Acremonium luzulae*. Based on the presence in New Zealand, no further assessment required.
Gloeosporium orbiculare	The species is present in New Zealand, under the synonym *Colletotrichum orbiculare* (NZOR 2021) and is non-regulated under the synonym *Glomerella lagenaria* (ONZPR 2021).
Gloeosporium sp.	Assumed to be covered by species assessed.
Golovinomyces cichoracearum	Synonym of *Erysiphe cichoracearum.*
Helminthosporium sp.	The fungus *Helminthosporium cassiicola* is mentioned as being associated to pineapples in an import risk analysis for the importation of pineapples to Australia (DAFF 2019b). However, no information was found in the literature searched using the search terms "Helminthosporium cassiicola AND pineapple" or the current name "Corynespora cassiicola AND pineapple". Given that no association with the commodity was found, the species was not assessed further.

Kloeckera sp.	Members of the *Kloeckera* genus are present in NZ (NZOR 2021). They are fermentation fungi (Díaz-Montaño and Córdova 2009) and opprtunistic human pathogen (Sánchez-Cárdenas et al. 2021), suggesting a ubiquitus nature. Based on the available information there insufficient information to justify an assessment- This is the only report found of a member of this genus causing pineapple disease, no relevant emerging risks about this genus causing plant disease, literature found in Google/Google scholar searches mostly relate to biocontrol uses, cannot identify if the causative agent is present in exporting markets (or is absent from New Zealand) as the only report is from Brazil (Korres et al. 2010), the isolate did not cause symptoms when individually inoculated. This suggests an opportunistic infection of multiple species that caused disease, rather than an established disease causing complex that can be assessed. If further information becomes available, this may need to be reassessed. Genus is so broad and ubiquitous that an assessment cannot be done based on available information.
Lasiodiplodia theobromae	This species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Lembosia sp.	Some species in this genus are present in New Zealand (NZOR 2021). *Lembosia orbicularis* is listed in ONZPR (2021) and is regulated. No evidence found for association with pineapple fruit.
Macrophoma sp.	Some species in this genus are present in New Zealand (NZOR 2021) and some species are regulated (ONZPR 2021). *Macrophoma* species may be associated with the leaves of pineapples, but no evidence was found for association with pineapple fruits. *Macrophoma* sp. has been isolated from necrotic areas of leaves of pineapple in Malaysia. The fungus *M. phaseoli* is associated with the root of the plant (Farr and Rossman 2021). Given that no evidence of the genus associated with the commodity was found, this was not assessed further.
Macrophomina phaseolina	This species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021)
Marasmiellus scandens	The species is absent from New Zealand (NZOR 2021) and is regulated (ONZPR 2021). Associated with pineapple but cocoa is the main host. Even on cocoa, *M. scandens* is of little economic significance when the plants are properly managed. The disease is associated with poorly maintained plants already weakened by poor field management, other pests and diseases. The fungus forms a network of white mycelial strands that ramify across the leaves, petioles and branches. The infected leaves then undergo abscission and are then held together by the fungal threads and dense mycelial pads (CABI 2021; Farr and Rossman 2021). This fungus is associated with leaves and the pest or symptoms are usually visible to the naked eye.
Marasmius crinis-equi	The species is absent from New Zealand (NZOR 2021) and is regulated (ONZPR 2021). Pineapple is regarded as a secondary host, although it is only reported associated with leaves and not the fruit (Ministry of Agriculture and Agro-based industry Malaysia 2004) (DAFF 2011; CABI 2021). This species is synonym with *Marasmius equicrinis*.
Marasmius palmivorus	The fungus can affect the fruitlet and plants are not able to develop a full mature fruit. The fungus is normally saprophytic on decaying and dead materials. It spreads to a new source via infected plant parts that include flowers, fruit, leaves, roots, stems, wood, seeds or via windblown rain, water-splash, or air-currents. Given that the fungus prevents the fruit maturing, it is not going to be associated with the commodity.

Marasmius sacchari	The species is present in New Zealand (NZOR 2021) and is regulated (ONZPR 2021). In the literature no association was found with pineapple using the search terms "Marasmius sacchari AND pineapple". This fungus' main host is sugarcane and is called pineapple wilt because it liberates a smell similar to pineapple; in sugarcane it affects the roots and stem (Cook).
Mariannaea elegans	This fungus is present in New Zealand (NZOR 2021),but is not listed in ONZPR (2021). No evidence was found that the pineapple isolate represents a strain that is not present in New Zealand.
Meyerozyma guilliermondii	The species is present in New Zealand (NZOR 2021). It is not listed in ONZPR (2021).
Microdiplodia ananasae	Species is not listed in NZOR (2021) and ONZPR (2021). Occurs on pineapple leaves (DAFF 2001). No evidence found for association with pineapple fruits (Google /scholar search: 'Microdiplodia ananasae' and pineapple/'ananas comosus'). Given that the species is not associated with the commodity, it was not assessed further.
Microdochium nivale	This fungus species is already present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Microxyphium sp.	CAB Abstract and Google Scholar search returned no relevant references (Microzyphium pineapple/Ananas comosus). The USDA database lists pineapple of a host, but does not give a species. Given that there is no other references to an association with pineapple and none from the exporting markets there is insufficient information for further assessment. May need to be reconsidered if more/new information becomes available.
Mollisia sp.	This genus is associated with pineapple but it is not clear from the sources found (all mainly in Hawaii) (Raabe et al. 1981; Crop Knowledge Master undated; HEAR 2004) if the fungus is associated only with the leaves or can infect fruit. Because we are not sure what species is affecting pineapple (all the reports are Mollisia sp), we cannot know if the fungus is present in the exporting markets, or not present in New Zealand.
Monilia sp.	Genus is so broad and ubiquitous that an assessment cannot be done based on available information. There is insufficient information available to justify a PRA.- In Korre (2010) the species did not cause symptoms when in single inocualtion -there are no emerging risks of Monilia on pineapple -only one other record was found of the genus on *A. comosus* (in Hawaii), the nature of the infection was not described -the genus appears to be a synonym of Candida (NZFungi 2021), which is a widespread genus with species present in NZ -members of the Candida genus are opportunistic human pathogens -it cannot be determined if the species occurs in exporting markets as the only report is currently from Brazil (Korres et al. 2010). This appears to be an opportunistic infection rather than an established species complex that can be assessed. If further information becomes available, such as through the ERS, may need to be reassessed.
Muyocopron pandani	The species is not listed in NZOR (2021) or ONZPR (2021). This fungus is associated with the leaves of pineapple (Pavgi and Gupta 1967; Sarbhoy et al. 1971). There are no reports in the literature that this fungus is associated with pineapple fruit (Google/Google Scholar: Muyocopron pandani pineapple). Referred in the literature as *Myiocopron pandani*.
Mycosphaerella sp.	No literature was found using the search terms 'Mycosphaerella AND pineapple' OR 'Mycosphaerella AND Ananas comosus', where there is association of the genus Mycosphaerella with pineapple. There are two reports of this genus on USDA fungal database, but there are no details about

	the association (Lu 2000; Zhuang 2001). These references were not possible to access.
Nectria ananatis	The species is not listed in NZOR (2021) or ONZPR (2021). This fungus infects the leaves (DAFF 2001) and is therefore not associated with the commodity.
Neocosmospora solani	This fungus is present in New Zealand (NZOR 2021).
Neofusicoccum mangiferae	This species is present in New Zealand (NZOR 2021; PPIN 2021) and the synonym (Nattrassia mangiferae) is under assessment for regulatory status (ONZPR 2021).
Neoscytalidium dimidiatum	This species is present in New Zealand (NZOR 2021). It is not listed in ONZPR (2021).
Nigrospora oryzae	The fungus is present in New Zealand (NZOR 2021; PPIN 2021). No evidence was found of the species having strains that may not be present in New Zealand.
Nigrospora sp.	Lack of evidence associating an undescribed *Nigrospora* sp. with pineapple. There is one interception of *Nigrospora* sp. on pineapple from Vanuatu listed in (LIMS 2021). The other interception of *Nigrospora* on pineapple was identified as *N. sphaerica*. There was an undescribed *Nigrospora* sp. that was found to cause postharvest rot of kiwifruit (Kwon et al. 2017). It was considered a possibility that the undescribed kiwifruit species may be the same as the undescribed species intercepted on pineapple. However, according to Xinhua (2018) the causative agent was identified as *N. sphaerica*. *Nigrospora sphaerica*, which is present in New Zealand and is non-regulated (ONZPR 2021). Given that there were no records of an undescribed species of *Nigrospora* causing disease of pineapple found, and there were multiple records of *N. sphaerica* as a pineapple pathogen, there is in sufficient informaiton to do an assessment on the *Nigrospora* sp. identified in LIMS. Furthermore, as there is no context around the interception on LIMS that it was unable to be identified to species level. No further assessment.
Paraconiothyrium fuckelii	The species is present in New Zealand (NZOR 2021). It is not listed in ONZPR (2021).
Paramyrothecium roridum	The species is present in New Zealand (NZOR 2021; PPIN),but is not listed in ONZPR (2021). However, it is non-regulated under the basionym Myrothecium roridum (ONZPR 2021). The fungus has been collected from different regions on different hosts (NZOR 2021; PPIN). No evidence was found of the species having strains that may not be present in New Zealand.
Penicillium chrysogenum	Species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Penicillium citrinum	Species is present in New Zealand (NZOR 2021; PPIN 2021) but is not listed in ONZPR (2021). No evidence was found of strains that may not be present in New Zealand.
Penicillium expansum	Species is present in New Zealand (NZOR 2021; PPIN 2021) and regulatory status has not been assessed (ONZPR 2021). No evidence was found strains that may not be present in New Zealand.
Penicillium glabrum	Species is present in New Zealand (NZOR 2021; PPIN 2021) but is not listed in (ONZPR 2021). No evidence was found strains that may not be present in New Zealand.

Penicillium pinophilum	The species is listed as the synonym *Talaromyces pinophilus* which is absent from New Zealand (NZOR 2021). The regulatory status is listed as 'not assessed' in ONZPR (2021). There is a record of this fungus (as *Talaromyces pinophilus*) on pineapple in Costa Rica. However, this is a soil-borne fungus that has been used as a biological control of other fungi. No other evidence of the fungus in exporting markets was found (CABI; Google/Google Scholar search: Talaromyces pinophilus and Penicillium pinophilum).
Penicillium rolfsii	The species is absent from New Zealand (NZOR 2021), and is not listed in ONZPR (2021). There is a record of this fungus from 1930 on fruit of pineapple in North America (Index Fungorum 2022), however, except from saying it is on fruit of pineapple, there is no other information or original reference cited. Furthermore, there is no other record found on google on its association with pineapple fruit or the damages it inflicts to the fruit (Google/Scholar search: Penicillium rolfsii pineapple ananas comosus).
Penicillium roqueforti	Species is reported as present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021). No evidence was found strains that may not be present in New Zealand.
Penicillium sp.	Assumed to be covered by species assessments.
Penicillium vulpinum	Species is reported present in New Zealand (NZFungi 2021) but is not listed in ONZPR (2021). No evidence was found strains that may not be present in New Zealand.
Periconia atropurpurea	This fungus is absent from New Zealand (NZOR 2021), but is not listed in ONZPR (2021).This fungus is saprophytic known to be associated in host plants. It is known to be associated with the leaves of pineapple only by a record from Ghana (Farr and Rossman 2021).
Periconia effusa	The species is not listed in NZFungi (2021) or ONZPR (2021). This fungus is reported as saprophytic on pineapple. No literature was found that indicates this species affect the fruit using the google search terms 'Periconia effusa AND Ananas'. Farr and Rossman (2021) reports this fungus in pineapple but there are no details. It association on leaves is bases on an IRA from Australia and a citation that was retrieved by the Farr and Rossman (2021) but no information about its association was found. In general, this Genus is known to fed on dead litter (Agriculture, Fisheries and Forestry. 2001; Farr and Rossman 2021).
Periconia minutissima	This fungus is present in New Zealand (NZOR 2021) and the regulatory status is 'under assessment' in ONZPR (2021). It's a saprophytic fungi and was reported to be associated with pineapple leaves in Ghana (Hughes 1953 cited in Farr and Rossman 2021).
Pestalotia ananas	This species is not reported to be present in New Zealand (NZOR 2021) and is not listed on ONZPR (2021). This fungus is associated with pineapple leaves, but is not associated with the fruit (DAFF 2019b).
Pestalotia bromeliicola	This species is not reported present in New Zealand (NZOR 2021). Minimal information available about this species, and it does not appear to be associated with pineapples (Google/scholar search: Pestalotia bromeliicola pineapple ananas comosus).
Pestalotia microspora	This species is not present in New Zealand (NZOR 2021) and regulated (ONZPR 2021). This species is reported cause leaf blotch disease on pineapple plants (Rao and Mhaskar 1973), but no evidence was found associating the fungus with pineapple fruits (Google/Google scholar: Pestalotia microspora fruit).

Pestalotia sp.	Assumed to be covered by species assessments.
Pestalotiopsis funerea	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Pestalotiopsis neglecta	The species is listed as present in New Zealand (NZOR 2021) but regulated in ONZPR (2021). This fungus is associated with the leaves of an ornamental pineapple (*Ananas lucidu*) in Brazil, on which it induces symptoms such as oval-sunken necrotic lesions (Meireles-Barguil et al. 2008; Souza et al. 2020). 2008). There are no reports in the literature that this fungus is associated with pineapple fruits using the google search terms Pestalotiopsis neglecta AND Ananas.
Pestalotiopsis royenae	The species is not listed in NZOR (2021) or ONZPR (2021). There is scarce literature regarding the association of this fungus to pineapple. There is a reference from USDA fungal database (Farr and Rossman 2021) being reported in China, but could not get access. It has been detected in cardamom and is known as leaf streak. The disease is characterized by rectangular spots running parallel to the veins and elongated, rectangular translucent streaks appearing on young leaves along the veins (Gopi et al. 2018). Given that no evidence was found of the species affecting pineapple fruit, and in other hosts it causes leaf symptoms, this species is not considered to be associated with the commodity.
Pestalotiopsis sphaerelloides	The species is not listed in NZOR (2021) or ONZPR (2021). This fungus is associated with the leaves of pineapple (Arnold 1986; Agriculture, Fisheries and Forestry 2001). No evidence was found of it associated with pineapple fruits.
Pestalotiopsis versicolor	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Phialocephala sp.	This genus was intercepted in Mexico from pineapple fruit and leaves in 1979 (BPI undated, cited in Farr and Rossman (2021)). Species in this genus are typically associated with roots and decaying wood. No evidence found of association with pineapple fruits except a very old interception record (Google/Google Scholar: Phialocephala pineapple).
Phoma comosi	The species is not listed in NZOR (2021) or ONZPR (2021). Farr and Rossman (2021) refers to the species associated with pineapple. These refer to *Phoma comosi* on pineapple leaves in India. No other references were found (Google/Google Scholar: Phoma comosi pineapple/Ananas comosus). Based on a lack of evidence of commodity association and presence in exporting markets, was not assessed further.
Phoma sp.	Assumed to be covered by the species assessed. No further species of Phoma, beyond that already identified, was found associated with pineapple (Google/Google Scholar: Phoma pineapple/Ananas comosus).
Phomopsis sp.	Assumed to be covered by the species assessed.
Phomopsis ananassae	The species is not listed in NZOR (2021) or ONZPR (2021). This species is reported associated with pineapple leaves (Zeng 2004), but is not known to be associated with the fruit.
Phomopsis diplodinoides	The species is not listed in NZOR (2021) or ONZPR (2021). This species is reported associated with pineapple leaves (Zeng 2004), but is not known to be associated with the fruit.
Phomopsis spectabilis	The species is not listed in NZOR (2021) or ONZPR (2021). This species is reported associated with pineapple leaves (Zeng 2004), but is not known to be associated with the fruit.

Phyllachora sp.	The species found in this genus are associated with the leaves of the host e.g. Phyllacora sacchari & Phyllacora maydis amongst others. The Pacific Islands Pest List Database (2022) records the genus *Phyllacora* associated with pineapple but there are no details on what part of the plant, but based on the behaviour on other hosts, it is assumed to be the leaves (Kranz 1964; Koite 1988).
Phyllosticta ananassae	The species is not listed in (NZOR 2021) or (ONZPR 2021). This fungus is associated with the leaves of pineapple, commonly known as leaf spot. no evidence found indicate it is associated with the commodity.
Physalospora sp.	*Physalospora rhodina* may cause post harvest fruit rot of pineapples (DAFF 2001; Ministry of Agriculture and Agro-based industry Malaysia 2004). This species is a synonym of Lasiodiplodia theobromae which is present in New Zealand (NZOR 2021) and in non-regulated (ONZPR 2021). No evidence found of other species in this genus that may be associated with pineapples.
Pilobolus crystallinus	The species is present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021). No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Pilobolus crystallinus	This fungus is present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021). No evidence that the pineapple isolates represent a strain not present in New Zealand.
Pleurostoma richardsiae	The presence of *P. richardsiae* in New Zealand requires validation and is listed as uncertain (NZOR 2021). The species is not listed in ONZPR (2021). The fungus is reported to be associated with pineapple in India (Farr and Rossman 2021). However, the source to this record, Sharma et al. (1981), is not available through available pathways. No other references to the fungus being associated with pineapple was found. Due to no confirmed association with pineapple, no further assessment.
Polynema sp.	No evidence was found of the genus being associated with pineapple (Google/Google Scholar: Polynema pineapple/Ananas comosus).
Pseudopestalotiopsis theae	The species is absent from New Zealand (NZOR 2021) but is not listed in ONZPR (2021). No literature was found of the association of this fungus with pineapple using the key words 'Pseudopestalotiopsis thea AND Ananas'.
Pseudopithomyces chartarum	The species is present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021).
Pseudopithomyces maydicus	The species is present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021).
Pseudopithomyces sacchari	The species is absent from New Zealand (NZOR 2021) but is not listed in ONZPR (2021). (Kirk 1991) and two references in Farr and Rossman (2021) indicate its association with *Ananas* sp. and *Ananas comosus*. The Farr and Rossman references indicate an association with leaves from Cambodia, Ghana, Sierra Leone and Venezuela. Given that no commodity association was found, this species was not assessed further.
Rhizoctonia solani	Synonym of *Thanatephorus cucumeris* which is present in New Zealand (NZOR 2021). Strains present in New Zealand are non-regulated (ONZPR 2021). The species is soil-borne and causes root disease of hosts (Williamson-Benavides and Dhingra 2021). No evidence was found of the species associated with pineapple fruits (Google scholar Rhizoctonia solani pineapple fruit).
Rhizoctonia sp.	Assumed to be covered by species assessments.
Rhizopus sp.	Assumed to be covered by species assessments.

Rhizopus arrhizus	This species present in New Zealand NZOR (2021) and has a regulatory status of 'under assessment' in ONZPR (2021). The synonyms listed in NZOR are *R. oryzae* and *R. maydis* (with *R. arrhizus* as the preferred name). There is a record of *R. oryzae* collected from New Zealand in PPIN (2021). No evidence of strains that may not be present in New Zealand. No further assessment.
Rhizopus stolonifer	Present in New Zealand (NZFUNGI 2022) and is non-regulated (ONZPR 2021). There are collection records from different regions of New Zealand. No evidence was found of there being other strains that may not be present in New Zealand. No further assessment.
Rhodotorula graminis	The species is present in New Zealand (NZFungi 2021) but is not listed in ONZPR (2021). No evidence was found of strains that may not be in New Zealand.
Saccharomyces cerevisiae	The species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). There are collections of the species from New Zealand. No evidence was found of strains that may not be present in New Zealand.
Saccharomyces sp.	Assumed to be covered by species assessments.
Septobasidium westonii	The species is not listed in NZFungi (2021) or ONZPR (2021). Very little literature/information was found for this fungus (Google/Google Scholar search Septobasidium westonii and Septobasidium westonii pineapple). However, it was found that the species occurs in Panama and has been recorded as present in Panama on pineapple leaves (Farr and Rossman 2021; DAFF 2001). Therefore, no association with the commodity was found.
Spegazzinia sundara	The species is absent from New Zealand (NZFungi 2021), and is not listed in ONZPR (2021). Saprophytic fungi that is associated with dead leaves and is not associated with pineapple fruit (DAFF 2001) Given that the species is not associated with the commodity, it was not assessed further.
Spegazzinia tessarthra	Species is present in New Zealand (NZFungi 2021) and is not listed in ONZPR (2021). No evidence was found of strains associated with pineapple being different from those present in New Zealand. The variety listed in NZOR (Spegazzinia tessarthra var. deightonii) is now recognised as a distinct species .
Sphaerobolus stellatus	Species is present in New Zealand (NZFungi 2021; PPIN 2021) and is non-regulated (ONZPR 2021). No evidence was found of the pineapple isolate representing a strain that may not be present in New Zealand.
Sphaeronaema sp.	Species in the genus *Sphaeronaema* are known to be present in New Zealand (NZOR 2021) and some species are regulated (ONZPR 2021). One species was detected that was associated with pineapple is *Sphaeronaema fimbriata*, however they reclassified this fungus to Ceratocystis fimbriata, which is present in New Zealand and assessed above. No evidence found of association of this genus with pineapple fruit (google/scholar search: Sphaeronaema pineapple ananas comosus)
Stachybotrys sp.	Assumed to be covered by species assessments.
Stachybotrys parvispora	The species is listed as present in New Zealand (NZFungi 2021) and the regulatory status is listed as 'under assessment' (ONZPR 2021). There are collection records from regions of New Zealand. No evidence was found of the species having strains that may not be present in New Zealand.
Steirochaete ananassae	The species is not listed in NZFungi (2021) or ONZPR (2021). Fungus may be associated with the leaves of pineapple, but no evidence was found of association with pineapple fruit.

Stomiopeltis sp.	The genus does not appear to be associated with pineapple fruits. DAFF (2001) reports this fungus as being present on the fruit with crown and states that this fungus occurs only on leaves and cited Sing (1980) which is not accessible.
Syncephalastrum racemosum	This species is present in New Zealand (NZFungi 2021) and non-regulated (ONZPR 2021). No evidence was found of the species having strains that may not be present in New Zealand.
Talaromyces flavus	Species is reported present in New Zealand (NZFungi 2021), and the regulatory status is under assessment (ONZPR 2021). Synonym of this species is *Penicillium dangeardii* (anamorph taxon) which is also reported present in New Zealand (NZOR 2021).
Talaromyces funiculosus	The fungus is reported present in New Zealand and *Penicillium funiculosum* is reported as a synonym (NZFungi 2021). The regulatory status of *P. funiculosum* is listed in ONZPR (2021) as 'not assessed', and *T. funiculosus* is not listed. Although the species has been reported to cause of fruit core rot in pineapple (Lim and Rohrbach 1980; Barral et al. 2020), and is present in exporting markets, given that it is present in New Zealand (and no relevant strains were identified), is not assessed further.
Talaromyces minioluteus	The species is absent from NZFungi (2021) and not listed in ONZPR (2021). According to HerbIMI (2022) this fungus has been recorded on pineapple but there are no details on which part of the plant. No evidence found for association with pineapple fruit (Google/Scholar search: Talaromyces minioluteus pineapple ananas comosus).
Talaromyces pinophilus	The species is absent from New Zealand (NZFungi 2021) and not listed in ONZPR (2021). No evidence found for association with pineapple fruit (Google/Scholar search: Talaromyces minioluteus pineapple ananas comosus).
Talaromyces purpureogenus	The fungus is reported present in New Zealand (NZFungi 2021), but is not listed in ONZPR (2021). No evidence was found of strains that may not be present in New Zealand.
Thielaviopsis ethacetica	Species is present in New Zealand (NZOR 2021; PPIN 2021) and not listed in ONZPR (2021). No evidence was found of strains that may not be present in New Zealand.
Thielaviopsis sp.	*Thielaviopsis paradoxa* is reported on pineapples. Thielaviopsis paradoxa was assessed further. No other species in this genus reported in association with pineapples (Google./scholar search: Thielaviopsis pineapple ananas comosus).
Trichoderma harzianum	The species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). No evidence was found of strains that may not be present in New Zealand.
Trichoderma sp.	Trichoderma species are present in New Zealand (NZOR 2021) and are frequently used worldwide as biological control agents of fungal diseases such as fusarium (Trocoli et al. 2017). No evidence found of association of this genus with pineapple fruits (Google/scholar search: Trichoderma pineapple ananas comosus).
Trichoderma viride	The species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). No evidence was found of strains that may not be present in New Zealand.

Trichosphaeria sacchari	The species is not listed on NZFungi (2021) or ONZPR (2021). The fungus is reported associated with pineapples in the West Indies (Farr and Rossman 2021). Other reports are on sugarcane in Brazil and Dominican Republic (Farr and Rossman 2021). Very little information was found on this fungus in Google/Google Scholar searches. The records found related to sugarcane disease. Very little information, no information that it is in exporting markets or associated with the commodity. No further assessment required.
Tripospermum sp.	This fungus has been recorded on pineapples in Cuba. This fungus grows on the honeydew produced by sap-sucking insects and cover the upper leaf surfaces of many plants (Thaman 2018). No evidence found indicates it is associated with the fruit.
Verticillium heterocladum	The species is absent from New Zealand (NZFungi 2021) and is regulated (ONZPR 2021). It was reported associated with pineapple in Hawaii but there are no details of the association. No presence of this fungus was found in any of the exporting markets using the google search terms 'Verticillium heterocladum' and it current name 'Paecilomyces cinnamomeus' according to Index Fungorum.
Insect	
Abgrallaspis cyanophylli	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). No evidence was found that the beetle vectors disease.
Acalolepta sp.	No association of the genus with decrowned pineapple was found (Google/Google Scholar: Acalolepta pineapple/Ananas comosus).
Acerophagus sp.	This is a genus of parasitic wasps and are not considered to be associated with the commodity.
Acrolophus sp.	Several species within the genus feed on roots, stems and leaves of Bromeliaceae. They mostly attack the plant base, close to the soil (Ministry of Economic Affairs 2015). Genus does not appear to be associated with pineapple fruits. (Google/scholar search: Acrolophus pineapple ananas comosus).
Adoretus ictericus	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). It attacks pineapple roots and is not considered to be associated with the commodity (Smith et al. 1995).
Adoretus tessulatus	The species is not listed in NZOR (2021), and is regulated in ONZPR (2021). It attacks pineapple roots (Sarah 1989) and is not considered to be associated with the commodity .
Aeolus sp.	No evidence found that this genus is associated with pineapple fruit.
Agallia sp.	The genus is not known to be associated with pineapple (Google/Google Scholar: Agallia pineapple/Ananas comosus).
Agrotis ipsilon	This species is present in New Zealand (NZOR 2021) and it is not known to be a vector (Joshi et al. 2020; CABI 2021).
Ahasverus advena	This species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Aleurodothrips fasciapennis	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Although the species has been reported from exporting markets, the species is not associated with pineapple fruit. Although it has been found in pineapple fields, this is a predatory thrips that can feed on scales associated with pineapples (APHIS 1979; Rohrbach and Johnson 2003), rather than the fruit.
Alpheias conspirata	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). There is a record of an interception in US border in 1962 but there is no detail

	on the interception. No further evidence of an association with pineapple fruit was found (Google/Google Scholar: Alpheias conspirata pineapple).
Althos obscurator	The species is not listed in NZOR (2021) or ONZPR (2021). Very little information was found about this species and no evidence that it is associated with pineapple (Google/Google Scholar: Althos obscurator pineapple/Ananas comosus).
Altica sp.	No evidence was found indicating that this genus is associated with pineapple fruit.
Amblypelta lutescens	The pest is mobile and big, so it is unlikely to be associated with the commodity due to commercial production process of the commodity and inspection.
Amorbia emigratella	Damage is typically to the foliage as larvae roll the leaves and feed on the leaf edges. However, it may extend to the fruit surface if leaves contact the fruit, or when two fruits are close together. Damage to fruit is likely to be visible. Mexican leafroller will occasionally travel with imported commodities (e.g. papayas, cut flowers). Given the weak association with the commodity, and the visibility of the damage, this species was not assessed further.
Anagyrus ananatis	The species is not listed in NZOR (2021) or ONZPR (2021). This is a parasitic wasp parasitic wasp and is a natural enemy of the pineapple mealybug *Dysmicoccus brevipes* (Pandey and Johnson 2006; CABI 2021), which is not known to be present in New Zealand (PPIN 2021). In the absence of its host it is assumed that the wasp would not be able to establish in New Zealand and for this reason it will not be considered further.
Anagyrus coccidivorus	The species is not listed in NZOR (2021) or ONZPR (2021). This is a parasitic wasp parasitic wasp and is a natural enemy of the pineapple mealybug *Dysmicoccus brevipes* (Pandey and Johnson 2006; CABI 2021), which is not known to be present in New Zealand (PPIN 2021). In the absence of its host it is assumed that the wasp would not be able to establish in New Zealand and for this reason it will not be considered further.
Anasa sp.	No evidence was found that the genus is associated with pineapple (Google/Google Scholar: Anasa pineapple/Ananas comosus).
Anaxipha sp.	The adults are very active and commonly inhabit low dense plants, but are occasionally found among litter on the ground or in tall shrubs or small trees. No other report about its association with pineapple was found other than a report of an interception in Panama (Fulton 1956). Likely that this cricket will be disturbed during harvest and not remain on the fruit.
Ancylosternus morio	Google and Google Scholar searches, including using the synonym (species AND pineapple (common and scientific name)) did not show an association with the commodity.
Anomala expansa	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). DAFF (2019b), an Australian IRA for decrowned pineapples from Taiwan concluded that the species only attacks roots. Therefore, it is not considered to be associated with the commodity.
Anomala nitidula	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). A search on Scholar and the web (species AND pineapple (common and scientific name) did not indicate an association with the commodity.
Anomala sp.	Assumed to be covered by species assessments.

Anomala xanthopleura	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). Not in exporting markets, appears to be limited to Japan (GBIF.org 2021). Furthermore no clear association was found with decrowned pineapples through a web and literature research, as members of the genus feed on plant roots.
Anomocaulus fulvovestitus	There are only very few published papers available on this pest and it remains unclear which plant parts are attacked. Based on the information available it appears to be a relatively large beetle that should be removed during harvesting and post-harvest processes. No evidence of internal feeding was found. While the beetle is noted as a serious but rare pest of pineapple there is not enough other information to do a PRA.
Anoplognathus porosus	The species is not listed in NZOR (2021) or ONZPR (2021). The species is reported from roots (Joy et al. 2012) and is not considered to be associated with the commodity.
Anoplolepis gracilipes	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be ~~a~~ foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Antitrogus mussoni	The species is not listed in NZOR (2021) or ONZPR (2021). The species is reported from roots (Joy et al. 2012) and is not considered to be associated with the commodity.
Antonina graminis	There is one reference associating this species with pineapple and the association is related to roots (Riherd 1950).
Aonidiella aurantii	This species is present in New Zealand (PPIN 2021; NZOR 2021) and has been collected from multiple hosts. It is non-regulated (ONZPR 2021). No evidence was found that the species acts as a disease vector.
Aphis gossypii	The species is not associated with the commodity. There is one reference indicating a possible association which is (Carter 1937). The study tested whether the aphid transmitted disease to pineapple plants, but does not mention that pineapple is a natural host of the aphid. No further evidence of the aphid associated with pineapple was found (Google/Google Scholar: Aphis gossypii pineapple/Ananas cosmosus).
Apis mellifera	It is present in New Zealand (NZOR 2021), but not listed in ONZPR (2021). Furthermore, it is not considered to be associated with the commodity.
Apis sp.	Assumed to be covered by species assessments. Members of this genus are not considered to be associated with the commodity.
Araecerus fasciculatus	While this species is listed as present in NZOR (2021), it should not be considered as present in New Zealand (PPIN 2021) and is regulated (ONZPR 2021). Known to lay eggs and complete lifecycle within citrus fruits and internal and external feeding in fruits is reported (Yokoyama et al. 2003). However, it is not reported feeding or developing on or within pineapple fruits and is therefore not considered to be associated with the commodity.
Araecerus fasciculatus	Although this species is listed as present in NZOR (2021), it should not be considered as present (PPIN 2021) and is regulated (ONZPR 2021). The species is known to lay eggs and complete its lifecycle within citrus fruits. However, no evidence was found of the species being associated with pineapple fruit (Google/Google Scholar: Araecerus fasciculatus pineapple/Ananas cosmosus).

Aspidiotus destructor	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species being associated with the commodity (Google/Google Scholar: Aspidiotus destructor pineapple/Ananas comosus).
Aspidiotus excisus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Aspidiotus excisus pineapple/Ananas comosus). There is an interception in the AssureQuality (2021) database on pineapple, however, when checked in QuanCargo the host was actually banana.
Aspidiotus nerii	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). It is not known to be a vector.
Aspidiotus sp.	Assumed to be covered by species assessments.
Assara albicostalis	The species is not listed in NZOR (2021) and the regulatory status is 'unassessed' ONZPR (2021). There is one report of this species on pineapple but there are no specifics about whether it is associated with the fruit (DAFF 2012a). The larvae is known to bore into pods and feed internally in other fruits (DSP 2016). Given a lack of information, and no association with the commodity being determined the species was not assessed further.
Atherigona orientalis	This species has been found associated with overripe fruits, which is not covered by the commodity description. The species is regulated, distributed in all exporting markets and appears to have some association with pineapples (amongst other fruit) (Sakimura and Linford 1940; CABI 2021). CABI (2021) includes *Ananas* in host list referring to a 1992 report, which is not accessible and this report indicates the association to "rotting pineapple". Sakimura and Linford (1940) report collection of the species on 1. ripe pineapple fruit; chiefly fruits that were picked and placed in groups on pineapple plants and examined repeatedly during one week. Before collections were terminated many of the fruits had begun to spoil and almost all were somewhat smeared with juice and 2. Net collections over decomposing plant waste and fallow soil 3. Net collection in fruiting pineapple fields during day and night, 4. from pineapple fruits picked after decay had begun. Moreover, there may be questions around the suitability of New Zealand for establishement as discussed by Cahill (1992) (they concluded it would not establish).
Atherigona sp.	Assumed to be covered species assessments.
Atractomorpha sinensis	The species is not listed in NZOR (2021) and is regulated in ONZPR (2021). Adults feed on a wide variety of cultivated plants of which pineapple is one of them. This grasshopper feeds on foliage, buds and tender stems. The eggs are laid in the soil. It is not known to attack the fruit and if so, adults and nymphs are likely to be disturbed and not remain on fruit during harvest (Martin Kessing and Mau 1992).
Atrichopogon sp.	Biting midges - No evidence found of specific association to *Ananas comosus* (Google/Google Scholar: Atrichopogon pineapple/Ananas comosus). There has been one interception of a live adult male associated to pineapple from the Philippines at the New Zealand border. However, no documented association with the commodity was found.
Aulacaspis maculata	Not known to be associated with pineapple fruit. *Ananas* sp. is listed as a host in Scalenet. However, no evidence of an association with pineapple was found in other databases.

Aulacorthum solani	The species is present in New Zealand (NZOR 2021), but is regulated (ONZPR 2021). The species can vector some viruses. However, no evidence was found of it associated with pineapple (Google/Google Scholar: Aulacorthum solani pineapple/Ananas comosus). Therefore, no further assessment required.
Aulacoscelis melanocera	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). No association with pineapples found through web searches (Aulacoscelis melanocera pineapple/Ananas comosus).
Bactrocera carambolae	No scientific literature mentioning association between pineapple fruit and this fruit fly species could be found (Google/Google Scholar: Bactrocera carambolae pineapple/Ananas comosus). The scientific evidence strongly suggests that 'Smooth Cayenne' varieties of pineapples are a 'non-host' of fruit flies including *Bactrocera dorsalis*, *B. cucurbitae* and *Ceratitis capitata*. Furthermore, there is evidence that show that varieties of pineapples with 50% 'Smooth Cayenne' parental lineage are also a 'non-host' for fruit flies of economic importance. This is attributed that these varieties may have some chemical attributes that either preclude attack or cause mortality to the eggs or larvae of these fruit flies (Armstrong and Jang 1997). The only reference found and cited by CABI (2021) in support of host status - Sauers-Muller 2005 - refers to a table within the original article that mentions one pupa of unspecified fruitfly species in one pineapple in Suriname.
Bactrocera cucurbitae	No evidence of association to commodity was found. The scientific evidence strongly suggests that 'Smooth Cayenne' varieties of pineapples are a 'non-host' of fruit flies including *Bactrocera dorsalis*, *B. cucurbitae* and *Ceratitis capitata*. Furthermore, there is evidence that show that varieties of pineapples with 50% 'Smooth Cayenne' parental lineage are also a 'non-host' for fruit flies of economic importance. This is attributed that these varieties may have some chemical attributes that either preclude attack or cause mortality to the eggs or larvae of these fruit flies (Armstrong and Jang 1997).
Bactrocera facialis	No evidence was found that pineapple is a host of the species. *Ananas* reported as dubious host by White and Elson-Harris (1992), but is not mentioned as a host in CABI (2021). During the Regional Fruit Fly Projects in the Pacific survey, no fruit flies ever emerged from the 143 ripe pineapples sampled in the Pacific Islands (Leblanc et al. 2012).
Bactrocera kirki	No evidence of association to commodity was found. More generally, highly dubious host status for *Ananas comosus*, from single source. No fruit flies ever emerged from the 143 ripe pineapples sampled in the Pacific Islands during the Regional Fruit Fly Projects in the Pacific survey surveys (Leblanc et al 2012). CABI (2021) included *Ananas comosus* in Host Plants and Other Plants Affected list, and this information is derived from White and Elson-Harris (1992) (other host plants associations refer to Leblanc et al. (2013), not including *A. comosus*). White and Elson-Harris 1992 reports association referring to Litsinger et al. (1991). Litsinger et al. (1991) reports association between *Ananas comosus* and *B. kirki* in Tonga, but this is considered a highly dubious host record (Leblanc et al 2012).
Bactrocera sp.	Assumed to be covered by species assessments.

Bactrocera xanthodes	Reported that "[Bactrocera xanthodes] demonstrated not to breed on damaged pineapple exposed to gravid females in the laboratory" but no data given (Leblanc et al 2013). Drew et al. (1997) also noted that a record from pineapple derived from 1905 data which has never been replicated. No fruit flies ever emerged from the 143 ripe pineapples sampled in the Pacific Islands during the Pacific Islands during the Regional Fruit Fly surveys (Leblanc et al. 2012). Given a lack of evidence for commodity association, this species is not assessed further.
Baris sp.	*Baris* sp. that have been reported damaging pineapples do not seem to be reported from the exporting markets. No information available when doing detailed searches on the distribution using "Baris" and the various markets, "Baris" AND distribution and "Baris" and pineapple as search terms. However, this genus was listed as an actionable regulated pest on the old IHS for pineapples from Ecuador. The only evidence we came across that species from this genus are associated with pineapple and transmit gummosis are associated with Venezuela. DAFF (2019b) lists *Baris* spp. as a significant pest of decrowned pineapple. However, no particular detail is given and the information was not very well traceable and somewhat outdated.
Batrachedra comosae	The species is not listed in NZOR (2021) or ONZPR (2021). The are no records of this species in any of the exporting markets; the only records available are in Puerto Rico (Google/Google Scholar Batrachedra comosae). The larvae of this moth causes gummosis that affects the lower portion of the fruit, and subsequently the quality of the juice (Montalvo-Zapata et al. 1989).
Beckerina sp.	One live adult was intercepted on pineapple from the Philippines (AssureQuality 2021). However, no other evidence found of an association to *Ananas comosus* (Google/Google Scholar: Beckerina pineapple/Ananas comosus).
Bemisia tabaci	The species is present in New Zealand (NZOR 2021), but is regulated (ONZPR 2021). Some biotypes are present in New Zealand. However, the species is not known to be associated with fruit and therefore does not require further assessment.
Berecynthus hastator	Stink bugs are likely to fly away or fall off fruit during harvesting. They are generally large enough to be visible to the naked eye and are likely to be managed by commercial production methods. For this reason they have been excluded from further assessment.
Blapstinus sp.	A web search showed that the genus is associated with roots.
Blatella germanica	The species is present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021).
Blepyrus schwarzi	The species is not listed in NZOR (2021) or ONZPR (2021). This is a parasitic wasp (Pacheco da Silva et al. 2021). Its main hosts are *Dysmicoccus brevipes*, *D. neobrevipes* (Noyes 2019), and neither is present in New Zealand (PPIN 2021; NZOR 2021). In the absence of its hosts it is assumed that the wasp would not be able to establish in New Zealand and for this reason it will not be considered further.
Blissus sp.	Members of the genus are not known to be associated with pineapple (Google/Google Scholar: Blissus pineapple/Ananas comosus).
Blitopertha orientalis	The species is not listed in NZOR (2021) or ONZPR (2021). The species was found associated with roots of plants (Yokoyama et al. 2003) and is therefore not considered to be associated with the commodity.

Brachypeplus basalis	The species not listed in NZOR (2021), but is regulated (ONZPR 2021). It appears to be associated with pollen stored in beehives (Sagili et al. 2016), no documented association with pineapples was found (Google/Google Scholar: Brachypeplus basalis pineapple/Ananas comosus).
Bradysia sp.	No evidence found on association to the commodity. Included in screening for four interception records of live adults (known for two records) associated to pineapple (three from the Philippines, one from Ecuador). *Bradysia ocellaris* larvae were found feeding on decaying sugar cane, pineapple, wheat seedlings and many cultivated crops. Females are monogenic or more often digenic in laboratory rearing. Larvae were found feeding on the roots and/or stems of campanula, carnations, corn, cucumbers, geraniums, lettuce, nasturtiums, young orchid plants, peas, pineapple, poinsettia, potato tubers, primula seedlings, sugar cane, wheat, and in the soil around cactus plants (Steffan 1974). No evidence of any specific species feeding on pineapple fruit.
Cadra cautella	The moth is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). It is not known to be a vector of any disease.
Calandra obscura	The species not listed in NZOR (2021) or ONZPR (2021). Sugarcane appears to be the main host of the species and is associated with the leaves and stalks (Napompeth et al. 1972). No documented association with pineapple was found (Google/Google Scholar: Calandra obsca pineapple/Ananas comosus).
Camponotus chloroticus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Camponotus sexguttatus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Capitophorus elaeagni	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). Not known to be a vector.
Cardiocondyla emeryi	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Cardiocondyla sp.	Assumed to be covered by species assessments.
Cardiocondyla wroughtoni	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Cardiophorus sp.	Only genus name available, very little indicative information available that this is a species associated with pineapple. Search terms included genus name and pineapple and Ananas comosus.
Carpophilus dimidiatus	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Carpophilus gaveni	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Carpophilus hemipterus	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Carpophilus maculatus	No evidence found of association with pineapple fruits (Google/Google Scholar: Carpophilus maculatus pineapple/Ananas cosmosus).

Carpophilus marginellus	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Carpophilus sp.	Assumed to be covered by species assessments.
Castnia invaria	The species is not listed in ONZPR (2021) or NZOR (2021). Although associated with pineapples (da Silva Jorge et al. 2021), the moth is not reported to be in any of the exporting markets (Google/Google Scholar Castnia invaria).
Castnia licus	The synonym *Telchin licus* assessed as not requiring further assessment.
Castnia penelope	The species is not listed in ONZPR (2021) or NZOR (2021). The larvae attack the stem and leaves of the young pineapple plant, killing it before it is able to produce flower. Its reported only in Brazil. It it not known if it is present in any of the exporting markets (de Melo and L; 2012).
Catolethrus sp.	*Catolethrus longulus* reported on pineapples in the USA in 1944, but no other association with pineapples found, therefore it is considered that there is insufficient information to require further assessment.
Celatoblatta sp.	Species of this cockroach genus are present in New Zealand, Australia and New Caledonia and no direct association was found with pineapples (Google/Google Scholar: Celatoblatta pineapple/Ananas comosus).
Ceratitis capitata	Evidence against the host status for *Ananas comosus* varieties (Armstrong and Jang 1997). *Ananas comosus* is of "unknown importance" as host (Thomas et al. 2001). White and Elson-Harris 1992 reported that "a recent datasheet (Doss 1989) also listed pineapple as a host, without any indication of the source of the data; however, it has been shown to be an unsuitable host (Armstrong et al. 1979)." Armstrong et al. demonstrated resistance of multiple pineapple varieties (Armstrong and Vargas 1982). The scientific evidence strongly suggests that 'Smooth Cayenne' varieties of pineapples are a 'non-host' of fruit flies including *Bactrocera dorsalis*, *B. cucurbitae* and *C. capitata*. Furthermore, there is evidence that show that varieties of pineapples with 50% 'Smooth Cayenne' parental lineage are also a 'non-host' for fruit flies of economic importance. This is attributed that these varieties may have some chemical attributes that either preclude attack or cause mortality to the eggs or larvae of these fruit flies (Armstrong and Jang 1997). Commercial pineapples of 50 per cent or more Smooth Cayenne genotype are now recognised as not being a host for *C. capitata* (DAFF 2002)(AUS IRA 2002).
Cerchysiella abilis	The species is not listed in NZOR (2021) or ONZPR (2021). This is a parasitic wasp. Host are beetles in the Genus *Carpophilus* -there are several species present in New Zealand (PPIN 2022) including the main host *C. Hemipterus* (NHM Universal Chalcidoidea Database, 2022). No *Carpophilus* spp. listed as native in PPIN or in NZOR. Klimaszewski and Watt (1997) list them as field and stored product pest. As such, it is unlikely to cause any significant impact in New Zealand.
Cerchysiella utilis	The species is not listed in NZOR (2021) or ONZPR (2021). This is a parasitic wasp. Host is beetles in the Genus *Carpophilus* (several species present in New Zealand (PPIN 2022) including the main host *C. Hemipterus* (Noyes 2019) and the pineapple sap beetle *Urophorus humeralis* (present in New Zealand PPIN (2022); non-Regulated (ONZPR)). No *Carpophilus* spp. listed as native in PPIN or in NZOR. Klimaszewski and Watt (1997) list them as field and stored product pest. As such, it is unlikely to cause any significant impact in New Zealand.

Ceroplastes floridensis	The species is not listed in NZOR (2021) and is regulated in ONZPR (2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Ceroplastes floridensis pineapple/Ananas comosus; Scalenet).
Cerotoma ruficornis	The species is not present in New Zealand (NZOR 2021) and is regulated (ONZPR 2021). No detail easily available around the association with pineapples (Google/Google Scholar: Cerotoma ruficornis pineapple/Ananas comosus).
Chaetocnema sp.	Literature/web search did not find an association with pineapple (Google/Google Scholar: Chaetocnema pineapple/Ananas comosus).
Chaetosiphon fragaefolii	The species is present in New Zealand (NZOR 2021) but is regulated (ONZPR 2021). It can vector some viruses, but since the species is not known to be associated with pineapple (Google/Google Scholar: Chaetosiphon fragaefolii pineapple/Ananas comosus), no further assessment required.
Chalcodermus sp.	No association of the genus with the commodity was found (Google/Google scholar search: Chalcodermus pineapple/Ananas comosus).
Chelinidea sp.	One species of the genus was found to be associated with pineapple leaves, but not with the fruit. Therefore, not associated with the commodity.
Chelisoches morio	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Chionaspis sp.	*Chionaspis* sp. was recorded on pineapple at the border (from Florida) in 1916. Evidence of *Chionaspis minor* associated with pineapple (DAFF 2012), this appears to be a synonym of *Pinnaspis strachani*, which is assessed separately.
Cholus sp.	Assumed to be covered by species assessments.
Cholus spinipes	The species is not listed in NZOR (2021) or ONZPR (2021). It is associated with pineapple and found native in Grenada (Frank 1999). However, no other markets are listed as having the pest and therefore, the species is not in exporting markets.
Cholus zonatus	The species is present in New Zealand (NZOR 2021) and is not listed in ONZPR (2021). Furthermore, this is a large beetle that would be removed by commercial production processes and is not reported the exporting markets (DAFF 2001).
Chrysomphalus ficus	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: Chrysomphalus ficus pineapple/Ananas comosus; Scalenet).
Clania formosicola	This species is not listed in NZOR (2021), but is regulated (ONZPR 2021). No evidence found indicate it is associated with pineapple.
Clania kondonis	There was no association with pineapple found.
Coboldia fuscipes	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021). The larvae feed in mushroom mycelium and/or on decaying fungal, animal or plant tissue (Choi et al. 2000).
Coccidencyrtus ochraceipes	The species is not listed in NZOR (2021) or ONZPR (2021). This is a parasitic wasp. Host are *Diaspis boisduvalii* and *D. Bromeliae*. *Diaspis boisduvalii* is present/ exotic in New Zealand (NZOR 2022; PPIN 2022). *Diaspis bromeliae* is not listed as present in New Zealand (NZOR 2021). No evidence found that the parasitic wasp can attack native insect species. As such, it is unlikely to cause any significant impact in New Zealand.

Coccinella sp.	Assumed to be covered by species assessments.
Coccinella transversalis	This species is not listed in NZOR (2021), but is regulated (ONZPR 2021). This is a ladybird species that is not biologically associated with pineapples (Google/Google Scholar: Coccinella transversalis pineapple/Ananas comosus). There is an interception of this species recorded at the New Zealand border, which is likely to have been due to the ladybird's prey being on the fruit.
Coccinellidae	Ladybird family. Assumed to be covered by species assessments.
Coccotrypes sp.	Beetles of this genus are regulated, but no evidence was found of an association with pineapples (Google/Google Scholar: Coccotrypes sp. pineapple/Ananas comosus) - they are sometimes listed on some documents about pineapples, but not in direct association.
Coccus formicarii	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Coccus formicarii pineapple/Ananas comosus; Scalenet).
Coccus hesperidum	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Coccus viridis	No reference found reporting the species associated with pineapple fruit and therefore is not considered associated with the commodity.
Colaspis sp.	No association with pineapple found (Google/Google Scholar: Colaspis pineapple/Ananas comosus).
Colobopsis conithorax	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Colopterus sp.	Members of this genus are sap feeding beetles. No clear association with pineapple was found when the genus name was searched in combination with pineapple (Google/Google Scholar: Colopterus pineapple/Ananas comosus).
Conocephalus affinis	The species is not listed in NZOR (2021) and is regulated in ONZPR (2021). Occurs in areas with tall grass, including in cultivated lands. This katydid is both diurnal and nocturnal and poses no threat to crops in Madagascar (Van Itterbeeck et al. 2019). There is a report of this species on the flower and fruit of pineapple when intercepted in United States in 1979 (APHIS 1979). No other evidence of an association with pineapple was found (Google/Google Scholar Conocephalus affinis pineapple). Furthermore, the species is likely to be disrupted by commercial production procedures.
Conocephalus saltator	These grasshoppers can cause damage to the fruitlet but have not been reported to be present eating the mature fruit ready for export. These grasshoppers mainly feed on the leaves, gnawing on the tips, but there are records of the insect feeding upon the softer parts of the pineapple flowers and in some cases even gnawing the harder bracts covering the fruitlets. Females have been observed laying their eggs on the fruits. At the time of flowering the pineapple is small and therefore at this stage the female grasshoppers find it very convenient to shove its ovipositor into the heart of tender flowers. Wherever the ovipositor ruptures the floor of the calyx cavity, fungi can gain entrance. In a few instances, the ovipositor had gone so deeply as to puncture the stem, leaving the egg deeply embedded in the solid tissue. Therefore, not considered to be associated with the commodity.

Cotinis mutabilis	The species is listed as occasionally associated with pineapple fruits and the only reference to it causing damage are adult damaging fruits with their clypeal horn and spined legs. The species does not reproduce on the fruit. No evidence was found of other lifestages being associated with the fruits. Given that the adults are large commercail processes, such as washing, brushing a grading, are concluded to be sufficient to remove any associated beetles.
Crematogaster sp.	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Cryptamorpha desjardinsi	Species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Cryptoblabes sp.	Evidence of one species from this genus being associated with pineapple (*Cryptoblabes gnidiella*) was found. However, this comes from one report from a US interception record prior to 2000 reported in USDA (2019). The association was not confirmed in the literature and no further evidence of species in this genus being associated with pineapples was found (Google/Google Scholar: Cryptoblabes pineapple).
Cryptolaemus montrouzieri	Species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Cryptostigma sp.	The genus is not known to be associated with pineapple (Google/Google Scholar: Cryptostigma pineapple/Ananas comosus).
Cryptothelea gloverii	The species is not listed in NZOR (2021) or ONZPR (2021).This species doesn't seem to be associated with pineapple. In the literature it is associated with 'pineapple guava' (feijoa) and 'pineapple orange' (an orange variety) (Villanueva 2002; Google/Google Scholar: Cryptothelea gloverii pineapple).
Ctenopseustis obliquana	Present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Cyclocephala sp.	The genus does not appear to be associated with pineapple fruit. Based on a Cuban publication, although the genus seems to be associated with pineapple, they were talking about the possibility to control it through nematodes, this does line up with general available information referring to this genera as 'white grubs' and mostly root feeding (Akol et al. 2011).
Cymus melanotylus	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Cymus melanotylus pineapple/Ananas comosus).
Dactylosternum abdominale	This species is present in New Zealand (NZOR 2021) but is regulated (ONZPR 2021). It is not known that this species can transmit any disease.
Darna trima	The species is not known to be present in New Zealand (NZOR 2021). The regulatory status of the species is recorded as 'not assessed' in ONZPR (2021). The literature shows that this species mainly damages the leaves of pineapple and the association to the pineapple fruit has been inferred from other plant species (USDA 2019). Given that the species damages leaves, and no association with the fruit was determined, no further assessment required.
Dermaptera	This order is assumed to be covered by species assessment.
Diadegma sp.	This is a genus of parasitic wasps. Members of this genus are present in New Zealand. Because the wasp parasitising insect larvae associated with pineapple has not been identified to species, its host range and environmental tolerances are unknown and it cannot be determined whether the wasp is

	already present in New Zealand. For this reason the wasp will not be assessed further.
Diapriidae	This is an insect family. Assumed to be covered by species assessments.
Diaspididae	This is an insect family. Assumed to be covered by species assessments.
Diaspis boisduvalii	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Diaspis sp.	Assumed to be covered by species assessments.
Dinoderus minutus	The species is listed as present (NZOR 2021) and has a regulatory status of 'under assessment' in ONZPR (2021). However, it appears that the species is not present in New Zealand, but rather has been intercepted at the border. No evidence was found of the species being associated with pineapple (Google/Google Scholar: Dinoderus minutus pineapple). All references checked indicate that this species is associated with bamboo and occasionally stored products (CABI 2021).
Diphthera festiva	The species is not listed in ONZPR (2021) or NZOR (2021). The larvae of this moth feeds mainly on plants in the families Sterculiaceae, Fabaceae and Malvaceae; the family Bromeliaceae is not mentioned as a host. The larvae feed only on the leaves on early growth stages of the host plant (Dunford and Barbara 2021). Therefore, the species is not considered associated with the commodity
Diplazon laetatorius	This species is present in New Zealand (NZOR 2021) and is not listed in ONZPR (2021).
Discocephalessa humilis	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Discocephalessa humilis pineapple/Ananas comosus).
Disonycha sp.	A generic and association with pineapple search in CABI, the web, Google scholar did not found evidence that decrowned pineapple would be likely to harbour species from this genus.
Dohrniphora sp.	No evidence found of an association to pineapple (Google/Google Scholar: Dohrniphora pineapple/Ananas comosus).
Dolichoderinae	This is a family of ants. Assumed to be covered by species assessments.
Dolichoderus sp.	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Draeculacephala clypeata	The species is not listed in NZOR (2021) or ONZPR (2021). There is one report from the leaves of pineapple (Frank 2014), however, this was unconfirmed. No other records of the species being associated with this host (Google/Google Scholar: Discocephala clypeata pineapple/Ananas comosus). Given that this species is a leafhopper, it is unlikely to be associated, and remain associated with the commodity.
Draeculacephala soluta	The species is not listed in NZOR (2021) or ONZPR (2021). There is one report from the leaves of pineapple (Frank 2014), however, this was unconfirmed. No other records of the species being associated with this host (Google/Google Scholar: Discocephala soluta pineapple/Ananas comosus). Given that this species is a leafhopper, it is unlikely to be associated, and remain associated with the commodity.

Drosophila ananassae	Aside from CABI, EPPO, GBIF global distribution info, a web search was conducted to identify additional countries (first three pages of google and google scholar). No evidence of association with the commodity found. *Drosophila ananassae* is reported on rotting fruit (Brncic 1987). Reported as being associated with pineapple fruit by Yunus and Ho (1980). However, the condition of the fruit was not described. It was considered an improbable association with importation of pineapple from Malaysia to Australia, as *Drosophila* species deposit their eggs on or near the surface of rotting or fermenting (over-ripe) fruit and vegetable matter (DAFF 2012). Larvae of most *Drosophila* species are also associated with decaying fruit and fungi (DAFF 2012).
Drosophila busckii	Present in the New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Drosophila immigrans	Present in the New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Drosophila melanogaster	Present in the New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Dryadaula terpsichorella	The species is present in New Zealand (NZOR 2021), and is not listed in ONZPR (2021). The moth is indigenous of the Kermadec Islands, New Zealand and is not reported from the mainland (NZOR 2021). It is not known to be a vector of any diseases. The larvae is found in dead leaves of banana and pineapple and no evidence was found of it being associated with fruits.
Dynastor darius	The species is not listed in NZOR (2021) or ONZPR (2021). Larvae feeds on the leaves of bromeliads (Urich 1991). There are no records of the larvae feeding on the fruit including pineapple fruits (Google/Google Scholar: Dynastor darius/pineapple).
Dynastor macrosiris	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). It feeds only on the leaves of Bromeliads, being its main host a large bromeliad species *Aechmea nudicaulis* and pineapple leaves a secondary host (Urich and Emmel 1991). No evidence was found of the species associated with pineapple fruits (Google/Google Scholar Dynastor macrosiris pineapple).
Dynastor napoleon	The species is not listed in NZOR (2021) or ONZPR (2021). It feeds only on the leaves of Bromeliads and no evidence was found of the species associated with pineapple fruits (Emmel 1991; Penz 1999) (Google/Google Scholar Dynastor napoleon pineapple).
Dysdercus sp.	No evidence was found of members of the genus associated with pineapple (Google/Google Scholar: Dysdercus pineapple/Ananas comosus).
Dysmicoccus bispinosus	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Discocephala soluta pineapple/Ananas comosus; Scalenet).
Dysmicoccus boninsis	No evidence of commodity association. No reference to the species being assocaited with pineapple was found (Google/Google Scholar: Dysmicoccus boninsis pineapple/Ananas cosmosus), and was therefore not assessed further.
Dysmicoccus grassii	Some reports indicate its host association with pineapple (García Morales et al. 2016; Sipes and Wang 2017; DAFF 2019a). There is no original reference in DAFF (2019) and it is a group assessment on a few mealybug, so the information is not specific to *D. grassii*. Original references from García Morales et al. (2016) do not specify plant part. Sipes and Wang mention that the two most important mealybugs found on pineapple are *D. brevipes* and *D. grassii*, the pink and grey mealybugs, respecitvely. Grey mealybug is the

	common name of another species, so we consider this record is in error, and there is no original reference cited.
Dysmicoccus mackenziei	No evidence was found of the species associated with the commodity. The original references from García Morales et al. (2016) were checked and the affected plant part of pineapple is not specified in the references. No reference to the species associated with pineapple fruit was found via literature searches (Google/Google Scholar: Dysmicoccus mackenziei pineapple/Ananas cosmosus).
Dysmicoccus sp.	Assumed to be covered by species assessments.
Dysmicoccus texensis	See *Dysmicoccus bispinosus* (preffered name).
Ectopsocus sp.	Some species in this genus are reported present in New Zealand (NZOR 2021). No evidence was found in literature that any species of this genus is associated with pineapple fruit (Google/Google Scholar: Ectopsocus pineapple). Members of the genus are book/bark lice and are unlikely to be associated with fresh produce.
Egidemia anceps	The species is not listed in NZOR (2021) or ONZPR (2021). There is one interception record of the species on pineapple. Given that this species is a leafhopper, it is unlikely to be associated with, and remain associated with the commodity after commercial production process.
Elachiptera sp.	No evidence found of an association to pineapple (Google/Google Scholar: Elachiptera pineapple/Ananas comosus). There has been one interception of a live adult male associated to pineapple from the Philippines at the New Zealand border. However, no documented association with the commodity was found.
Elasmopalpus lignosellus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Larvae are in the soil moving to the host to feed on constructed tunnels at the base of the stem. Recognized pathways with possible risks of entry are fruit and vegetables (stems and pods). There are reports of an interception of this species in the USA on pineapple but there are no details. No evidence was found of the species being associated with the commodity (Google/Google scholar Elasmopalpus lignosellus pineapple) (Solis 2006; DEFRA 2021).
Elaunon bipartitus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of an association with pineapple (Google/Google Scholar: Elaunon bipartitus pineapple/Ananas comosus). However, there may be some indirect association with scale insects. Such indirect associations are excluded from further assessment.
Epicaerus sp.	This genus does appear on the same documents as some pineapple associated pests, however, we did not come across any actual associations through standard search terms (Google and Google scholar, 'Epicaerus AND pineapple' and 'Epicaerus AND ananas').
Epuraea zealandica	The species is present in New Zealand (NZOR 2021) not recorded in ONZPR (2021).

Erechthias flavistriata	The species is present in New Zealand (NZOR 2021), and is not listed in ONZPR (2021). Although reported as present in New Zealand, it has only been reported from the Kermadec Islands and not the mainland. However, no evidence was found of the species being associated with pineapple fruit (Google/Google Scholar, 'Erechthias flavistriata' and pineapple).
Erechthias minuscula	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Larvae are scavengers of dead plant materials, like dead trunks, stems, leaves, fruits and seed pods (Robinson 1993). Therefore, the species is not considered to be associated with the commodity.
Euborellia annulipes	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Euborellia sp.	Assumed to be covered by species assessments.
Eudocima phalonia	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). The larvae only feed on leaves and the adult oviposits on leaves. Adults, with their well developed proboscis puncture the fruit and feed on its juices. Fruits become soft, and mushy and lose their market value (Kueh-Jui-Heng 2012). However, this is external feeding behaviours. Even though, not depositing or burrowing inside the fruit and would therefore be removed through commercial processes.
Euetheola bidentata	The species is not listed in NZOR (2021) or ONZPR (2021). DAFF (2019b) found that the species feeds on leaves and stems and is therefore not associated with the commodity.
Euproctis lutea	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Eggs are deposited on leaves and larvae feed on leaves. The main host is reported to be Barringtonia acutangula (freshwater mangrove) (DHF 2010). No literature was found that this insect is associated with pineapple (Google/Google Scholar Euproctis lutea pineapple).
Euproctis Taiwana	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Larvae feed on leaves of host (DAFF 2012). No evidence was found of an association with the fruit of pineapple (Google/Google Scholar, 'Euproctis Taiwana' and pineapple/ananas). It infests the flower of pineapple and completes life cycle on flower (Huang and Wang 2016) so it is not associated with the commodity.
Eurychilella sp.	No evidence was found of members of the genus being associated with pineapple (Google and Google Scholar: Eurychilella and pineapple/'Ananas comosus').
Euschistus sp.	Stink bugs are likely to fly away or fall off fruit during harvesting. They are generally large enough to be visible to the naked eye and are likely to be managed by commercial production methods. For this reason they were excluded from further assessment.
Euxesta quadrivittata	Reported as being associated with pineapple fruit by Yunus and Ho (1980), but the condition of the fruit was not described. Sakimura and Linford (1940) report collection of the species on one ripe pineapple fruit; chiefly fruits that were picked and placed in groups on pineapple plants and examined repeatedly during one week. Before collections were terminated many of the fruits had begun to spoil and almost all were somewhat smeared with juice. Two net collections over decomposing plant waste and fallow soil. It was considered an improbable association with importation of pineapple from Malaysia to Australia. No evidence found on association with the commodity.

Exomala orientalis	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). According to the EPPO pest categorisation (EFSA 2020) although pineapple is a major host for the species, it is not associated with the commodity as the larvae are associated with the roots and soil.
Falagria sp.	No evidence was found of the genus being associated with pineapple (Google/Google scholar: 'Falagria pineapple' and 'Ananas comosus').
Fannia sp.	No evidence found of an association to pineapple (Google and Google Scholar: Fannia and pineapple/'Ananas comosus'). There has been one interception of a live adult male associated to pineapple from the Philippines at the New Zealand border. However, no documented association with the commodity was found.
Ferrisia dasylirii	Although a reference was found of the species associated with pineapple plants, only one reference indicates its association with pineapple; no evidence was found of it being associated with pineapple fruit (Google and Google Scholar: 'Ferrisia dasylirii' and pineapple/'Ananas cosmosus') and therfore, is not considered to be associated with the commodity.
Ferrisia sp.	Assumed to be covered by species assessments.
Forcipomyia brevis	The species is not listed in NZOR (2021), but is regulated (ONZPR 2021). This species is a biting midge, called "pineapple midge" - No evidence found on association to pineapple fruit, and it is a pollinator (Google and Google Scholar: 'Forcipomyia brevis' and pineapple).
Forcipomyia sp.	Assumed to be covered by species assessments.
Forficula auricularia	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Formicococcus njalensis	The species is not recorded from New Zealand (NZOR 2021; PPIN 2021). The regulatory status is not assessed (ONZPR 2021). Pineapple is a reported host of the species (García Morales et al. 2016), however the species is currently only reported from Western/Central Africa (García Morales et al. 2016; CABI 2021; EPPO 2021). No evidence was found of the species in any of the exporting markets during Google and Google Scholar searches.
Frankliniella fusca	*Frankliniella fusca* is not reported from New Zealand (NZOR 2021; PPIN 2021). This thrips is associated with pineapple (Petty et al. 2002) and is a vector of viruses (TSWV, INSV, IYSV-weak transmission) that are present in New Zealand. It is reported to vector the bacterium *Pantoea ananatis*, an organism of concern which is not reported from New Zealand. It is a regulated organism (ONZPR 2021). It is not reported from the pineapple exporting markets listed in this IRA and is therefore excluded from further assessment. However, if any exporting markets freedom status for *F. fusca* changes, or other countries are added to the IHS that is current at 2021 then this thrips should be reassessed.
Frankliniella occidentalis	One strain of this species is present in New Zealand, but is mainly restricted to the yellow tree lupin host (Mound et al. 2017). The species is still listed as regulated in ONZPR and may be a vector of several economically important viruses, but the viruses vectored by *F. occidentalis* (other than Tomato Spotted Wilt Virus, TSWV) do not infect pineapple. TSWV is present in New Zealand.
Frankliniella occidentalis	Two distinct strains of this species are reported, the lupin strain and the glasshouse strain. The lupin strain is present in New Zealand- and the species is regulated (ONZPR 2021). No reports found of which strain may be associated with pineapples. Petty et al. (2002) report this species found in the

	floral cavities of pineapples as a minor or occasional pest. In this source it appears that floral cavities refer to the flowering stage, rather than the cavities of floral remnants on the formed fruits, but this is uncertain. No recorded interceptions on pineapples. The virus that *F. occidentalis* may vector are evaluated in a vector analysis in 2018 and it was determined that only *Tomato spotted wilt virus* may infect pineapples (TSWV is already present in New Zealand and there are no issues with differing strains). A more recent report by He et al (2020) states four other viruses that may be vectored by *F. occidentalis* (Tomato yellow ring virus, Parientaria mottle virus, Pelargonium flower break virus, and maize chlorotic mottle virus). None of these additional viruses are reported to infect pineapples.
Frankliniella schultzei	Pineapple is reported as a main host of this species (CDFA 2018). There are no records on interceptions of this species on pineapple fruit entering New Zealand. It is primarily a floral feeder and this feeding may lead to distortion and damage to the fruits. May also feed on fruit crown. Does not appear to feed directly on fruits. Petty et al. (2002) report this species found in the floral cavities of pineapples as a minor or occasional pest. In this source it appears that floral cavities refer to the flowering stage, rather than the cavities of floral remnants on the formed fruits, but this is uncertain. DAFF (2019b), the Australian IRA for pineapples from Taiwan considers that this species for further assessment as it is a vector, although its association with decrowned pienapples is not clear. Given no evidence of a commodity association was found, the species was not assessed further.
Geisha distinctissima	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species being associated with pineapple (Google and Google Scholar: 'Geisha distinctissima' and pineapple/'Ananas comosus').
Genopaschia protomis	The species is not listed in NZOR (2021) or ONZPR (2021). Larvae were reported to be found in the axils of pineapples leaves (Plank 1940). There is a record of an interception in the USA from pineapple coming from Puerto Rico, but no details about the interception is given (Solis 2006). This species does not appear to be associated with the commodity and there is insufficient information for an assessment.
Geococcus coffeae	Not associated with the commodity/pathway, as this mealybug affects roots (García Morales et al. 2016).
Glycyphana quadricolor sinuata	The species is not listed in NZOR (2021) or ONZPR (2021). According to DAFF (2012b), there is only one reference from 1980 that reported this pest on flowers and fruits. It may also feed on overripe fruits. DAFF (2012) concluded that the species did not require further assessment. No association with decrowned pineapple was found (Google and Google Scholar: Glycyphana quadricolor sinuata pineapple).
Glyphidocera sp.	There is not much information of *Glyphidocera* species, except one, *Glyphidocera juniperella* (Mizel and Schiffhauer 1987). The larvae of this species feed on stems causing girdling on young plant stems. No information about association with pineapple plant or fruit was found for any species (Google and Google Scholar: Glyphidocera pineapple).
Gryllodes sigillatus	The species is not listed in NZOR (2021) and is non-regulated (ONZPR 2021). A single specimen was detected in January 2007 in New Zealand and a biosecurity response ensued, no other individuals were detected. It is known as an unpredictable hitchhiker in vessels. Another detection in 2020 in Tauranga in a container yard ensued a response for eradication (McNeill et al 2009; MPI. 2020). There is a report of an interception of this species on

	pineapples (Townsend 1984), however in the literature there was no record found of this insect eating, or laying eggs on the fruit (Google and Google Scholar: Gryllodes sigillatus pineapple). Given that no association with the commodity was determined, the species was not assessed further.
Gryllus bimaculatus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No information was found about this insects associated with pineapple using the keywords in Google and Google Scholar "Gryllus bimaculatus AND Pineapple". This insect attacks seedlings and is a major pest in wheat and crucifers in Pakistan. Feeds on living and dead plant parts (Wagner 2022). It is reported to be present in New Zealand in GBIF.org (2021) but there is no record in NZOR (2021).
Gymnonerius fuscus	The species is not listed in NZOR (2021), but is regulated (ONZPR 2021). Found in exporting market (e.g. Malaysia). Yunus (1980) have reported this species on pineapple fruit. However, no further records have been found to show *G. fuscus* as a pest of on pineapple or other crops. Larvae of this family are saprophagous and feed on decaying plant material (Oosterbroek 1998; Zumbado 2006). Identified as not being a quarantine pest (DAFF 2002). Potential for establishment and spread was considered not feasible.
Gymnonerius sp.	Assumed to be covered by species assessments.
Hadrosomus teapensis	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found of it being associated with pineapple (Google and Google Scholar: Hadrosomus teapensis pineapple/'Ananas comosus').
Halmus chalybeus	The species is present in New Zealand (NZOR 2021). The regulatory status is 'not assessed' in ONZPR.
Hambletonia pseudococcina	The species is not listed in NZOR (2021) or ONZPR (2021). This is a parasitic wasp (CABI 2021). Its main hosts are *Dysmicoccus brevipes*, *Planococcoides njalensis* and *Pseudococcus brevipes* (Noyes 2019). None of which are listed as present in New Zealand (PPIN 2022, NZOR 2022). In the absence of its host it is assumed that the wasp would not be able to establish in New Zealand and for this reason it will not be considered further.
Haplothrips gowdeyi	Halothrips gowdeyi is not listed in New Zealand (NZOR 2021) and is regulated (ONZPR 2021). This species is reported associated with pineapple plantations in Hawaii, but as it is a flower feeder, it appears unlikely that it would be specifically associated with pineapple fruit (Rohrbach and Johnson 2003; Mound et al. 2017).
Hemiberlesia rapax	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). Has been associated with *Fusarium coccophilum* which is present (NZFungi 2021) and non-regulated (ONZPR 2021).
Hemiptera	This is an order of insects. Assumed to be covered by species assessments.
Hercinothrips femoralis	*Hercinothrips femoralis* has been reported present in New Zealand (PPIN 2021) and is listed as non-regulated on ONZPR (2021). However, the species is not listed in NZOR. Based on the PPIN report, and it’s non-regulated status, no further assessment required.
Heteronychus arator	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).

Holopothrips ananasi	*Holopothrips ananasi* is not reported from NZ (NZOR 2021; PPIN 2021). It was historically recorded on the pest list for Ecuador but this is now thought to be an error. No record can be found of this thrips in Ecuador or any of the other markets currently (2021) under consideration for exporting pineapple to New Zealand. As such it is excluded from further assessment. Should the country freedom status change or countries where this thrips is present be added to the IHS then *H. ananasi* will need to be reassessed.
Homalodisca ichthyocephala	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: 'Homalodisca ichthyocephala' and pineapple/'Ananas comosus').
Horistonotus sp.	No literature associations with pineapples was found (Google/Google Scholar: Horistonotus and pineapple/'Ananas comosus'). The results suggest that members of the genus are more associated with cotton.
Hortensia similis	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: 'Hortensia similis' and pineapple/'Ananas comosus').
Hydrellia sp.	Assumed to be covered by species assessments.
Hydrellia tritici	Present in the New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Hymenoptera	It is an order of insects. Assumed to be covered by species assessments.
Hyperodes sp.	No literature associations with pineapples was found (Google/Google Scholar: Hyperodes and pineapple/'Ananas comosus'). Given that no association with the commodity was found, was not assessed further.
Hypothenemus sp.	This genus does appear on the same documents as some pineapple associated pests, however, no evidence was found of an actual association with pineapple (Google/Google Scholar: Hypothenemus pineapple). Most literature is dedicated to the coffee berry borer. However, an old reference that is not accessible appears to link this genus under the synonym Stephanoderes to pineapple fruit (Yunus 1980). Further original references were not found with standard terms.
Icerya aegyptiaca	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: 'Icerya aegyptiaca' and pineapple/'Ananas comosus').
Icerya seychellarum	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: 'Icerya seychellarum' and pineapple/Ananas comosus).
Ischyja manlia	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). The larvae feeds on leaves and the adult is a fruit piercing moth (DAFF 2004; Ngampongsai 2005). It will damage the fruit to suck the juices, but it will not deposit eggs on the pineapple fruit. The feeding behaviour is external and even if the species is associated with pineapple fruit at the point of harvest, it is unlikely to remain on the fruit during the harvest and post-harvest processes.
Karnyothrips melaleucus	Not listed in NZOR (2021) and is regulated (ONZPR 2021). The species is reported to be a predatory thrips species and has been associated with populations of phytophagous mites, on dead leaves and branches where it predates mites or other thrips. No evidence was found in literature of an association with pineapples (Google search: Karnyothrips melaleucus

	pineapple ananas comosus). Interception records may result from incidental presence on pineapples.
Kilifia acuminata	No evidence that the species is associated with the commodity. García Morales et al. (2016) does not list pineapple as a host and no other reference was found in the literature (Google/Google Scholar: 'Kilifia acuminata' and pineapple/'Ananas cosmosus'). Based on a lack of commodity association, the species was not assessed further.
Lachesilla pedicularia	This species has been reported present in New Zealand (PPIN 2021) and is listed as non-regulated on (ONZPR 2021) but is not listed in NZOR (2021). Based on the PPIN record and the regulatory status, no further assessment required.
Lachesilla sp.	Genus not present in New Zealand (NZOR 2021). No evidence found in literature of association with pineapples. Bark lice are considered unlikely to be associated with fresh produce but may be associated with packaging.
Lamprolonchaea smaragdi	The species is not listed in NZOR (2021) or ONZPR (2021). We could not find an association with decrowned pineapple through a web/literature search. However, considered an improbable association with the pathway as the immature stages of most species of the Lonchaeidae family are considered secondary invaders in diseased or injured plant material. Larvae of this species are reported living in damaged tomatoes within Australia. It does not appear that the species is associated with intact fruit. Since overripe fruit is out of scope of the project (the stage most likely to be damaged), the species is not considered to be associated with the commodity.
Largus sp.	No evidence was found that the species is associated with pineapple (Google/Google Scholar: Largus and pineapple/'Ananas comosus').
Lasiodites pictus	The species is not listed in NZOR (2021) or ONZPR (2021). There appear to be a few synonyms for this relatively widespread species (e.g. *Phenolia picta*). The species is commonly associated with fallen and overripe fruit (Kalaentzis 2019), which do not meet the commodity description.
Lawana imitata	The species is not listed in NZOR (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: 'Lawana imitata' and pineapple/'Ananas comosus').
Lema sp.	There does not appear to be an association with pineapple based on a standard web and literature search. However, there was anecdotal evidence by Malumphy (2015) that *Lema bilineata* had been intercepted on pineapple leaves, however even in that circumstance the author assessed pineapples as a not significant pathway. Given that the commodity under consideration is decrowned, not considered to be associated with the commodity.
Lepadoretus sinicus	The species is not listed in NZOR (2021) or ONZPR (2021). This species appears to be a polyphagous beetle that is widespread. However, it is a leaf feeder. Furthermore, pineapple is not listed as a host in CABI (CABI 2020). No association was found between Lepadoretus simicus and pineapple (Google/Google Scholar: 'Lepadoretus simicus' and pineapple/'Ananas comosus').
Lepidiota sp.	Assumed to be covered by species assessments.
Lepidiota stigma	The species is not listed in NZOR (2021) or ONZPR (2021). This is a large beetle that is associated with roots (CABI 2021). Therefore, is not considered to be associated with the commodity.

Lepidosaphes gloverii	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). One reference was found that mentioned the species as a pineapple pest in China. However, no other evidence of an association was found (Watson 2002). Based on a lack of evidence of a commodity association, it was not assessed further.
Lepidosaphes laterochitinosa	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: 'Lepidosaphes laterochitinosa' and pineapple/'Ananas comosus').
Leptacinus sp.	No evidence was found of an association with pineapple (Google/Google Scholar: Leptacinus and pineapple/'Ananas comosus'). There is an interception on pineapple (AssureQuality). The interception was a dead adult beetle, which was most likely a hitchhiker rather than actually associated with pineapple as a commodity.
Leptococcus metroxyli	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: 'Leptococcus metroxyli' and pineapple/'Ananas comosus').
Leptoconops sp.	No evidence found of an association with pineapple (Google/Google Scholar: Leptoconops and pineapple/'Ananas comosus').
Leptocorisa acuta	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: 'Leptococcus acuta' and pineapple/'Ananas comosus').
Leucopholis irrorata	The species is not listed in NZOR (2021) but is regulated (ONZPR 2021). This species of beetle is quite large with 25-31mm (CABI 2021) and it is known to affect leaves and roots of some commercial crops in the Philippines (Litsinger 1983). No association with pineapple was found (Google/Google Scholar: 'Leucopholis irrorata' and pineapple/'Ananas comosus'). Therefore, it is not considered to be associated with the commodity.
Linepithema humile	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). Not known to be a vector.
Liposcelis bostrychophila	This species has been reported present in New Zealand (PPIN 2021) and is listed as non-regulated on ONZPR (2021) but is not listed in NZOR (2021). Based on the PPIN record and the regulatory status, no further assessment required.
Liposcelis sp.	One species (*Liposcelis corrodens*) reported present in New Zealand (NZOR 2021). No evidence found in literature of association with pineapple fruit. Psocids are unlikely to be associated with fresh produce but may be associated with packaging.
Litargus sp.	No association was found with pineapples (Google/Google Scholar: Litargus and pineapple/'Ananas comosus').
Locusta migratoria	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). This species is present in both North and South Island in New Zealand. It is not known to be a vector of diseases.
Lonchaea sp.	No evidence of association to commodity. One paper (Lim and Lowings 1977) mentions an association of this genus with pineapple fruits and flowers. The paper lists "Insects associated with collapsed pineapple fruits, heart rot plants and inflorescences". Given that overripe fruits are not in scope of the project (the most likely to be collapsed), this was not assessed further.

Lycoriella sp.	There is one interception (AssureQuality 2021) record from 2012 for live adult flies from this genus associated with pineapples from the Philippines. However, no association of the genus with pineapple is documented in the literature (Google/Google Scholar: Lycoriella and pineapple/'Ananas comosus'). The closest reference was in a paper by Mohrig (2019) where a reference was made that 'sciarid species are of economic importance, damaging the roots of pineapples and hampering efforts to set up commercial mushroom farms in Hawai'i'.
Maconellicoccus hirsutus	No evidence found indicating commodity association. Google Scholar (English and Spanish), CAB Abstract and reference in García Morales et al. (2016) have been check, although it has been reported on pineapple plants, reports indicating its host association do not mention if it was detected in fruits. Insufficient evidence of an association with the commodity to assess further.
Macunolla ventralis	The species is not listed in NZOR (2021) or ONZPR (2021). One reference to the species being associated with pineapple was found, plus an interception at the New Zealand border. Given that this is a leafhopper, it is unlikely to be associated, and remain associated with decrowned pineapple fruit after commercial production process.
Magusa orbifera	The species is not listed in NZOR (2021) or (ONZPR 2021). There are records of the larvae defoliating *Rhamnus betulaefolia.* There is a research on fruit piercing moths in which this species was attracted to pineapple bait. The moth is recorded to be south of Canada down to Argentina so it is assumed that it is found in Costa Rica, Panama and Ecuador. No records of larvae feeding on pineapple (McFarland (1975); Zenker-Moraes (2010); Google/Google Scholar: Magusa orbifera pineapple). Given that no association with the commodity was found, this was not assessed further.
Maruca vitrata	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021).There is only one record of this pest via an interception of a pineapple consignment coming from Fiji. The interception is a live larva but AssureQuality laboratory clarified that is not associated with pineapple but with the container.
Megalographa biloba	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence found in literature of association with pineapples (Google/ google scholar searches: 'Megalographa biloba' and pineapple/'ananas comosus'). Not enough evidence is available of its association with pineapple to do a full assessment.
Megaselia scalaris	Present in the New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Megaselia sp.	Assumed to be covered by species assessments.
Melanaspis bromiliae	García Morales et al. (2016) and Google Scholar were searched ('Melanaspis bromiliae' and pineapple/'Ananas cosmosus'). The host of the pest are only tropical crops, mainly pineapple (*Ananas* spp.) but also *Cocos nucifera* (García Morales et al. 2016). No evidence indicates it can have impact on the environment. Given the limited host range, it was concluded that based on a lack of host avaliability the species would not have the potenital to establish in New Zealand.
Melanaspis smilacis	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). The species is not associated with the commodity. The species feeds on stems and leaves, sucking sap from plant tissue (Huang and Wang 2016; DAFF 2019b)). No association with fruit was found.

Melanaspis sp.	Assumed to be covered by species assessments
Melanitis leda	Regulated and unwanted organism (ONZPR 2021). Caterpillars feed on leaves and are known to be associated with pineapple leaves, but not reported on fruits. Adults do feed on other fruits and likely feed on pineapples, but will not remain associated with harvested fruits.
Melanitis leda ismene	*Melanitis leda ismene* is not listed in (NZOR 2021) and is regulated (ONZPR 2021). Caterpillars feed on leaves and are known to be associated with pineapple leaves, but not reported on fruits. Adults do feed on other fruits and likely feed on pineapples, but will not remain associated with harvested fruits.
Meromyza sp.	There is one single record of a live adult found on a consignment from the Philippines in 2005. No evidence was found documenting the genus being associated with pineapple (Google/Google Scholar: Meromyza and pineapple/'Ananas comosus'). Therefore, it is not considered to be associated with the commodity.
Metamasius bromeliadicola	No further evidence was found for an association with pineapple. Search terms included the species name plus host/distribution/ananas/pina/pineapple but no indication was found.
Metamasius callizona	The adults feed on leaves, sometimes the flower and larvae are associated with mining the leaves and stem. No clear association with decrowned pineapples and therefore the commodity. Additinally it appears questionable if the species is present in exporting markets due to the doubts of the records from Panama.
Metamasius dimidiatipennis	It appears that although the species is present in exporting markets and the host association is clearly documented as are the economic impacts, the species is not associated with pineapple fruits and is therefore not associated with the commodity.
Metapocyrtus sp.	It appears that this species was considered for Australian pineapple PRAs but was only found to potentially feed on leaves and stems (DAFF 2019b). Therefore, members of the genus are not considered to be associated with the commodity.
Metopina climieorum	Present in the New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Metopina sp.	Assumed to be covered by species assessments.
Mezium americanum	The species is present (NZOR 2021) and is non-regulated (ONZPR 2021).
Milviscutulus mangiferae	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). The scale has been associated with pineapple in New Caledonia (Mille et al. 2016). However, it was not described which part of the plant. It was not classified as an economic pest, suggesting limited damage. Other references describe the scale from leaves and stems. No evidence was found of the scale affecting fruit and therefore is not considered to be associated with the commodity.

Mimegralla albitarsis	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Mimegralla albitaris pineapple/Ananas comosus). The sources from SAPHL did not yield any further information. The paper from Mitra (2015) confirms the presence in Sri Lanka. From DAFF (2012a):"Yunus and Ho (1980) have reported Mimegralla albitarsis on fruit. However, it is considered an improbable association with the pathway as adults are reported as either predaceous on small insects or are attracted to decaying fruit and excrement (Evenhuis 1998). The larvae of Micropezidae are reported to live in decaying wood and other vegetable matter (Colless and McAlpine 1991)." Therefore, the species is not considered to be associated with the commodity.
Mimegralla sp.	Assumed to be covered by species assessments.
Mocis sp.	Some species are reported to be present in New Zealand but there are many species on this genus that are not present in New Zealand. The association of the genus is based on a pest list from 1984 and no further evidence found of association of this genus with pineapples. Not assessed further based on lack of evidence for commodity association.
Monomorium destructor	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Monomorium floricola	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Monomorium minutum	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Monomorium pharaonis	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). Not known to be a vector.
Monomorium sp.	Assumed to be covered by species assessments.
Mythimna separata	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Myzolecanium robertsi	Other than an interception from the Philippines, there is no evidence of the species assocaited with pineapple (Google/Google Scholar: Myzolecanium robertsi pineapple/Ananas cosmosus). Based on the lack of evidence for commodity association, the species was not assessed further.
Myzus persicae	The species is present in New Zealand (NZOR 2021) but is regulated (ONZPR 2021). Given that no evidence was found of the species associated with pineapple (Google/Google Scholar: Myzus persicae pineapple/Ananas comosus), it was not assessed further.
Napaea eucharila	The species is not listed in NZOR (2021) or ONZPR (2021). The larvae of the moth feeds from the leaf of the plant; the larvae does not feed on the fruit. The species is reported as a problem on pineapple grown close to forest (Quesada 2013). The species is not associated with the commodity
Naupactus cervinus	The species is present (NZOR 2021) and is non-regulated (ONZPR 2021).
Neacoryphus bicrucis	The species is present in New Zealand (NZOR 2021) but is regulated (ONZPR 2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: Neacoryphus bicrucis pineapple/Ananas comosus)

Neodecadarchis flavistriata	The species is not listed in NZOR (2021) or ONZPR (2021). Although associated with pineapple, the moth is not present in any of the exporting markets.
Neoleucinodes sp.	Literature found suggests that this moth is not associated with pineapple (Google/Google Scholar: Neoleucinodes pineapple). One of the exporting markets (Ecuador) has a species of Neoleucinodes but is not associated with pineapple.
Nezara viridula	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Nilio villosus	No evidence was found that this species is present in exporting markets. If this were to change, may need to be reassessed.
Nipaecoccus nipae	The only reference indicating host association is from García Morales et al. (2016), this reference has been checked and does not specify which pineapple plant part the scale insect is associated with. Given that no association of the species and pineapple was found in general searches (Google/Google Scholar: Nipaecoccus nipae pineapple/Ananas cosmosus), and the Scalenet reference does not describe an association with pineapple fruits there is not considered sufficient evidence of a commodity association.
Nisia buxtoni	The only evidence of an association with pineapple is an interception in the LIMS database. There is no consignment information and no further evidence was found (Google/Google Scholar: Nisia buxtoni pineapple/Ananas comosus).
Nitidulidae	Assumed to be covered by species assessments.
Nylanderia bourbonica	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Nylanderia sp.	Assumed to be covered by species assessments.
Ochetellus glaber	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). Not known to be a vector.
Odontoponera sp.	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Oligotoma saundersii	The species is not listed in NZOR (2021) and is regulated ONZPR (2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Oligotoma saundersii pineapple/Ananas comosus). There is one interception record of a live adult on pineapples in 2014 (no detail is available on the interception). However, given no association with the commodity was found, this is likely a coincidental interception.
Omophoita aequinoctialis	It appears that this species is associated with pineapples and is present in exporting markets. However, not association with the commodity was found (Google/Google Scholar: Omophoita aequinoctialis pineapple/Ananas cosmosus). Given no documented commodity association, the species was not assessed further.
Opogona aurisquamosa	This species is present in New Zealand (NZOR 2021).

Opogona glycyphaga	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). There are records of association of this species with pineapple, although it is not clear the association (NHM 2021). This appears to be based on an interception record from New Zealand and no detail of the nature of the association was given. No further evidence of an association with the commodity was found (Google/Google Scholar: Opogona glycyphaga pineapple). Therefore, insufficient evidence of association with the commodity to assess further.
Opogona omoscopa	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021). The species is not known to be a vector of disease.
Opogona regressa	There is one interception record of this species on fresh pineapple from Fiji in 1996 (LIMS 2021). However, no other evidence found on host association in literature search (Google Scholar and CAB Abstract search returned no result; no information found on this species in CABI (2021) or EPPO (2021); pineapple is not recorded as host of this species in NHM (2021). As such, there is insufficient evidence on commodity association.
Opogona spp.	Assumed to be covered by species assessments.
Oryctes rhinoceros	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Larvae and eggs are not associated with fruits (except overripe fruits) and adults present on the fruits would be removed by harvest and processing methods (CABI 2021).
Othreis fullonia	The species is not listed in NZOR (2021) or ONZPR (2021). The adults cause damage by piercing tough-skinned fruit and feeding upon the juices, including pineapple. Feeding causes the fruit to become mushy, which reduces the market quality (Martin and Mau 1993). Since the moth does not burrow into the fruit, it is unlikely that the moth would remain associated with the fruit during harvesting and post-harvest processes. The fruit will be rotten and not accepted for export.
Oxya chinensis	This species is regulated (ONZPR 2021). This species is known to feed mainly on rice (Huadi et al. 2007). It is considered a minor pest of pineapple in Hawaii (Illingworth 1929; Pemberton 1964). This species is reported as associated with pineapples flowers and fruit by Stout (1982), however no other literature was found that it was reported association with the fruit. Not likely to stay on the fruit after harvest and quality control processing. In other hosts, such as sugarcane, it has been reported causing defoliation.
Oxya velox	The species is listed as present in New Zealand (NZOR 2021) and is not listed in ONZPR (2021). Nymphs are known to eat newly germinated rice seedlings and cause them to whither. Adult grasshoppers feed on the leaves and shoots and sometimes cut the earheads. They can feed on the emerging inflorescence. In pineapple it is known to feed on the leaves and not the fruit (BPI 2000; Sultana 2012). Therefore, there is no reported association with the commodity and the grasshopper is unlikely to remain associated with pineapple during harvesting and post-harvest processes.
Pachybrachius sp.	No evidence was found that the genus is associated with pineapple (Google/Google Scholar: Pachybrachius pineapple/Ananas comosus).
Paracoccus marginatus	Although there are a few literature listing pineapple as a host of the scale insect, no evidence was found of it associated with the fruit. Therefore, there is no documented evidence of an association with the commodity and was not assessed further.

Paracoccus solani	The species is not listed in NZOR (2021) and has a regulatory status of 'unassessed' in ONZPR (2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: Neacoryphus bicrucis pineapple/Ananas comosus).
Paragonatas divergens	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found that the species is associated with pineapple (Google/Google Scholar: Paragonatas divergens pineapple/Ananas comosus).
Paralipsa gularis	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). The insect is known to be a pest of stored nuts and grain. The NHM (2021) reports this species as associated with pineapple, however the record comes from an interception from the USA. There is no detail of the association. No evidence found in literature of association with pineapple fruit (Google/Google Scholar: Paralipsa gularis). Therefore, insufficient evidence of association with the commodity to assess further.
Parasa lepida	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found in the literature of the species associated with pineapple fruit (Google/Google Scholar: Parasa lepida pineapple).
Parasaissetia nigra	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). Not known to be a vector.
Paratrechina bourbonica	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Paratrechina longicornis	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Paratrechina sp.	Assumed to be covered by species assessments.
Paratrechina vaga	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Parcoblatta sp.	Cockroaches of this genus are generally fairly large and are expected to be removed by commercial production processes. Furthermore, no evidence was found of the genus associated with pineapples (Google/Google search: Parcoblatta pineapple)
Parisoschoenus ananasi	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). According to DAFF (2019), this species feeds on the base of the fruiting shoot and is therefore not associated with decrowned pineapples. Furthermore, No evidence was found of the species being in exporting markets.
Parlatoria pergandii	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Not known to be associated with pineapple (Google/Google Scholar: Paragonatas pergandii pineapple/Ananas comosus).
Pentalonia nigronervosa	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Not known to be associated with pineapple (Google/Google Scholar: Paragonatas pergandii pineapple/Ananas comosus).
Periplaneta americana	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).

Pheidole fervens	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Pheidole megacephala	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). Not known to be a vector.
Pheidole oceanica	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Pheidole sp.	Assumed to be covered by species assessments.
Phenacoccus hargreavesi	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found of the species associated with the commodity (Google/Google Scholar: Phenacoccus hargreavesi pineapple/Ananas comosus; Scalenet). Furthermore, the species is not reported from the exporting markets-restricted to Africa (García Morales et al. 2016).
Phenacoccus madeirensis	DAFF (2001) assessed this species as it was considered associated with pineapple. The original references of DAFF (2001) are Ben-Dov (1994) and CAB International (2000). Ben-dov (1994) does not specify which plant part of pineapple the pest was found. The original references of CAB International (2000) are likely to be Williams (1987) and Culik et al. (2007). Culik (2009) collected the pest on another plant host but not pineapple. William (1987) does not mention that the pest is associated with pineapple. It was therefore concluded that there was insufficient evidence that the species is associated with the commodity and was not assessed further.
Phenacoccus solani	The only relevant references, Willers (1992b) and Willers (1992a), indciate the scale insect was found on pineapple leaves and inflorescences during anthesis. No evidence found indicates it is associated with mature pineapple fruit. It is therefore not considered to be associated with the commodity and was not assessed further.
Phenacoccus solenopsis	The primary reference for the association with pineapple is Spodek et al. (2018). The study does not specify plant parts or how many scales/plants were assessed. No other reference to an association with pineapple was found. May need to be reassessed if further evidence of the species being associated with pineapple is found.
Phenolia picta	This species is covered under *Lasiodites pictus*.
Phera obtusifrons	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Phera obtusifrons pineapple/Ananas comosus).
Phthorimaea operculella	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021). The species is not known to vector disease.
Phyllophaga hogardi	The species is not listed in NZOR (2021) or ONZPR (2021). This species appears to be only associated with pineapple leaves and roots (DAFF 2001) and therefore does not need to be further assessed.
Phyllophaga plaei	The species is not listed in NZOR (2021) or ONZPR (2021). This is a large beetle and no association of the species with pineapples was found (Google/Google Scholar: Phyllophaga plaei pineapple/Ananas comosus).
Phyllophaga sp.	Assumed to be covered by species assessments.

Pinnaspis aspidistrae	The species is not listed in NZOR (2021) or ONZPR (2021). The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). No evidence was found that the scale vectors disease.
Pinnaspis buxi	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Pinnaspis buxi pineapple/Ananas comosus).
Pinnaspis dysoxyli	The species is present in New Zealand (NZOR 2021) and has a regulatory status of 'not assessed' in ONZPR (2021). No evidence was found of the species vectoring disease.
Pinnaspis minor	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Pinnaspis minor pineapple/Ananas comosus).
Pinnaspis strachani	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). García Morales et al. (2016) list pineapple as a host. However the full-text of the reference is not available. Culik et al. (2007) report the species as a 'potential pest of pineapple in Brazil'. However, the authors did not isolate the scale from pineapples plants. Based on a lack of evidence that the species is associated with the commodity, not assessed further.
Pison spinolae	The species is present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021). No evidence was found of the species vectoring disease.
Plagiolepis alluaudi	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Planococcoides njalensis	Duplicate of *Formicococcus njalensis.*
Planococcus lilacinus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Planococcus lilacinus pineapple/Ananas comosus).
Planococcus sp.	Assumed to be covered by the species assessments.
Platynota rostrana	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). The moth is recorded as associated with pineapples by the Natural History Museum (2021) but no details of the association were given. No evidence of the species with pineapple fruit was found in the literature (Google/Google Scholar: Platynota rostrana pineapple). Therefore, insufficient evidence of association with the commodity to assess further.
Plautia brunnipennis	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Plautia brunnipennis pineapple/Ananas comosus). Stink bugs are likely to fly away or fall off fruit during harvesting. They are generally large enough to be visiblt to the naked eye and are likely to be managed by commercial production methods. For this reason they have been excluded from further assessment.
Plintheria sp.	No association of the genus with pineapples was found (Google/Google Scholar: Plintheria pineapple/Ananas comosus). There is also no record of the genus in the LIMS database between 2000 and 2020.
Podoparalecanium machili	The species is not listed in NZOR (2021) or ONZPR (2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Podoparalecanium machili pineapple/Ananas comosus).

Polistes humilis	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). No evidence was found that the species vectors disease.
Prionocyphon sp.	No evidence was found of the genus associated with pineapples (Google/Google Scholar: Prionocyphon pineapple/Ananas comosus).
Prococcus acutissimus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Prococcus acutissimus pineapple/Ananas comosus).
Prometheus garbei	The species is not listed in NZOR (2021) or ONZPR (2021). The moth is not found in any of the exporting markets.
Protaetia fusca	The species is rarely associated with pineapple fruits, and is more commonly found on overripe fruits, which is out of scope of the project. Furthermore, this is a relatively large beetle would be removed/displaced by harvesting or post-harvest processing and any feeding damage would likely be conspicuous.
Pseudaonidia trilobitiformis	The abstract of Culik et al. (2009) suggests that this is a potential pest of pineapple. However, the full text shows that the species actually wasn't found on pineapples but on other plants. A potential association with pineapple fruit in Wang and Spies is described (2017). However, given that this association could not be confirmed in the literature, the species was not assessed further based on a lack of evidence for commodity association.
Pseudaphycus dysmicocci	The species is not listed in NZOR (2021) or ONZPR (2021). This is a parasitic wasp. Its main hosts are *Dysmicoccus brevipes* and *Planococcoides njalensis* (Noyes 2019). Neither of which are listed as present in New Zealand (PPIN 2022, NZOR 2022). In the absence of its hosts, it is assumed that the wasp would not be able to establish in New Zealand and for this reason it will not be considered further.
Pseudaulacaspis sp.	No evidence was found of the genus being associated with pineapple (Google/Google Scholar: Pseudaulacaspis pineapple/Ananas comosus).
Pseudococcidae	Assumed to be covered by species assessments.
Pseudococcus cryptus	No evidence that the species is associated with the commodity. García Morales et al. (2016) lists pineapple as a host of the scale, however no other reference was found in the literature (Google/Google Scholar: Pseudococcus cryptus pineapple/Ananas cosmosus). Based on a lack of evidence of commodity association, this species was not assessed further.
Pseudococcus elisae	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Pseudococcus pineapple/Ananas comosus; Garcia Morales et al. (2016)).
Pseudococcus sp.	Assumed to be covered by the species assessed
Pseudococcus viburni	Pineapple is listed as a host on García Morales et al. (2016), however no other evidence of a host association was found (Google/Google Scholar: Pseudococcus viburni pineapple/Ananas cosmosus). Scalenet does not describe which plant part the scale was founs on. It was concluded that there was insuffcent evidence of commodity association to assess further.
Psocoptera	*Hemipsocus roseus* has reported on pineapples (in Hawaii), but unclear if associated with the fruit. No other evidence found associating this species specifically with fruit. No evidence found for other species of psocoptera being associated with pineapples (google search: Psocoptera pineapple ananas comosus). Interception records have found psocoptera on pineapples,

	but it is likely that this contamination has resulted from cardboard packaging (Thornton 1981).
Psychoda sp.	There was one record of interception from the Philippines on pineapples in 2003. No further evidence of an association with pineapple was found (Google/Google Scholar: Psychoda pineapple/Ananas comosus). There is one reference (Rosa 2014), where they talked about Psychoda larvae and pineapples, but the methods were not clear. Given the lack of information, there is insufficient justification to assess the genus further.
Pulvinaria psidii	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Pulvinaria psidii pineapple/Ananas comosus; García Morales et al. (2016)).
Pycnoscelus surinamensis	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). This is a large cockroach that damages plant roots. Therefore, it is not considered to be associated with the commodity.
Pyroderces aellotricha	The species is present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021). The species is not known to be a vector of disease.
Rhabdoscelus obscurus	There is no evidence found to indicate that the larval and egg stage of the pest can be found inside or on the pineapple fruit. The adult weevil is large and mobile and likely to be easily detected visually. Therefore. this weevil could potentially be managed by commercial production activities. Only these two references found indicating its association with pineapple fruit (Google Scholar; Google; CPC; EPPO; CAB Abstract). The original reference cited by Petty et al (2002) is Waite (1993), where it says “Damage in pineapple is Samoa, Taiwan, Tonga, Vanuatu confined to the fruit, mostly of the rough leaf variety. The adult weevils chew shallow holes in the skin of the fruit which can cause fermentation and rotting. While damaged fruit cannot be transported to distant market, they may be sold locally.” This reference does not mention whether the pest lays eggs on pineapple fruit or if any other life stages can be found on pineapple fruit. The other reference found indicating the association with pineapple is an interception from Canada, where it says the weevil was intercepted once on a shipment of pineapple from Hawaii in 2004 (CDFA 2018).
Rhizobius ventralis	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Rhizoecus americanus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence that the species is associated with the commodity, as it is a root affecting mealybug.
Rhizoecus mayanus	The species is not listed in NZOR (2021) or ONZPR (2021). There is a reference in García Morales et al. (2016) that the species is associated with pineapple, however no details are given. It is unlikely to be associated with the commodity as members of the genus are associated with roots (Mathew 2016).
Rhopaea sp.	According to Joy et al. 2013, species of this genus are referred to as white grubs (larvae feed on the roots) and adults are very conspicuous (i.e. very large). This is also mirrored in Rohrbach and Johnson (2003). Therefore, not considered to be associated with the commodity and does not require further assessment.

Rhopalosiphum padi	The species is present in New Zealand (NZOR 2021) but is non-regulated (ONZPR 2021). It known to transmit some viruses and intercepted on pineapple according to AssureQuality (2021). However, no evidence was found that the species is associated with the commodity (Google/Google Scholar: Rhopalosiphum padi; CPC; CAB Abstract).
Rhopalosiphum rufiabdominale	The species is present in New Zealand (NZOR 2021) but is regulated under the synonym *Rhopalosiphum rufiabdominalis* (ONZPR 2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Rhopalosiphum rufiabdominale pineapple/Ananas comosus).
Rhynchophorus palmarum	This is a large weevil, and even if it is associated with the commodity, it is unlikely to remian associated with fruit following harvest and post-harvest processes.
Rhyssomatus sp.	This is a genus of white grubs. No association with pineapples was found (Google/Google Scholar: Rhyssomatus pineapple/Ananas comosus).
Rhyzobius ventralis	This species is present in New Zealand (BiotaNZ 2022) and non-regulated (ONZPR 2022).
Ribua innoxia	The species is not listed in NZOR (2021) or ONZPR (2021). The moth is not reported to be in any of the exporting markets. The species is only reported on pineapple imported into USA from Cuba (Heinrich 1940).
Saccharicoccus sacchari	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Pineapple is listed as a host in CABI (2021), however no specific plant part is specified. Pineapple is not a host on García Morales et al. (2016). Both databases describe the species as living on leaves, stems and possibly roots. In Hawaii, *S. sacchari* is reported from pineapple fields, but is not considered important as it occurs sporadically and in low numbers (Dey et al. 2018). So although there a report of the species on pineapple was found, it does not look like it would be associated with decrowned pineapples.
Saissetia coffeae	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). It is not known to be a vector.
Saprosites sp.	No association with pineapple found (Google/Google Scholar: Saprosites pineapple/Ananas comosus). There is an interception record from the Philippines of one adult, of an unknown species. Given that no association with the commodity was found, not assessed further.
Scatella sp.	There is a consignment interception record from the Philippines from 2014 with one live adult found. No other evidence of the genus being associated with pineapple was found (Google/Google Scholar: Scatella pineapple/Ananas comosus).
Schedorhinotermes intermedius	The species is not listed in NZOR (2021), but it is regulated in ONZPR (2021). This is a subterranean termite, despite pineapple being listed on CABI (2021) as a host plant, a general search did not yield any results for an association with decrowned pineapples (Google/Google Scholar: Schedorhinotermes intermedius pineapple). Therefore, is not considered to be associated with the commodity.
Sciaridae	Assumed to be covered by species assessments.
Scoparia sp.	No information was found of its association with the pineapple fruit.
Setothosea asigna	The species is not listed in (NZOR 2021) or (ONZPR 2021). The larvae is a defoliating pest, and causes damage to the leaves (USDA 2019). There is no evidence of the larvae feeding on the pineapple fruit (Google/Google Scholar: Setothosea asigna pineapple).

Silvanus sp.	There was one live adult beetle of this genus intercepted on a pineapple consignment from the Philippines. These are large beetles and the interception was likely a contaminant. No evidence was found of Silvanus species associated with pineapples (Google/Google Scholar: Silvanus pineapple/Ananas comosus).
Sitophilus oryzae	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Sitophilus zeamais	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Solenopsis geminata	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Solenopsis invicta	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Solenopsis sp.	Assumed to be covered by species assessments.
Sphenophorus incurrens	The species is not listed in NZOR (2021) or ONZPR (2021). There appears to have been an interception record on commodity from Costa Rica, however, more details other than it has been on fruit were not obtainable. No association to pineapple could be established (Google/Google Scholar: Sphenophorus incurrens pineapple/Ananas comosus).
Sphenophorus venatus	The species is not listed in NZOR (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). There appears to have been an interception record on commodity from Costa Rica, however, more details other than it has been on fruit were not obtainable. No association to pineapple could be established (Google/Google Scholar: Sphenophorus venatus pineapple/Ananas comosus).
Spodoptera exempta	The species is listed as 'sometimes present' in New Zealand (NZOR 2021) and is regulated (ONZPR 2021). This species is mainly a pest of plants of the Poaceae and Cyperaceae (CABI 2021).
Spodoptera exigua	The species is not listed in NZOR (2021), but is regulated (ONZPR 2021). The larvae of this insect is known to attack the leaves of other hosts (Capinera 1999).
Spodoptera litura	The species is present in New Zealand (NZFungi 2021) and non-regulated (ONZPR 2021). The species is not known to vector disease.
Spoladea recurvalis	This species is recorded as present in New Zealand (NZOR 2021) and the regulatory status is recorded as 'under assessment' in ONZPR (2021). It is not known to be a vector of diseases. However, this species appears to be a vagrant species that is a moderately regular migrant. It does not appear to be permanently established in New Zealand. No record found of association with pineapple fruits (Google/Google Scholar: Spoladea recurvalis pineapple).
Stegasta bosqueella	The species is not listed in NZOR (2021) or ONZPR (2021).There is a record of the larvae of this moth found in the axils of the leaves of pineapples in Brazil (Pinto 2020). No information about association with the pineapple fruit was found (Google/Google Scholar: Stegasta bosqueella pineapple).
Stenocatantops splendens	The species is not listed in NZOR (2021) or ONZPR (2021). No information was found on this insect feeding on pineapple using the search terms 'Stenocatantops splendens AND pineapples'.

Stephanitis typica	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Stephanitis typica pineapple/Ananas comosus).
Stephanoderes sp.	Already assessed under the synonym Hypothenemus.
Sticholotis sp.	The only connection found with pineapples was an association with mealybugs (which can be found on pineapples). Apparently the ladybird was introduced to Hawaii for mealybug control purposes (Gonzalez-Hernandez 1995).This is a very indirect association that seems to be not very widely recognized and measures against mealybugs should minimize this indirect association.
Strategus aloeus	The species is not listed in NZOR (2021) and recorded as 'not assessed' in ONZPR (2021). This is a very large beetle species that is not commonly associated with pineapple when searched for with standard terms. The only association with pineapple was found under the synonym *Strategus julianus* on CABI (2021) with one references that was also cited in the Australian Pest assessment. The association was that beetles were found to feed on the leaves of pineapples and larvae on the roots. No connection to decrowned pineapples was found.
Strategus anachoreta	The species is not listed in NZOR (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). This is a large beetle species that is not commonly associated with pineapple when searched for with standard terms. The association was that beetles were found to feed on the leaves of pineapples and larvae on the roots. No connection to decrowned pineapples was found.
Strigoderma micans	The species is not listed in NZOR (2021) or ONZPR (2021). A standard web search did not show any associations with pineapples, therefore recommend to not consider further. Species returned no results on CABI (2021), EPPO (2021).
Strymon basilides	Larvae attacks the flower and the young fruitlet. The adult butterfly deposits eggs at the base of the flower bracts, open flower, crown and leaves that emerge from the lower section of the fruit. When the larvae emerge, they penetrate the softer section of the bract, devour the flower and they bore into the flower down to the young fruit creating internal cavities and galleries. This results on the fruit being deformed and rejection in the packhouse. The damage is very obvious because there is gummosis that looks at first whitish-amber colour but with air contact, this sticky exudate turns brown. These galleries allow disease causing fungi such as *Fusarium moniliforme* and *Penicillium foniculosum* to enter.
Tapinoma melanocephalum	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Tapinoma sp.	Assumed to be covered by species assessments.
Taygete parvella	The species is not listed in NZOR (2021) or ONZPR (2021). There is very little information available for this species. There is not much information available about the association of this species with pineapple. No evidence was found of the species being associated with pineapple fruit (Google/Google Scholar: Taygete parvella pineapple).

Technomyrmex albipes	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). There are 144 interception records of *Technomyrmex* spp. (AssureQuality 2021). Technomyrmex worker/adult were intercepted and identified three times associated to pineapple (LIMS 2021; AssureQuality 2021). The colony reproductive strategy of the *Technomyrmex albipes* group is unique in the Formicidae, given the presence of reproductive inter-caste workers (Bolton 2007). Inter-caste workers are developmentally intermediate between worker and queen in that they have functional ovaries, can mate and produce offspring. They differ from queens in that they do not have a spermatheca and typically only produce other workers and males. However, inter-caste workers do not engage in any activity outside the nest (Yamauchi 1991). No report of association of ant nests to pineapple plants or fruit could be found, and the possibility of ant nests associated to the commodity is considered negligible. Associated ants are likely to be foraging workers unable to establish a population. For these reasons, this species was not considered further.
Technomyrmex sp.	Assumed to be covered by species assessments.
Technomyrmex vitiensis	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). There are 144 interception records of *Technomyrmex* spp. (AssureQuality 2021). *Technomyrmex* worker/adult were intercepted and identified three times associated to pineapple (LIMS 2021; AssureQuality 2021), and two records specifically refer to *T.vitiensis* adults (AssureQuality 2021). The colony reproductive strategy of the *Technomyrmex albipes* group is unique in the Formicidae, given the presence of reproductive inter-caste workers (Bolton 2007). Inter-caste workers are developmentally intermediate between worker and queen in that they have functional ovaries, can mate and produce offspring. They differ from queens in that they do not have a spermatheca and typically only produce other workers and males. However, inter-caste workers do not engage in any activity outside the nest (Yamauchi et al. 1991). No report of association of ant nests to pineapple plants or fruit could be found, and the possibility of ant nests associated to the commodity is considered negligible. Associated ants are likely to be foraging workers unable to establish a population. For these reasons, this species was not considered further.
Telchin licus	The species is not listed in NZOR (2021) or ONZPR (2021). The main host is sugarcane but it has been reported on pineapple; it feeds on stems and rhizomes (Triana et al. 2020). No evidence was found of the species affecting pineapple fruit (Google/Google scholar: Telchin licus pineapple).
Teleogryllus oceanicus	The species is present in New Zealand (NZOR 2021) and regulated (ONZPR 2021). There is little information regarding feeding habits. Most of the information is about its mating behaviours. This species is intermediate vector of *Abbreviata antarctica* (Nematoda) and *Ormia ochracea* (Diptera) (King 2013). No information was found regarding the association of this species with pineapples using the search words Teleogryllus oceanicus AND pineapple.
Tetramorium bicarinatum	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). Not known to be a vector.
Tetramorium guineense	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.

Tetramorium simillimum	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Associated ants are likely to be foraging, sterile individuals unable to establish a population. For this reason, this species was not considered further.
Tetramorium sp.	Assumed to be covered by species assessments.
Thaumatotibia leucotreta	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). Fruit feeding larvae. MPI could not find any evidence of its presence in exporting markets. Appears to be restricted to Africa with transient populations in Europe (Gilligan and E.; 2014; EPPO 2021). No specific cases were found of its association with pineapple other than reports that it's a host (Google/Google Scholar: Thaumatotibia leucotreta pineapple).
Thecla legota	The larvae were spotted in Brazil feeding on new pineapple fruits. There is uncertainty as whether this moth is found in any of the exporting markets. Also the taxonomy of this species is convoluted. It appears that now is considered *Strymon lucena*. Different species seem to be the same one. The only difference is where they originated from. More research needs to be done for clarification. Google scholar search using the scientific name returned only 2 results. From Robbins (2010), "Thecla legota" is an unresolved species complex. The species that attack pineapple within the species complex, according to the paper, are *Strymon lucena* and *S. oreala*, which have not been reported in exporting markets.
Thecla oreala	This species has been reported emerging from pineapple fruit but most likely the fruitlet and not the mature fruit. Only reports from Brazil were found. The larvae of this species have been recorded in various Bromeliads species eating the inflorence and feeding on developing fruits. It has been reported emerging from pineapple fruit but most likely the fruitlet and not the mature fruit. Google scholar search using the scientific name returned three results and only one is relevant (Robins 2010). According to the paper, the pest is likely to be in the *Thecla legota* species complex, and the species that attack pineapple within the complex are not known to present in exporting market.
Thlastocoris laetus	The species is not listed in NZOR (2021) or ONZPR (2021). It is not known from the exporting markets. The species is a pest of pineapple fruit but only reported from Brazil, Peru and Venezuela (Couturier 1993; DAFF 2001). If the exporting markets changed, may need to be reassessed.
Thrips flavus	Not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence in literature of association with pineapple fruit (Google search: Thrips flavus pineapple ananas comosus). This thrips feed and oviposit on flowers, leaves and pods causing direct damage. The damage caused appears as necrotic silvering on the leaves and results in the curling, deformation and withering of the leaves and early senescence or deformation of flowers. No records that its associated with the pineapple fruit.
Thrips hawaiiensis	The species is present in New Zealand (NZOR 2021), but is regulated (ONZPR 2021). However, it is recorded as not present in New Zealand in PPIN (2021). Mound et al. (2017) states that as single female was reported on Campbell Island in 1964. Present in exporting markets. Flower feeder, not clearly associated with pineapple fruits (Rohrbach and Johnson 2003).

Thrips tabaci	Petty et al. (2002) report this species found in the floral cavities of pineapples and can be a major pest. In this source it appears that floral cavities refer to the flowering stage, rather than the cavities of floral remnants on the formed fruits, but this is uncertain. Infections of the floral cavities at the flowering stage significantly affect the fruitlet, so the fruit would likely not be export quality. No records found of interceptions on pineapples. Uncertain if there is an association with pineapple fruits as defined by commodity description. Has the potential to vector *Pantoea ananatis*, which may infect economically significant species in New Zealand. Based on the information provided, the thrips is not known to be on mature pineapple fruit (it is known to present on young pineapple fruits). As there is not sufficient evidence to establish commodity association, the species was not assessed further.
Trachyderes succinctus	The species is not listed in NZOR (2021) or ONZPR (2021). Despite a thorough search, there was no clear association with decrowned pineapples found - there was anecdotal evidence, that the species may feed on leaves, stem and trunk (there was some evidence that the beetle can be baited with a purposefully fermented pineapple/sugarcane solution (DAFF 2021)). The species seems to be at least present in the Caribbean. CABI (2021) does list it as associated with pineapples, but does not give a specific reference for this host species.
Trialeurodes vaporariorum	The species is present in New Zealand (NZOR 2021) but is listed as regulated in ONZPR (2021). No evidence was found of the species being associated with pineapple (Google/Google Scholar: Trialeurodes vaporariorum pineapple/Ananas comosus).
Tribolium castaneum	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021). No evidence was found that the beetle vectors disease.
Trionymus internodii	The species is not present in New Zealand (NZOR 2021) but is listed as regulated in ONZPR (2021). Two references from García Morales et al. (2016) indicate its association with pineapple, but not do not specify the plant part. However, DAFF (2001) found that the species is associated with leaves, stems, crowns and roots of pineapple and would therefore not be associated with the commodity. Furthermore, from the distribution listed in García Morales et al. (2016) (Israel, Egypt and Senegal) the species is not present in the exporting markets.
Trochalus politus	The species is not known to be present in New Zealand (NZOR 2021) and is regulated (ONZPR 2021). In Smith et al.1995 the biology of *T. politus* in relation with pineapples was described as 'not specifically associated with pineapples, but adults damage pineapple stems and encourage decay'. Therefore, the species is not considered to be associated with the commodity.
Tylozygus fasciatus	The species is present in New Zealand (NZOR 2021) but is listed as regulated in ONZPR (2021). No evidence was found of the species being associated with pineapple fruit (Google/Google Scholar: Tylozygus fasciatus pineapple/Ananas comosus). An unconfirmed record of the species on pineapple leaves in Nicaragua was found (Frank 2014). Given that no commodity association was determined, was not assessed further.
Typhaea stercorea	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).

Unaspis citri	Search has been performed in Google Scholar, Google, CAB Abstract, CABI (2021) and EPPO (2021) (Unaspis citri pineapple/Ananas cosmosus). The pest is associated with pineapple but not documented associated with pineapple fruit. Given that there is no record of the scale associated with pineapple fruit in all the usual sources, there is insufficient information to require further assessment.
Urophorus humeralis	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Valanga nigricornis	The species is present in New Zealand (NZOR 2021) and regulated (ONZPR 2021). The species feeds on the top of trees. It is recorded as a pest of coconut palms in Indonesia. It has a wide range of hosts, including *Areca*, tea, coffee, rubber, *Ficus*, and *Citrus* (Lever 1969). There is a reference mentioning that this insect has been associated with the flower and pineapple fruit (Yunus and Hua 1980), but not possible to access. Furthermore, the species is not likely to remain associated with fruit after harvesting and processing. In the literature, no obvious association was found to the pineapple fruit (Google/Google Scholar: Valanga nigricornis pineapple).
Wasmannia auropunctata	Wasmannia auropunctata is not listed in NZOR (2021) and is regulated (ONZPR 2021). This ant species was intercepted five times in New Zealand (LIMS 2021). Four intereceptions were workers (id unknown in the fifth record). Two of these records relate to fresh produce pathway (fresh produce leaves and coconut). Little fire ants are very small, and simlarly to other ant spp., they nest in leaf axils e.g. of coconut palms (Way and Bolton 1997). However, the commodity description exclude the possibility of leafs being present, and pineapple fruit bracts are not providing the same spatial niche. No report of association of ant nests to pineapple plants or fruit could be found, and the possibility of ant nests associated to the commodity is considered negligible. Associated ants are likely to be foraging workers. Despite the peculiar reproductive system of this species (clonal reproduction of queens and males, Foucaud et al. 2006), workers are unable to establish a population. For this reason, this species was not considered further.
Xyleborus ferrugineus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). No evidence was found of the species associated with pineapple (Google/Google Scholar: Xyleborus ferrugineus pineapple/Ananas comosus). Therefore, it is not considered to be associated with the commodity.
Xyleborus sp.	Assumed to be covered by species assessments.
Xyleborus volvulus	The species is not listed in NZOR (2021) or ONZPR (2021). According to the CABI (2021) this species albeit polyphagous is not known to be transported through fruits and pineapple was not listed as a host. The species is associated with woody plant parts (Cruz et al. 2019) (Google/Google Scholar: Xyleborus volvulus pineapple/Ananas comosus).
Zaplatycerus fullawayi	The species is not listed in NZOR (2021) or ONZPR (2021). This is a parasitic wasp parasitic wasp and is a natural enemy of the pineapple mealybug *Dysmicoccus brevipes* (CABI 2021; Pandey & Johnson 2006), which is not known to be present in New Zealand (PPIN 2022). In the absence of its host it is assumeed that the wasp would not be able to establish in New Zealand and for this reason it will not be considered further.

Zonocerus elegans	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). Although its been recorded to feed on pineapple, this insect is big enough to be detected on the fruit and will likely not survive the cleaning and processing prior to packaging. This insect does not lay egg on the fruit, but in the soil (Lomer et al. 1999).
Zonocerus variegatus	The species is not listed in NZOR (2021), but is regulated in ONZPR (2021). This species is considered a serious pest in Africa and does not appear to be present in exporting markets. No association with fruits, including pineapple fruits, was found (Google/Google Scholar: Zonocerus variegatus pineapple).
Kinetoplastea	
Phytomonas ananas	Synonym of *Pseudomonas ananas* which has been assessed.
Malacostraca	
Porcellio laevis	The species is not listed in NZOR (2021), but is regulated (ONZPR 2021). This species feeds on wood, detritus, compost (highly rotten vegetables and fruits). It dwells in damp areas, in dark areas, under rocks and logs. Pineapple fruit is above the soil exposed to the sun so highly unlikely this species will be around (BMIG 2021). Rotten pineapples will not be selected for export and will not pass the sugar grading analysis before packing.
Mollusca	
Achatina fulica	The species is not listed in BiotaNZ (2022), but is regulated (ONZPR 2021). Excluded because this is a large contaminating pest and not truly associated with pineapple. Furthermore, should be managed by commercial production measures and general measures to manage contaminating pests.
Bradybaena similaris	The species is not listed in NZOR (2021) and is regulated in ONZPR (2021). Snails are considered as contaminating pests and managed by commercial production methods.
Diplosolenodes occidentalis	The species is not listed on NZOR (2021) or ONZPR (2021). Slugs are considered to be managed by commercial production measures.
Opeas sp.	Snails are contaminating organisms that will be removed during post harvest processes.
Pallifera costaricensis	Slugs are contaminating organisms that will be removed during post harvest processes.
Sarasinula plebeia	Slugs are considered out of scope of the project and are considered to be removed from the commodity by commercial production measures
Stylommatophora	Slugs and snails are considered to be removed by the commercial production methods.
Succinea costaricana	Snails are considered to be removed by the commercial production methods
Succinea sp.	Snails are considered to be removed by the commercial production methods
Succineidae	Snails are considered to be removed by the commercial production methods
Zonitoides arboreus	Snails are considered to be removed by the commercial production measures.
Nematode	

Aphelenchoides sp.	Species of the genus occur in soil, decaying plant residues, moss, and on the surfaces of rocks and trees (Ferris 2021) and as such, it is not associated with the commodity.
Aphelenchus avenae	Present in New Zealand (NZOR 2021) and non-regulated (ONZPR 2021).
Aphelenchus eremitus	The species is not listed in NZOR (2021) and is regulated in ONZPR (2021). There is little information available on this nematode and the information that is available suggests that it is not associated with the pathway, as it feeds on roots.
Carphodorus sp.	Nematodes of the family Dolichodoridae are obligate ectoparasites of plant roots and are therefore not associated with the commodity (Ferris 2021).
Cranifera sp.	Members of the family Thelastomatidae are parasites of insects and other invertebrates (Ferris 2021). All references found on the species in the genus *Cranifera* related to insect parasitisum.
Criconemoides	Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence found that they are associated with other plant parts.
Diphtherophora sp.	Members of the order Dorylamida are ectoparasites with their feeding site at the root tip and are therefore not considered to be associated with the commodity (Ferris 2021).
Discocriconemella sp.	Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence that they are associated with other plant parts and therefore not considered to be associated with the commodity.
Ditylenchus intermedius	There was a single source found stating that this nematode is present in Australia, but no evidence was found of presence in other exporting markets. No evidence found of association with pineapple fruits (Google/Google Scholar: Ditylenchus intermedius pineapple/Ananas cosmosus). The family Anguinidae contains faculative and obligate parasites of higher plants, frequently parasites of the above ground parts of plants. This species has been reported associated with pineapple plants in Hawaii. However, the only report found that detailed when in the pineapple plant the nematode was found recorded it from the roots and no evidence of the nematode associated with pineapple fruits was found. Given the lack of commodity association, the species is not assessed further.
Ditylenchus myceliophagus	The species is recorded as present in New Zealand (NZOR 2021), but regulated (ONZPR 2021). It is reported feeding on fungal hyphae (nemaplex 2021). No reports found (Google/Google scholar: Ditylenchus myceliophagus) of it being a plant pest.
Ditylenchus sp.	Assumed to be covered by species assessments.
Dolichodorus minor	The species is not listed on NZOR (2021) or ONZPR (2021). Recorded from soil surrounding roots. Ectoparasite that mainly feeds at the root tip. Members of the Dolichodoridae are obligate ectoparasites of the root tip (Ferris 2021). Therefore, not associated with the commodity.
Filenchus filiformis	The species is not listed in NZOR (2021) or ONZPR (2021). Members of the family feed on algae, mosses, lichens and plant roots. Members of the genus also feed on fungi (Ferris 2021). Therefore, not associated with the commodity.
Filenchus sp.	Assumed to be covered by species assessents.

Helicotylenchus cavenessi	The species is not listed on NZOR (2021) or ONZPR (2021). Hoplolaimids are a unique group of migratory root ectoparasites, semi-endoparasites and true endo parasites (Krall 1990). No evidence that they are associated with other plant parts.
Helicotylenchus digonicus	This species is listed as present in New Zealand (NZOR 2021) but is regulated (ONZPR 2021). Hoplolaimids are a unique group of migratory root ectoparasites, semi-endoparasites and true endo parasites Krall 1990. No evidence that they are associated with other plant parts.
Helicotylenchus dihystera	This species is listed as present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Helicotylenchus erythrinae	This species is listed as present in New Zealand (NZOR 2021) but is regulated (ONZPR 2021). Hoplolaimids are a unique group of migratory root ectoparasites, semi-endoparasites and true endo parasites (Krall 1990). No evidence that they are associated with other plant parts.
Helicotylenchus microcephalus	This species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Hoplolaimids are a unique group of migratory root ectoparasites, semi-endoparasites and true endo parasites (Krall 1990). No evidence that they are associated with other plant parts.
Helicotylenchus mucronatus	This species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Hoplolaimids are a unique group of migratory root ectoparasites, semi-endoparasites and true endo parasites (Krall 1990). No evidence that they are associated with other plant parts.
Helicotylenchus multicinctus	This species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Hoplolaimids are a unique group of migratory root ectoparasites, semi-endoparasites and true endo parasites (Krall 1990). No evidence that they are associated with other plant parts.
Helicotylenchus pseudorobustus	This species is listed as present in New Zealand (NZOR 2021) but is non-regulated (ONZPR 2021).
Helicotylenchus sp.	Assumed to be covered by species assessments.
Hemicriconemoides sp.	Assumed to be captured by species assessments.
Hemicriconemoides cocophillus	This species is listed as present in New Zealand (NZOR 2021) but is regulated (ONZPR 2021). Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence that they are associated with other plant parts
Hemicriconemoides mangiferae	This species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (nemaplex 2021). No evidence that they are associated with other plant parts.
Hemicycliophora oostenbrinki	The species is not listed in NZOR (2021) or ONZPR (2021). Little information was found about this species. Other members of the genus are not associated with the fresh fruit pathway as the affect roots. No evidence on Google or Google scholar searches that this species affects above ground plant parts.
Heterodera schachtii	Present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021), however some suggestion of subspecies. Not considered further because the lifecycle of the nematode occurs in soil and associated with roots (Ferris 2021) and is therefore not considered associated with the commodity.

Heterodera sp.	Members of the family Heteroderinae feed on developing roots (Ferris 2021). No evidence that they are associated with other plant parts.
Hoplolaimus pararobustus	This species is not listed in NZOR (2021) and is regulated (ONZPR 2021). This is a root associated nematode (CABI 2021; Ferris 2019) and is not associated with the commodity
Hoplolaimus seinhorsti	This species is not listed in NZOR (2021) and is regulated (ONZPR 2021). The species is a root infecting nematode (CABI 2020; Vovlas 1983). It is also associated with soil. CABI (2021) stats that it is spread via soil and root, but is not spread via other plant parts including fruit. No evidence was found of the species being associated with plant parts other than roots.
Longidorus elongatus	This species is not listed in NZOR (2021) but is regulated (ONZPR 2021). This is a root associated nematode and is not considered to be associated with the commodity (CABI 2021).
Longidorus sp.	Although *Longidorus* spp. have been isolated from pineapple fields they were found associated with soil rather than fruits or above ground plant parts (Sirengo 2020). Members of the genus are ectoparasitic and are detected by isolation from soil. They feed on host roots (EPPO 2021). No evidence found indicates it is associated with the commodity.
Meloidogyne acronea	The species is not listed in NZOR (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). Members of the family Heteroderinae feed on developing roots (Ferris 2021). No evidence that they are associated with other plant parts.
Meloidogyne arenaria	The species is listed as present in NZOR (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). Members of the family Heteroderinae feed on developing roots (Ferris 2021). No evidence that they are associated with other plant parts.
Meloidogyne enterolobii	The species is not listed in NZOR (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). Members of the family Heteroderinae feed on developing roots (Ferris 2021). No evidence that they are associated with other plant parts.
Meloidogyne hapla	This species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Meloidogyne incognita	The species is not listed in NZOR (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). Members of the family Heteroderinae feed on developing roots (Ferris 2021). No evidence that they are associated with other plant parts.
Meloidogyne javanica	The species is not listed in NZOR (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). Members of the family Heteroderinae feed on developing roots (Ferris 2021). No evidence that they are associated with other plant parts.
Meloidogyne konaensis	The species is not listed in NZOR (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). Members of the family Heteroderinae feed on developing roots (Ferris 2021). No evidence that they are associated with other plant parts.
Meloidogyne sp.	Members of the family Heteroderinae feed on developing roots (nemaplex 2021). No evidence that they are associated with other plant parts.

Mesocriconema curvatum	This species is not listed in NZOR (2021) and is regulated (ONZPR 2021). This species is found in soil and feeds on roots (Ferris 2021). Therefore, it is not considered to be associated with the commodity.
Mesocriconema denoudeni	This species is not listed in NZOR (2021) or ONZPR (2021). Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence that they are associated with other plant parts.
Mesocriconema ferniae	This species is not listed in NZOR (2021) or ONZPR (2021). Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence that they are associated with other plant parts.
Mesocriconema onoense	This species is not listed in NZOR (2021) or ONZPR (2021). Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence that they are associated with other plant parts.
Mesocriconema xenoplax	This species is not listed in NZOR (2021), but is non-regulated ONZPR (2021). Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence that they are associated with other plant parts.
Paratylenchus bukowinensis	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence found that they are associated with other plant parts
Paratylenchus minutus	The species is present in New Zealand (NZOR 2021) and is not listed in ONZPR (2021). Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence that they are associated with other plant parts.
Paratylenchus sp.	Members of the family Criconematidae feed ectoparasitically on plant roots, some at root tips, others in more mature regions of the root (Ferris 2021). No evidence that they are associated with other plant parts.
Pratylenchus brachyurus	The species is not listed in NZOR (2021) and is regulated ONZPR (2021). The entire lifecycle of species in the genus occur in or associated with soil and roots (Davis and MacGuidwin 2000). The species are not associated with other plant parts and therefore are not associated with the commodity.
Pratylenchus coffeae	The species is present in New Zealand NZOR (2021) and is non-regulated ONZPR (2021).
Pratylenchus goodeyi	The species is not listed in NZOR (2021) and has a regulatory status as 'unassessed' in ONZPR (2021). The entire lifecycle of species in the genus occur in or associated with soil and roots (Davis and MacGidwin 2000). The species are not associated with other plant parts and therefore are not associated with the commodity.
Pratylenchus pratensis	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Pratylenchus sp.	The entire lifecycle of species in the genus occur in or associated with soil and roots (Davis and MacGidwin 2000). The species are not associated with other plant parts and therefore are not associated with the commodity.

Pratylenchus zeae	The species is not listed in NZOR (2021) and is regulated ONZPR (2021). The entire lifecycle of species in the genus occur in or associated with soil and roots (Davis and MacGidwin 2000). The species are not associated with other plant parts and therefore are not associated with the commodity.
Quinisulcius curvus	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Members of the genus are associated with soil and roots (Hussain and Iqbal 2019). No evidence was found of them infecting other plant parts and is not considered associated with the commodity.
Radopholus similis	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021).The species is root associated and completes its life cycle in plant roots (Sekora and Crow 2018). Not associated with other plant parts and therefore not considered to be associated with the commodity.
Rotylenchulus reniformis	The species is present in New Zealand (NZOR 2021) but is regulated (ONZPR 2021). The entire lifecycle of the species takes place in or in association with plant roots (Wang 2019). Not described as being associated with any other plant parts and is therefore not considered associated with the commodity.
Rotylenchulus sp.	These are semi-endoparasites of roots (Ferris 2019) and are therefore not considered associated with the commodity.
Rotylenchus robustus	The species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Scutellonema brachyurus	The species is present in New Zealand (NZOR 2021) and is not listed in ONZPR (2021). Members of this genus would not be associated with the pathway as they feed on roots (Whitehead 1959; Demeure et al. 1980). No evidence was found of the affecting other plant parts and are therefore not considered to be associated with the commodity.
Scutellonema bradys	The species is not listed in NZOR (2021), but is regulated (ONZPR 2021). It is an endoparasite of roots and tubers and also present in soils around the host plant (CABI 2021). No evidence that the species is associated with other plant parts and therefore not associated with the commodity.
Scutellonema siamense	The species is not listed in NZOR (2021) or ONZPR (2021). The species has been found associated with rhizosphere soil of pineapple (Timm 1965), but no evidence was found of it associated with pineapple fruit. Members of this genus feed on roots (Whitehead 1959; Demeure et al. 1980) and are therefore not considered to be associated with the commodity.
Scutellonema sp.	Assumed to be covered by species assessments.
Sphaeronema sp.	All results for members of this genus related to their association with roots. No evidence was found of species affecting other plant parts and are therefore not considered to be associated with the commodity.
Trichodorus primitivus	The species is present in New Zealand (NZOR 2021), bit is listed as regulated (ONZPR 2021). Trichodoridae are polyphagous root-ectoparasites; they also vector viruses (Decraemer and Robbins 2007). No evidence was found that they are associated with other plant parts, so are not considered to be associated with the commodity

Tylenchorhynchus annulatus	The species is not listed in NZOR (2021) but is regulated in ONZPR (2021). The species is reported isolated form soil samples and other references to the nematode are related to damage to plant roots (Ferris 2021). No evidence was found of the species associated with other plant parts and therefore is not considered associated with the commodity.
Tylenchorhynchus digitatus	The species is not listed in NZOR (2021) or ONZPR (2021). Members of the family are generally true ectoparasites on epidermal cells and root hairs, but capable of endoparasitic feeding on some hosts; all the reports of *Tylenchorhynchus* spp. were from soils (Ferris 2021). No evidence was found of them associated with other plant parts and therefore are not considered to be associated with the commodity.
Tylenchorhynchus sp.	Assumed to be covered by species assessments.
Tylenchus sp.	The species is not listed in NZOR (2021) or ONZPR (2021). Members of the family are generally true ectoparasites on epidermal cells and root hairs, but capable of endoparasitic feeding on some hosts; all the reports of *Tylenchorhynchus* spp. were from soils (Ferris 2021). No evidence was found of them associated with other plant parts and therefore are not considered to be associated with the commodity.
Xiphinema brasiliense	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Longidoridae are polyphagous root-ectoparasites and also vector viruses (Decraemer and Robbins 2007). No evidence that they are associated with other plant parts, so not considered associated with the commodity
Xiphinema brevicolle	This species is present in New Zealand (NZOR 2021) and is non-regulated (ONZPR 2021).
Xiphinema elongatum	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Longidoridae are polyphagous root-ectoparasites and also vector viruses (Decraemer and Robbins 2007). No evidence that they are associated with other plant parts, so not considered associated with the commodity
Xiphinema ensiculiferum	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Longidoridae are polyphagous root-ectoparasites and also vector viruses (Decraemer and Robbins 2007). No evidence that they are associated with other plant parts, so not considered associated with the commodity
Xiphinema ifacolum	The species is not listed in NZOR (2021) or ONZPR (2021). The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Longidoridae are polyphagous root-ectoparasites and also vector viruses (Decraemer and Robbins 2007). No evidence that they are associated with other plant parts, so not considered associated with the commodity
Xiphinema insigne	The species is not listed in NZOR (2021) and is regulated (ONZPR 2021). Longidoridae are polyphagous root-ectoparasites and also vector viruses (Decraemer and Robbins 2007). No evidence that they are associated with other plant parts, so not considered associated with the commodity.
Xiphinema radicicola	The species is present in New Zealand (NZOR 2021) but is not listed in ONZPR (2021). Longidoridae are polyphagous root-ectoparasites and also vector viruses (Decraemer and Robbins 2007). No evidence that they are associated with other plant parts, so not considered associated with the commodity.
Oomycete	

Aphanomyces sp.	No information was found that diseases occurs on fruit (Google/Google scholar Aphanomyces). Therefore, it is not considered associated with the pathway.
Globisporangium acanthophoron	The species is not recorded in NZFungi (2021). It is regulated as *Pythium acanthophoron* (ONZPR 2021), which appears to be the name commonly used in the literature. References found relate to the species as a mycoparasite and as a root rot pathogen (Google and Google scholar: 'Pythium acanthophoron' and 'Globisporangium acanthophoron'). In the current IHS for fresh pineapple from Ecuador, the species is listed as a root rot. No evidence was found of the species associated with fruit (Google and Google scholar: 'Globisporangium acanthophoron' and pineapple, and 'Pythium acanthophoron' and pineapple, and Pythium acanthophoron fruit and Globisporangium acanthophoron fruit). Therefore, it was determined that the species is not associated with the pathway.
Globisporangium debaryanum	NZFungi (2021) states that the presence of the species in New Zealand is uncertain, as although there are collections under the name *Pythium debaryanum*, this name has been misapplied on occasion and the cultures should be re-examined. Pythium species are generally associated with soil and cause root disease. CABI (2021) states that the pathogen affects the whole plant at the pre-emergence and seedling stage and is not carried on fruits. All but on record in Farr and Rossman (2021) related to root rot and damping off. The one record of fruit rot is from watermelon (Farr and Rossman 2021), which is likely to have occurred following contact with the soil. The record of the species affecting pineapple in Hawaii relates to root rot (Raabe et al. 2009). No evidence was found in Google and Google scholar searches ('Globisporangium debaryanum' and pineapple, and 'Pythium debaryanum' and pineapple) of the pathogen causing disease on pineapple fruits. Therefore, it was determined that the species is not associated with the pathway.
Globisporangium intermedium	*Globisporangium intermedium* is listed as present in New Zealand (Robertson 1980; NZFungi 2021). No subspecific taxa were found, which may not be present in New Zealand.
Globisporangium irregulare	Present in New Zealand (NZFungi 2021) and non-regulated (ONZPR 2021). There are multiple collections of the species from different regions of New Zealand and on different hosts. No evidence found that *G. irregulare* associated with pineapple represents a strain not present in New Zealand.
Globisporangium mamillatum	Present in New Zealand (NZFungi 2021) and non-regulated (ONZPR 2021). There are multiple collections of the species from different regions of New Zealand and on different hosts. No evidence found that *G. irregulare* associated with pineapple represents a strain not present in New Zealand.
Globisporangium megalacanthum	Present in New Zealand (NZFungi 2021) and non-regulated as *P. megalacanthum* (ONZPR 2021). There is a collection of the species from NZ. No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Globisporangium rostratum	Present in New Zealand (NZFungi 2021) and non-regulated as *P. rostratum* (ONZPR 2021). There are collections of the species from different regions of New Zealand. No evidence found that isolates from pineapple represent a strain not present in New Zealand.

Globisporangium spinosum	Present in New Zealand (NZFungi 2021) and non-regulated as *P. rostratum* (ONZPR 2021). There are collections of the species from different regions of New Zealand. No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Globisporangium splendens	Present in New Zealand (NZFungi 2021) and non-regulated as *P. splendens* (ONZPR 2021). There are collections of the species from New Zealand. No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Phytophthora cactorum	Present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). There are collections of the species from New Zealand. No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Phytophthora capsici	No evidence was found of the species being associated with pineapple: Google/Google Scholar: Phytophthora capsici pineapple/ Ananas). Other species of Phytoplthora assessed were not associated with the commodity.
Phytophthora cinnamomi	This species is present in New Zealand (BiotaNZ 2022) and non-regulated (ONZPR 2022).
Phytophthora citrophthora	This species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Phytophthora drechsleri	The presence of this species in New Zealand is uncertain (NZFungi 2021), but is reported as present in PPIN (2021). Although other Phytophthora species have been associated with heart rot of pineapple (Anderson et al. 2012; Shen et al. 2013), no evidence was found of *P. drechsleri* causing this disease (Google/Google scholar searches Phytophthora drechsleri pineapple). There was also no evidence found of the pathogen associated with pineapple fruit (Google and Google Scholar search: Phytophthora drechsleri pineapple fruit and Phytophthora drechsleri ananas fruit).
Phytophthora infestans	The species is present in New Zealand (NZOR 2021). The A1 mating strain is non-regulated, whereas the A2 mating strain is regulated (ONZPR 2021). No evidence of *P. infestans* associated with pineapple was found (Google/Google scholar Phytophthora infestans pineapple). Pineapple is not listed as a host in Farr and Rossman (2021), CABI (2021) or (K.; et al. 1994).
Phytophthora meadii	The species is present in New Zealand (NZFungi 2021). The regulatory status is listed as 'under assessment' (ONZPR 2021). No evidence that *P. meadii* associated with pineapple represents a strain not present in New Zealand
Phytophthora megakarya	The species is not listed in NZFungi (2021) and has a regulatory status of 'not assessed' in ONZPR (2021). The species is not present in the exporting markets. This species is confined to West Africa (Akrofi 2015). The CABI (2021) distribution table list Papua New Guinea as also having the pathogen, however no primary sources were found for this and no other records outside of Africa were found.
Phytophthora nicotianae	The species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). *P. nicotianae* var. *parasitica* is also present in New Zealand (NZFungi 2021). There are collections of the species (inc. var. parasitica) from New Zealand (NZFungi 2021). No evidence found that isolates from pineapple represent a strain not present in New Zealand.

Phytophthora palmivora	This species is one of the phytophthoras that cause heart rot of pineapple (Bartholomew and Malézieux 1994; Shen et al. 2013). The disease causes rotting at the base of the leaves, in the centre of the leaf whorl (heart) of young flowering plants. As the disease progresses the plant collapses and dies (Shen et al. 2013). Bartholomew and Malézieux (1994) describe that the inital symptoms are failure of the young leaves to elongate. Later symptoms are yellowing to bronzing of the young leaves, which may then lean to one side of the plant. Phytophthora infections are limited to the stem and basal white portion of the leaves. There is no mention of the pathogen affecting fruit. Green and Nelson (2015) describe that although the main disease symptoms are rotting of leaves, the pathogen can move through the plant of susceptible varieties and rot the fruit. The pictures associated with this show a small fruit rotted on the plant. It is unlikely that such fruit would be harvested or if it was by mistake, that it would be removed during cleaning/packing. Therefore, unlikely to be assocaited with the pathway.
Phytophthora sp.	Assumed to be covered by species assessments.
Phytopythium indigoferae	The species is not recorded in NZFungi (2021) or (ONZPR 2021). Google and Google scholar results (searches 'P. indigoferae fruit' and 'P. indigoferae pineapple fruit') related to the pathogen causing root rot. All evidence of the species being associated with pineapple refers to it causing root rot. No evidence was found that the pathogen has been isolated associated with pineapple fruit.
Phytopythium vexans	The species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021) and there are collections of the species from New Zealand (NZFungi 2021). No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Pythium acanthicum	This species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). There are collections of the species from New Zealand. No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Pythium aphanidermatum	The species is recorded as absent from New Zealand (NZFungi 2021) and is regulated (ONZPR 2021). No evidence was found of the species on pineapple fruit (Google/Google scholar searches Pythium aphanidermatum pineapple fruit and Pythium aphanidermatum Ananas comosus fruit). Therefore, no evidence was found of the species being associated with the commodity or pathway.
Pythium arrhenomanes	This species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). There are collections of the species from New Zealand. No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Pythium butleri	The species is present in New Zealand (NZFungi 2021) but is not listed in ONZPR (2021). In NZFungi, no synonyms are given. A Google search failed to identify any synonyms. However, the species is regulated in ONZPR as a synonym of P. aphanidermatum. Not proceeded as recorded as present and no valid synonyms found.
Pythium graminicola	This species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). There are collections of the species from New Zealand. No evidence found that isolates from pineapple represent a strain not present in New Zealand.

Pythium hydnosporum	The species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). Furthermore, as per the 2001 Australian risk assessment for pineapple in 2001 the pathogen is not associated with the pathway.
Pythium myriotylum	The species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Pythium polymorphon	The species is not listed in NZFungi (2021) and is non-regulated under *P. irregulare* (ONZPR 2021). Farr and Rossman (2021) also list these as synonyms but they are not in NZFungi. In addition, a search in Google Scholar, Index Fungorum, Mycobank, has not found evidence on it being associated with fruit of pineapple. Index Fungorum records that it is "on root of *Ananas sativus".*
Pythium sp.	Assumed to be covered by species assessments.
Pythium torulosum	The species is present in New Zealand (NZFungi 2021) and is non-regulated (ONZPR 2021). There are collections of the species from New Zealand. No evidence found that isolates from pineapple represent a strain not present in New Zealand.
Phytoplasma	
"*Candidatus* Phytoplasma" (16SrXII)	Given that phytoplasmas are spread through propagation of infected plant material and vectors, there is no plausible means of establishment from pineapple fruit. Particularly as the commodity description requires decrowning and therefore is unable to be propagated. (EFSA 2015) consider infected fruit unlikely to represent an efficient entry pathway for vector-transmitted pathogens.
"*Candidatus* Phytoplasma asteris"	There is no record of "Candidatus Phytoplasma asteris" in NZFungi (2021), NZOR (2021), PPIN (2021), or Veerakone et al. (2015). The phytoplasma is regulated (ONZPR 2021). "Candidatus Phytoplasma asteris" has been reported associated with pineapple shoot proliferation in the Wallis and Futuna territory (Davis et al. 2005), and in India causing witches broom and shoot proliferation (Mitra et al. 2019). Given that phytoplasmas are spread through propagation of infected plant material and vectors, there is no plausible means of establishment from pineapple fruit. Particularly as the commodity description requires decrowning and therefore is unable to be propagated. EFSA (2015) consider infected fruit unlikely to represent an efficient entry pathway for vector-transmitted pathogens.
"*Candidatus* Phytoplasma prunorum"	There is no record of *Ca*. P. prunorum in NZFungi (2021), NZOR (2021), PPIN (2018) or Veerakone et al. (2015). It is regulated in ONZRP (2021). This phytoplasma was reported from pineapple (variety 'Mayanes" -crown leaves exhibited witches' broom symptoms) in East Colombia. This is a first detection of *Ca*. P. prunorum on the American continent (Satta et al. 2015). A vector was not identified by the authors. No further evidence of this phytoplasma in South America, or of it associated with pineapples was found. Given that phytoplasmas are spread through propagation of infected plant material and vectors, there is no plausible means of establishment from pineapple fruit. Particularly as the commodity description requires decrowning and therefore is unable to be propagated. EFSA (2015) consider infected fruit unlikely to represent an efficient entry pathway for vector-transmitted pathogens. This phytoplasma has also not been reported from the current (2021) pineapple exporting markets.

"*Candidatus* Phytoplasma solani"	"*Candidatus* Phytoplasma solani" is not known from New Zealand. It is not recorded in NZFungi (2021) or PPIN (2021) and is regulated in ONZPR (2021). Given that phytoplasmas are spread through propagation of infected plant material and vectors, there is no plausible means of establishment from pineapple fruit. Particularly as the commodity description requires decrowning and therefore is unable to be propagated. EFSA (2015) consider infected fruit unlikely to represent an efficient entry pathway for vector-transmitted pathogens.
Virus	
Ananas metavirus	The species is not listed in NZOR (2021), Veerakone et al. (2015) or ONZPR (2021). Very little information on this virus. All results (Google and Google scholar of Ananas metavirus) related to the virus associated with pineapple (Gambley et al. 2008). Therefore, based on available information unlikely to establish and cause impacts in NZ. If further hosts are identified, may need to be reassessed.
Capsicum chlorosis orthotospovirus	CaCV is transmitted by thrip vectors *Frankliniella occidentalis* (Sun et al. 2018), *Frankliniella shultzei*, *Thrips palmi* and *Ceratothripoides claratris* (Rotenberg et al. 2015). In general Tospoviruses are transmitted by thrips vectors in a persistant, propagative manner (Rotenberg et al. 2015). No evidence was found that the virus is naturally transmitted via soil (Google scholar/google searches; tomatoesnz). Of the described vectors, *F. occidentalis* is present in New Zealand (NZOR 2021). In the MPI (2022) it was determined that there is no feasable route of establishment for vector transmitted pathogens that are associated with fresh fruit. This conclusion is also shared by EFSA (2015) and DEFRA (2020) that do not consider that infected fresh fruit is an efficinet entry pathway for *X. fastidiosa*. Vectors of pathogens are considered seperately.
Cucumber mosaic virus	*Cucumber mosaic virus* is present in New Zealand and has been isolated from many host species (Veerakone et al. 2015). The species is recorded as non-regulated in ONZPR (2021). No evidence was found that isolates from pineapple represent a strain that is not present in New Zealand.
endogenous Pineapple pararetrovirus-1	There is not much information about this virus, however, all of the information found related to infection of pineapple plants (Hernandez-Rodriguez et al. 2013). No evidence of other hosts was found (Google and Google scholar). Therefore, exposure and establishment in New Zealand are unlikely.
Pineapple bacilliform CO virus	The species is not listed in NZOR (2021), Veerakone et al. (2015) or ONZPR (2021). All evidence found relating to these viruses identified pineapple as the only host (Gambley et al. 2008; Borah et al. 2013). No evidence was found of other hosts being infected by the virus and therefore, exposure and establishment is unlikely.
Pineapple bacilliform ER virus	The species is not listed in NZOR (2021), Veerakone et al. (2015) or ONZPR (2021). All evidence found relating to these viruses identified pineapple as the only host (Borah et al. 2013; Gambley et al. 2008). No evidence was found of other hosts being infected by the virus and therefore, exposure and establishment is unlikely.
Pineapple chlorotic leaf streak virus	No information found. Google and Google Scholar of 'Pineapple chlorotic leaf streak virus' did not find any information that this is an identified virus of pineapples.

Pineapple mealybug wilt-associated virus	The species is not recorded in Veerakone et al. (2015) and the regulatory status is listed as ‘not assessed’ (ONZPR 2021). From information found the hosts are limited to Ananas and Pseudoananas species (Hu et al. 2005; Jackson 2019). Therefore, based on available information unlikely to establish in New Zealand based on a lack of host availability. If further hosts are identified, such as through the emerging risk system, this may need to be reassessed.
Pineapple mealybug wilt-associated virus 1	The species is not recorded in Veerakone et al. (2015) and the regulatory status is listed as ‘not assessed’ (ONZPR 2021). From information found the hosts are limited to Ananas and Pseudoananas species (Hu et al. 2005; Jackson 2019). Therefore, based on available information unlikely to establish and cause impacts in New Zealand, based on a lack of host availability. If further hosts are identified, such as through the emerging risk system, this may need to be reassessed.
Pineapple mealybug wilt-associated virus 2	The species is not recorded in Veerakone et al. (2015) and the regulatory status is listed as ‘not assessed’ (ONZPR 2021). From information found the hosts are limited to Ananas and Pseudoananas species (Hu et al. 2005; Jackson 2019). Therefore, based on available information unlikely to establish and cause impacts in New Zealand, based on a lack of host availability. If further hosts are identified, such as through the emerging risk system, this may need to be reassessed.
Pineapple mealybug wilt-associated virus 3	The species is not recorded in Veerakone et al. (2015) and the regulatory status is listed as ‘not assessed’ (ONZPR 2021). From information found the hosts are limited to Ananas and Pseudoananas species (Hu et al. 2005; Jackson 2019). Therefore, based on available information unlikely to establish and cause impacts in New Zealand, based on a lack of host availability. If further hosts are identified, such as through the emerging risk system, this may need to be reassessed.
Pineapple mealybug wilt-associated virus 4	The species is not recorded in Veerakone et al. (2015) ONZPR (2021). From information found the hosts are limited to Ananas and Pseudoananas species (Hu et al. 2005; Jackson 2019). Therefore, based on available information unlikely to establish and cause impacts in New Zealand, based on a lack of host availability. If further hosts are identified, such as through the emerging risk system, this may need to be reassessed.
Pineapple mealybug wilt-associated virus 5	The species is not recorded in Veerakone et al. (2015) ONZPR (2021). From information found the hosts are limited to Ananas and Pseudoananas species (Hu et al. 2005; Jackson 2019). Therefore, based on available information unlikely to establish and cause impacts in New Zealand, based on a lack of host availability. If further hosts are identified, such as through the emerging risk system, this may need to be reassessed.
Tomato spotted wilt orthotospovirus	The species is present in New Zealand (Veerakone et al. 2015) and is non-regulated (ONZPR 2021). No evidence was found that the virus isolated from pineapple represents a strain not present in New Zealand.

References for Appendix 1

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Appendix 2 Taxa excluded during PRA stage

The following organisms have been included in the preliminary PRA list at the hazard identification stage. However, with further assessment, they are considered not to be a hazard in this IRA. The reason that they have been excluded in the PRA stage is documented here.

Appendix 2.1 *Dickeya dadantii* (bacterial wilt / soft rot)

Scientific name: *Dickeya dadantii* Samson et al. 2005
Order: Enterobacteria **Family:** Enterobacteriaceae
Other names: *Dickeya dadantii* subsp. *dadantii*; *Dickeya dadantii* subsp. *dieffenbachiae*; *Erwinia carotovora* var. *chrysanthemi*; *Erwinia chrysanthemi*; *Erwinia chrysanthemi* pv. *dieffenbachiae*; *Erwinia dieffenbachiae*; *Pectobacterium chrysanthemi*; *Pectobacterium chrysanthemi* pv. *dieffenbachiae***;** Soft rot of ornamentals/potato; bacterial wilt of ornamentals/potatoes.

Taxonomic notes:
The present *Dickeya* genus has been renamed on several occasions over the past 100 years. In 1920, *Dickeya* species all belonged to the *Erwinia* tribe that grouped all enterobacterial plant pathogenic bacteria (Winslow et al. 1920). In 1953, Burkholder et al. (1953) created the species *Erwinia chrysanthemi*. The species was elevated in 2005 to the genus *Dickeya* based on 16S rDNA sequence phylogeny (Samson et al. 2005). Six species were identified and confirmed by DNA-DNA hybridisation: *Dickeya chrysanthemi*, *Dickeya dadantii*, *Dickeya diffenbachiae*, *Dickeya dianthicola*, *Dickeya zeae* and *Dickeya paradisiaca*. *D. diffenbachiae* was later reclassified as a subspecies of *D. dadantii* by DNA-DNA hybridisation analysis and multilocus sequence analysis (Brady et al. 2012).

New Zealand status:
Dickeya dadantii is not known to be present in New Zealand.

- *Dickeya dadantii* and *D. dadantii* subsp. *dadantii* are recorded as absent in New Zealand (BiotaNZ 2022). The occurrence of *Dickeya dadantii* subsp. *dieffenbachiae* is recorded as Uncertain in BiotaNZ (2022) with a comment stating " Previously recorded as present based on the culture ICMP 8690 (Erwinia chrysanthemi) but that is a sample from PEQ[62]. [BSW, 17 July 2022]".
- The isolate referred to in BiotaNZ (2022) (ICMP 8690) was reclassified as *D. dadantii* subsp. *dadantii* by B.S. Weir in July 2022 based on assessment of multiple gene sequences. The bacterium was originally collected in 1984 by CF Hill from *Dieffenbachia* sp. showing rotten stem symptoms in an Ellersie [New Zealand] PEQ facility. At the time, it was identified as Erwinia chrysanthemi (ICMP 2022).
- There have been no subsequent records of *D. dadantii* in New Zealand since this detection in PEQ in 1984. As such, there is no record of *D. dadantii* in the environment in New Zealand.
- *Dickeya dadantii* is not listed in ONZPR (2022).

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[62] PEQ is post-entry quarantine facility.

Summary of reason for exclusion

Dickeya dadantii is not considered to be a hazard on pineapple fruit and excluded from this IRA because no evidence to confirm that *Dickeya dadantii* is associated with pineapple fruit or plants was found in the available English-language literature.

Supporting information

When Samson et al. (2005) described reclassified *Pectobacterium chrysanthemi* and *Brenneria paradisiaca* into a novel genus *Dickeya*, six new species were described. One of these species was *D. dadantii.* A collection of 75 strains were used to make this determination. In the Samson et al. (2005) description of *D. dadantii*, pineapple was listed as a plant host from which the pathogen was isolated. However, a thorough examination of descriptions and strains included in Samson et al. (2005) revealed none of the *D. dadantii* strains were isolated from pineapples. This was further demonstrated when the collections that hold the *D. dadantii* strains used by Samson et al. (2005) were also checked and found no evidence of the pathogen being isolated from pineapples was found (CIRM-CFBP 2021; NCPPB 2022).

The search terms [“Dickeya dadantii” AND “Pineapple” OR “Ananas comosus”] were used in Google Scholar. The first 50 results were checked and none of the results that listed pineapple as a host of *D. dadantii* had isolated the pathogen from the plant. All papers only cited Samson et al. (2005). Scientific papers published after 2005 on *Dickeya* species and/or *D. dadantii* cite the original Samson et al. (2005) article as evidence confirming pineapple as a host of *D. dadantii* or cite other authors who used Samson et al. (2005) as their evidence. Furthermore, the search terms “Bromeliaceae” AND “Dickeya dadantii” in Google Scholar and resulted found no original literature (i.e. not using Samson et al. (2005) as evidence) confirming *D. dadantii* host association with any member of the Bromeliaceae family.

A search of New Zealand interception records shows no records of *D. dadantii* or known synonyms between 2000–2020 (LIMS 2022). The European & Mediterranean Plant Protection Organization records interceptions of *Erwinia* sp. and *E. chrysanthemi* on potato seeds and tissue culture from the United Kingdom, Netherlands, Belgium, France, Taiwan, Thailand and Belgium (EPPO 2022).

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Appendix 2.2 *Melanoloma viatrix* (pineapple fly, mosca de la fruta de la piña)

Scientific name: *Melanoloma viatrix* Hendel 1911
Order: Diptera **Family:** Richardiidae
Other names: *Melanoloma canopilosum* Hendel 1933; *Melanoloma canopilosa; Melanoloma loew.*

New Zealand status:
Melanoloma viatrix is not known to be present in New Zealand.

- *Melanoloma viatrix* is not listed in NZOR (2022).
- *Melanoloma viatrix* is not listed in (BiotaNZ 2022).
- *Melanoloma viatrix* is not listed in PPIN (2022).
- *Melanoloma viatrix* is not listed in ONZPR (2022).

Summary of reasons for exclusion
MPI does not consider *Melanoloma viatrix* to be a hazard on pineapple fruit.

- We found no clear evidence that *M. viatrix* is present in any of the pineapple exporting markets in this IRA.
- Pineapple is the only known host of *M. viatrix*.

Supporting information
Google and Google Scholar searches (English and Spanish): *Melanoloma viatrix, Melanoloma canopilosum, Melanoloma canopilosa,* pineapple fruit fly, pineapple fruit fly, mosca de la fruta de la piña, mosca de la piña.

We found no clear evidence that *M. viatrix* is present in any of the pineapple-exporting markets in this IRA.

- There is a lack of information about *M. viatrix,* the genus *Melanoloma*, and the family Richardidae in general. *Melanoloma* is Neotropical (in Central and South America).
- *Melanoloma viatrix* is reported to be present in Mexico, Venezuela, Colombia, Ecuador (but see below), Perú, Bolivia (Bello Amez et al. 2020), Suriname (as *M. canopilosa*, Korytkoswski 1991 in Arevalo and Osorio (1995)) and Paraguay (Boscán de Martínez et al. (2000) in Sipes and de Matos (2018); Joy et al. 2012).
- *Melanoloma viatrix* has been reported in one pineapple exporting market included in this IRA, Ecuador, by a single source (Rogg 2001), cited by Bello Amez et al. (2020). Rogg (2001) wrote a generic document about integrated crop pest management in the Ecuadorian Amazon, and listed *M. viatrix* (as *M. canopilosum*) among the pests of pineapple, without providing any detail.
- *Melanoloma viatrix* is present in countries adjacent to Ecuador, Costa Rica and Panama, and coud be present also in these countries. However, we have no firm records, and therefore assume that *M. viatrix* is not present in Ecuador, Costa Rica and Panama for this IRA.

Pineapple is the only known host of *M. viatrix*.

- Pineapple is the only known host of *M. viatrix* (Arevalo and Osorio 1995; Bello Amez et al. 2020).
- Joy et al. (2012) reported that pineapple (*Ananas comosus*) is the “main host” of *M. viatrix*, citing Julca et al. (1992) and Bello Amez et al. (1997). The original sources report pineapple as the only known host (Bello Amez et al. 1997).
- Two other authors who published original research on *M. viatrix* confirmed that the only known host of *M. viatrix* is *A. comosus* (Dr Villalobos-Moreno and Mg. Sc. Germán Arellano Cruz, pers. comm.) (Arellano 2022; Villalobos-Moreno 2022).

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Appendix 2.3 Curvularia verruculosa

Scientific name: *Curvularia verruculosa* M.P. Tandon & Bilgrami ex M.B. Ellis 1966
Order: Pleosporales **Family:** Pleosporaceae
Other names: *Cochliobolus verruculosus* (Tsuda & Ueyama) Sivan.*; Pseudocochliobolus verruculosus* Tsuda & Ueyama.

New Zealand status:

- *Curvularia verruculosa* is recorded as an uncertain presence in New Zealand (BiotaNZ 2022).
- *Curvularia verruculosa* is regulated as the synonym *Cochliobolus verruculosus* (ONZPR 2022).

Summary of reason for exclusion
Curvularia verruculosa is not considered to be a hazard on pineapple fruit and is excluded from this IRA.

- There is insufficient evidence indicating *C. verruculosa* is associated with the commodity.

Supporting information
There is only a single source found indicating an association of *C. verruculosa* and pineapple, and all other literature found reporting an association use this source.

- MPI found a single field observation of *Curvularia verruculosa* on *Ananas comosus* (Adisa and Fajola 1982).
- There have been no new reports of *C. verruculosa* on *A. comosus* since 1982. A review of literature found five papers that mention an association between *C. verruculosa* and *A. comosus* (Adisa and Fajola 1982; Adisa 1983a; Adisa 1983b; Adisa 1985, 1988), all of which share an author. Sivanesan (1990) does not include *Ananas comosus* as a host, but does include *C. verruculosa* as a pineapple disease, referencing Adisa and Fajola (1982); Adisa (1983b).
- There have been no reported interceptions of this pest on pineapple in New Zealand (LIMS 2022).
- This association has not been reported since the original report. Only a single review paper has been sighted reporting this association, citing Adisa. No other sighted database, review, handbook, or compendium reported an association.

The association of *C. verruculosa* with pineapple fruit is based on morphological characteristics, which has limited diagnostic value for this genus.

- Adisa and Fajola (1982) used morphological identification to describe the association of *C. verruculosa* with *Ananas comosus.*
- In the same year that the pineapple observation was made, it was noted that: *"Uncertainty in practical identifications of* Curvularia *species is in part caused by variability in conidium morphology … This is also true for C. verruculosa"* (Tsuda and Ueyama 1982).

- Huang et al. (2005) reported that “The [*C.verruclosa*] spores are similar in morphology to those of *C. lunata* except for the verrucose surface. Past diagnoses of Curvularia leaf spot may have mistakenly identified *C. verruculosa* as *C. lunata.”*.
- Other recent studies have found that that morphological identification of *Curvularia* morphology does not correlate with molecular identification (Janardhan and Vijayan 2012; Manamgoda et al. 2012; da Cunha et al. 2013; Madrid et al. 2014).
- It is extremely difficult to distinguish species within the *Curvularia* genus based on morphological characteristics.

Literature review: We conducted a thorough online search of scientific literature using the Google chrome search engine, Google Scholar and CABI Direct.
["*Cochliobolus verruculosus*" OR “*Pseudocochliobolus verruculosus”* and "*Ananas comosus*" OR “Pineapple”] returned no relevant results. [“*Curvularia verruculosa*” AND "*Ananas comosus*" OR “Pineapple”] returned one relevant result (Adisa 1985) in Google scholar. ["*Curvularia verruculosa*" AND "Pineapple"] returned 584 results, of which the first 60 results were considered. Relevant results found were Adisa (1988), Adisa (1985) and Adisa (1982) using the Chrome search engine.

In CABI Direct [*Curvularia verruculosa Ananas comosus*] returned no results. [*Curvularia verruculosa*] returned 17 results, none of which were relevant. [*Pseudocochliobolus verruculosus*] returned 23 results, including Sivanesan (1990), which notes *C. verruculosa* as a disease of pineapple, referencing Adisa and Fajola (1982).

We also consulted review papers and databases concerning pineapple diseases.
These did not show an association between *Ananas comosus* and *Curvularia verruculosa* or synonyms. EPPO (2022) does not include *Ananas comosus* on the host list of *Curvularia verruculosa*. Rohrbach and Johnson (2003) did not include *C. verruculosa* as a pest of *A. comosus*. Rohrbach and Phillips (1989) did not include *C. verruculosa* as a post-harvest rot of pineapple fruit.

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Appendix 2.4 Curvularia eragrostidis

Scientific name: *Curvularia eragrostidis* (Henn.) J.A. Mey. 1959
Order: Pleosporales **Family:** Pleosporaceae
Other names: *Brachysporium eragrostidis* Henn. 1908**,** *Cochliobolus eragrostidis* (Tsuda & Ueyama) Sivan. 1987**,** *Curvularia maculans* (C.K. Bancr.) Boedijn 1933**,** *Pseudocochliobolus eragrostidis* Tsuda & Ueyama 1985**,** *Spondylocladium maculans* C.K. Bancr. 1913 (BiotaNZ 2022); Leaf blight of pineapple, leaf spot of maize (EPPO 2022).

New Zealand status

Curvularia eragrostidis is not known to be present in New Zealand,

- *Curvularia eragrostidis* is recorded in (NZOR 2022) as "Border Intercept".
- Biostatus of *Curvularia eragrostidis* in New Zealand is "Border intercept" in BiotaNZ (2022).
- There is an entry of *Curvularia eragrostidis* in PPIN (2022) stating that "This organism has been entered for use in border, post border and post entry quarantine identifications in the STARS database. This organism is not established in New Zealand. Dated: 03 May 2005, J. Khan".

Curvularia eragrostidis is a regulated pest for New Zealand (ONZPR (2022)).

Summary of reason for exclusion

Curvularia eragrostidis is not a hazard on pineapple fruit. MPI has not assessed the risk of *C. eragrostidis* further.

- *Curvularia eragrostidis* is known to cause of leaf spot symptoms in pineapple plants, but there is very limited information indicating it is a pathogen of pineapple fruit.
- It is unclear from available literature whether the reported postharvest rot symptoms in pineapple fruit are the result of opportunistic colonisation of wounded fruit by *C. eragrostidis* or whether the fungus is regularly associated with these symptoms in pineapple fruit.
- Previous MPI assessments suggest that the fungus can only spread over short distances.
- *Curvularia eragrostidis* is known to be associated with a number of hosts present or cultivated in New Zealand, but no evidence was found of economic impacts to hosts of economic importance to New Zealand.
- There are no known environmental impacts caused by *C. eragrostidis,* although the fungus is known to cause "rusty flower disease" symptoms in *Dendrobium* orchids in Thailand.

Supporting information

Literature search: we conducted an online search of scientific literature using Google Scholar, the web, CABI Abstracts and the CABI *Crop Protection Compendium*. We used the terms '*Curvularia eragrostidis* AND pineapple/*Ananas comosus*/la pina' and '*Curvularia eragrostidis* AND disease/distribution'. We included common synonyms of *C. eragrostidis* in the searches.

There is insufficient evidence that *Curvularia eragrostidis* is associated with decrowned pineapple (as described in the commodity description), although it is known to cause leafspot disease on *Ananas comosus.*

- *Curvularia eragrostidis* has been reported to cause leaf spot symptoms in pineapple plants (Kranz 1964, 1965; Luo et al. 2012; García-Ordaz et al. 2021).
- However, only three references, have found the fungus in association with pineapple fruits and only one of these references reported it as a pathogen on pineapple fruit.
    - Ferreira et al. (2014): *Curvularia eragrostidis* was found as the causal agent of postharvest rot of pineapple fruits, with initially no visible outer symptoms being infected by rot extending to the core; symptoms on pineapple fruits showed three days after being on the market.
    - Kranz, 1964: no details were given about the condition of the pineapple fruit, no pathogenicity tests were done, but a side note was provided stating that *C. maculans* (synonym of *C. eragrostidis*) was isolated from a pineapple fruit. In their later paper, Kranz (1965) associated their 1964 finding with dry rot (‘Trockenfaeule’).
    - Kuruppu et al. (2022): ‘*Thielaviopsis paradoxa* was the main black rot causal agent and *A. aculeatus, C. eragrostidis* and *T. asperellum* were confirmed as associated fungi with diseased fruits.’ Their study suggested either a very minor role in causing disease or a co-infection by *Curvularia eragrostidis*; however, pathogencity test was not conducted with *C. eragrostidis*.

It should be noted that if pineapple fruit is infected with the fungus it may not be obvious by visual inspection. However, it is unclear from the available literature whether the reported rot symptoms in pineapple fruit are the result of opportunistic colonisation of wounded fruit by *C. eragrostidis* or whether the fungus is regularly associated with these symptoms in pineapple fruit.

- *Curvularia eragrostidis* does not always cause externally visible symptoms (Ferreira et al. 2014), therefore it is possible it is not detected through visible inspection.
- MPI could not find any information available on typical incubation periods until symptom expression for near natural conditions. However, in inoculation experiments it took seven days until visible symptoms were present on pineapple fruit (Ferreira et al. 2014).
- However, only one paper (Ferreira et al. 2014) was found indicating the fungus is pathogenic to pineapple fruit, and it was reported as postharvest rot. It is uncertain if the reported rot symptoms in pineapple fruit are the result of opportunistic colonisation of wounded fruit by *C. eragrostidis*, and there is no evidence indicating the fungus is regularly associated with postharvest rot symptoms in pineapple fruit.

Previous MPI assessments suggest that the fungus can only spread over short distances.

- According to a previous PRA for onions by MPI (MAF 2009), *Curvularia eragrostidis* is expected to spread only over short distances with wind (Sivanesan 1990) and rain/irrigations as the main dispersal modes for conidia (asexual reproducing spores).

Curvularia eragrostidis is known to be associated with a number of hosts present or cultivated in New Zealand, but no evidence was found of economic impacts to hosts of economic importance to New Zealand.

- *Curvularia eragrostidis* has a wide host range (Farr and Rossman 2021), which includes species present in New Zealand such as: *Triticum, Allium cepa, Allium sativum, Ananas comosus, Capsicum annuum, Dioscorea* sp., *Eragrostis chapilieri, Eucalyptus globulosus, Solanum lycopersicum, Musa×sapientum, Panicum miliaceum, Phalaenopsis amabilis, Phaseolus vulgaris, Pinus patula, Sorghum*

plumosum, Vigna unguiculata, Zea mays, and *Saccharum officinarum* (Farr and Rossman 2021).
- Despite the wide host range and the wide distribution of *Curvularia eragrostidis* in mostly tropical and subtropical countries ((Ferreira et al. 2014; Farr and Rossman 2021)), MPI could not find any reports of damage to economical species of concern for New Zealand.
- There is one report (Zhu and Qiang 2004) on infection of corn (*Zea mays*) caused by *C. eragrostidis,* but it was an inoculation experiment: *Curvularia eragrostidis* was studied as a biocontrol agent for *Digitaria sanguinalis* (large crabgrass a weed species), and the study found that *C. eragrostidis* did not cause any significant changes to dryweight of corn nor cause mortality when had been inoculated with *C. eragrostidis* isolate QZ-2000.

There are no known environmental impacts caused by *C. eragrostidis*, although the fungus is known to cause “rusty flower disease” symptoms in *Dendrobium* orchids in Thailand.
- MPI could not find any direct reports of suceptability of native/endemic species to *Curvularia eragrostidis.* However, *Dendrobium* orchids were impacted in Thailand by *C. eragrostidis* where the fungus caused rusty flower disease rendering flowers impossible to sell (Středa et al. 2013). No information was given on reproductive impacts on the infected flowers. It is not known if *C. eragrostidis* would cause any symptoms on *Dendrobium cunninghamii* or other native orchid species.

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Appendix 2.5 Daldinia eschscholtzii

Scientific name: *Daldinia eschscholtzii* (Ehrenb.) Rehm (1904)
Order: Xylariales **Family:** Hypoxylaceae
Other names: *Sphaeria eschscholtzii* Ehrenb (1820); *Daldinia concentrica* var. *eschscholtzii* (Ehrenb.) (1901); *Sphaeria concentrica* var. *eschscholtzii* (Ehrenb.) (1823); *Daldinia eschscholzii* (Ehrenb.), Rehm (1904); *Daldinia concentrica* var. *eschscholzii* (Ehrenb.), Starbäck (1901); *Daldinia luzonensis* Rehm, (1913); *Sphaeria eschscholzii* Ehrenb. (1820); *Sphaeria concentrica* var. *eschscholzii* (Ehrenb.) (1823).

Taxonomic notes

Daldinia eschscholtzii is considered a species complex (Tarman et al. 2012). The complex has been revised multiple times (Child 1932; Triebel et al. 2005; Stadler et al. 2014).

New Zealand status

- *Daldinia eschscholtzii* is not known to be present in New Zealand (BiotaNZ 2022). It was previously erroneously recorded as present in the South Island, but that specimen has been identified as a fungus that is the southern hemisphere counterpart of *D. eschscholtzii* (Stadler et al. 2014).
- *Daldinia eschscholtzii* is not listed in ONZPR (2022).

Summary of reason for exclusion

MPI does not consider *Daldinia eschscholtzii* to be a hazard on pineapple fruit. MPI has not assessed the risk of *D. eschscholtzii* further.

- This fungus is not commonly associated with pineapples and is not known to cause disease in pineapples.
- This species complex is mostly found as an endophytic fungus or wood decaying fungus
- MPI found no reports of *Daldinia eschscholtzii* causing disease on other crops or non-crop plant species despite its very wide, almost exclusively tropical distribution.

Supporting information

We conducted an online search of scientific literature using Google Scholar, the web, CABI Abstracts and the CABI *Crop Protection Compendium*. We used the terms '*Daldinia eschscholtzii* AND pineapple/*Ananas comosus*/la pina' and '*Daldinia eschscholtzii* AND disease'. We included common synonyms of *D. eschscholtzii* in the searches.

There is insufficient evidence that *Daldinia eschoscholztii* is associated with decrowned pineapple (as described in the commodity description). Only two references, from the same authors (Castro and Umaña 2015, 2017) referring to one survey, have found the fungus in association with decrowned pineapple fruits and their study had some limitations:

- The authors conducted one survey on pineapples during the post-harvest process in Costa Rica and found a variety of fungi, including *D. eschscholtzii* in the disinfecting water, the reused wax, and the coolant room air. They reported that in about 10% of the tested pineapples *D. eschscholtzii* was found year-round.
- However, they did not conduct any experimental inoculum pathogenicity testing to confirm any disease symptoms on pineapples. Although the fungus appears to be able to colonise pineapples, this could be be an incidental observation due to

contamination of the post harvest process. How ripeness of the pineapple influenced the colonisation was not clear from the methods. Since the observation occurred in combination with other fungi, which were more frequently encountered and then mould occurred, there is high uncertainty about the fungi's ability to cause disease on its own on pineapples.

- One other study isolated *Daldinia eschscholtzii* as non-symptomatic endophytic fungus from *Ananas comosus* leaves in India from a monoculture, but not from a mixed crop area or where pineapples grew wild (Bhattacharya et al. 2020). It remained unclear if the fungus would be present in decrowned pineapples as per commodity description as only leaves and roots were tested in this study.
- Given the very wide host range of *D. eschscholtzii,* the fungus can be expected on a variety of species. *Daldinia eschscholtzii* most commonly has an endophytic or wood decaying lifestyle (Lee et al. 2019). Fungi in the genus *Daldinia* are not considered parasitic and specimens which were occasionally collected from living organisms such as trees, were thought by Stadler et al. (2014) to be most likely collected from wounded or naturally aged plants. Specimens of *D. eschscholtzii* have also been isolated from marine algae (Tarman et al. 2012) and human skin, nails and blood (Ng et al. 2016). Although the fungus does not typically cause disease in humans or plants, (Ng et al. 2012) identified genes of an isolate of *D. eschscholtzii* that are commonly associated with enzymes that degrade plant wall cells, mycotoxin production, and resistance to antifungal drugs.
- The genus *Daldinia* and the family Hypoxylaceae have undergone various revisions (Triebel et al. 2005; Bitzer et al. 2008; Stadler et al. 2014), and new records of *Daldinia eschscholtzii* have been found in new association and locations over the years. For example, in 2019, Samarakoon et al. (2019) reported *D. eschscholtzii* on *Musa* leaves in Thailand, and Lee et al. (2019) reported it from *Camellia japonica* in Korea. However, despite these new records there is no support for pathogenicity of *Daldinia eschscholtzii.* The *D. eschscholtzii* group is thought to have a very wide, almost exclusively tropical distribution and is considered to be the most important tropical group of *Xylariaceae* (Stadler et al. 2014)
- Despite the research interest in *D. eschscholtzii* due to its secondary metabolic compounds, there is no evidence of this fungus being a pathogen that causes disease on plants.

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Appendix 2.6 Fusarium concentricum

Scientific name: *Fusarium concentricum* Niremberg & O'Donnell (1998)
Order: Hypocreales **Family:** Nectriaceae

Taxonomic notes

Fusarium concentricum is part of the *Gibberella fujikuroi* species complex (GFSC) (Kvas et al. 2019). This species was considered part of *F. subglutinans* sensu lato within the GFSC based on morphological characteristics of the conidia (Niremberg and O'Donnell 1998). However, species within the GFSC were reevaluated based on morphological, molecular and phylogenetic analyses and as a result, *F. concentricum* was recognized along with others as a separate species (Aoki et al. 2001).

New Zealand status:

- *Fusarium concentricum* is not known to be present in New Zealand
  - It is not listed in BiotaNZ (2022).
  - It is not listed in PPIN (2022).
- *Fusarium concentricum* is regulated (ONZPR 2022).

Summary of reason for exclusion

MPI does not consider *Fusarium concentricum* to be a hazard on pineapple fruit and excluded it from this IRA because there is not enough evidence that it is associated with pineapple.

Supporting information

We searched scientific literature using Google and Google Scholar and the search terms "*Fusarium concentricum*", "*Fusarium concentricum* AND *Ananas comosus*" and "Gibberella fujikuroi species complex", as well as databases such as U.S. National Fungus Collections and Index Fungorum.

We did not find enough evidence that *Fusarium concentricum* is associated with decrowned pineapple (as described in the commodity description). There is one record found of *F. concentricum* associated with decrowned pineapples (Stępień et al. 2013). The fungus was collected from fruit purchased in Europe and South Asia to eat after the fruit had been exported from Costa Rica and other countries. MPI does not consider this evidence of host association because it is unknown if the fruit was infected in Costa Rica or after exportation (Stępień et al. 2013; Urbaniak et al. 2019)

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Appendix 2.7 *Chrysodeixis includens* (golden twin-spot moth)

Scientific name: *Chrysodeixis includens* (Walker, 1858)
Order: Lepidoptera **Family:** Noctuidae
Other names: *Autographa oo* (Stoll)**;** *Autographa rogationis* (Guenée)*; Phalaena oo* (Stoll, 1872)*; Phytometra oo* (Stoll)*; Phytometra rogationis; Plusia binotula* (Herrich-Schaffer, 1868)*; Plusia dyaus* (Grote, 1875)*; Plusia hamifera* (Walker, 1858)*; Plusia includens* (Walker, 1858)*; Plusia oo* (Stoll in Cramer, 1782)*; Plusia rogationis* (Guenée)*; Pseudoplusia includens* (Walker, 1858)*; Pseudoplusia oo* (Stoll in Cramer, 1782)*; Pseudoplusia pertusa* (Möschler, 1880)*; Pseudoplusia rogationis* (Guenée, 1852)*; Pusia culta* (Lintner, 1885) (CABI 2021)**;** Golden twin-spot moth; Soybean lopper moth.

New Zealand status:

- *Chrysodeixis includens* is not known to be present in New Zealand.
    - *Chrysodeixis includens* is not listed in NZOR (2022).
    - *Chrysodeixis includens* is not listed from New Zealand in BiotaNZ (2022).
    - *Chrysodeixis includens* is not listed in (PPIN 2022).
- *Chrysodeixis includens* is a regulated pest for New Zealand (ONZPR 2022).

Summary of reason for exclusion

MPI does not consider *Chrysodeixis includens* to be a hazard on pineapple fruit and excluded it from this IRA, because there is insufficient evidence indicating this species is associated with the commodity.

Supporting information

The search terms 'Chrysodeixis includens' and 'Ananas comosus', and 'Chrysodeixis includens' and 'pineapple' were used in the Centre for Agriculture and Bioscience International Abstracts, the European and Mediterranean Plant Protection Organization, Google, Google Scholar, and PubMed.

Chrysodeixis includens larvae have a weak association with pineapple fruit. Detoni et al. (2018) were the first to report pineapple fruit as a host of *C. includens*, and this is the only report so far of pineapple as a host of the insect. *C. includens* is well studied as an economically-important agricultural pest, and the larval association with pineapple fruit appears to be weak based on the lack of published observations in the literature. Females predominantly lay eggs on the underside of host leaves (Pereira et al. 2018), and so the egg stage is unlikely to be associated with pineapple fruit. Similarly, the adult stage is unlikely to be associated with pineapple fruit as larvae are the primary feeding stage of *C. includens*.

Chrysodeixis includens larvae are likely to be detected during packhouse (cleaning/grading) activities. According to evidence gathered by Detoni et al. (2018), external damage on pineapple fruit in the form of lesions and holes caused by larvae feeding is clearly visible. Furthermore, the caterpillars themselves are relatively conspicuous given they are predominantly light to dark green, with distinctive white stripes down the dorsal and lateral parts of its body (Carter and Gillett-Kaufman 2021). This, coupled with the body length of catepillars reaching around 3 cm (Carter and Gillett-Kaufman 2021) indicates it is unlikely larvae would go undetected by hiding under fruit bracts or other crevices.

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Appendix 2.8 *Elaphria nucicolora* (sugarcane midge moth)

Scientific name: *Elaphria nucicolora* (Guenée 1852)
Order: Lepidoptera **Family:** Noctuidae
Other names: *Monodes nucicolora; Elaphria clara; Elaphria paginata; Elaphria unisignata;* soldier worm (Rodríguez-Rodríguez 2010).

New Zealand status:

- *Elaphria nucicolora* is not known to be present in New Zealand.
    - There is no entry in BiotaNZ (2022) or PPIN (2022).
- *Elaphria nucicolora* is a regulated pest for New Zealand (ONZPR 2022).

Summary of reason for exclusion

MPI does not consider *Elaphria nucicolora* to be a hazard on pineapple fruit and it is excluded from this IRA, because fruit produced from plants infested by this pest will not meet the commodity description and are thereby highly unlikely to be selected for export.

Supporting information

Online search of scientific literature was conducted using Google and Google Scholar using the search terms "*Elaphria nucicolora*", "*Elaphria nucicolora*" AND "Pineapple" or "*Ananas comosus*" *Elaphria nucicolora*" and "Sugarcane Midge Moth". The first 50 results both in English and Spanish language were reviewed.

Fruits from pineapple plant infested with *Elaphria nucicolora* will not meet the commodity description for this IRA and are highly unlikely to be selected for export.

- *Elaphria nucicolora* mainly attacks pineapple crops at the onset of fruit development (Jiménez 2013). Eggs are laid on the inflorescence before it opens (Nath P 2015; Lam 2017) and when the eggs hatch, larvae can infest the young developing pineapple fruit (Vindas 2011; Jiménez 2013; Lam 2017). There is no report of eggs of *Elaphria nucicolora* being laid on pineapple fruit (Nath P 2015).
- Fruits from plants infected by *Elaphria nucicolora* have no market appeal, this leads to their rejection at pack houses (Vindas 2011; Nath P 2015). Larvae which are usually between 3-3.5 cm large voraciously feed on the exocarp of developing fruit causing visible damage to the skin; producing translucent colouration of pulp, external gummosis, and deformity (Vindas 2011; Jiménez 2013; Lam 2017).
- This pest is unlikely to be associated with fully matured fruits because it infests pineapple plants when the plant is about 76 days old, at the onset of flowering (Lam 2017). It takes 120-150 days after fruit initiation for pineapple fruit to mature (Connolly 2022). Under laboratory conditions at 21^{o} C, it completes its life cycle in approximately 32 days (Habeck 1965). This suggests that infested fruit will show obvious damage before it fully matures "120–150 days", as such damaged fruits are likely to be detected and culled.
- Very little information is available on the association of *Elaphria nucicolora* with pineapple. Studies on its association with pineapple are mainly unpublished theses (Rodríguez-Rodríguez 2010; Vindas 2011; Jiménez 2013), a review (Nath P 2015)

and an NPPO Risk Assessment (NPPO 2015). This suggests that it is mainly of interest in specific countries where it is reported to occur, such as Costa Rica, Mexico and Hawaii.
- There are no records of interception of *Elaphria nucicolora* on pineapples from any country (LIMS 1986–2020).

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Appendix 2.9 *Opogona sacchari* (banana moth)

Scientific name: *Opogona sacchari* (Bojer, 1856)
Order: Lepidoptera **Family:** Tineidae
Other names: *Alucita sacchari* Bojer; *Tinea subcervinella* Walker; *Gelechia sanctaehelenae* Walker; *Gelechia ligniferella* Walker; *Laverna plumipes* Butler; *Hieroxestis sanctaehelenae* (Walker); *Hieroxestis plumipes* Butler; *Hieroxestis subcervinella* (Walker); *Euplocamus sanctaehelenae* (Walker); *Opogona subcervinella* (Walker); *Opogona sanctaehelenae* (Walker) (EPPO, 2006), sugarcane stalk borer; sugarcane borer; sugarcane moth (EPPO 2022; Gibbs 1991)

New Zealand status:

- *Opogona sacchari* is not known to be present in New Zealand.
    - There is no entry for it in BiotaNZ (2022) or PPIN (2022).
- *Opogona sacchari* is regulated and is an unwanted organism (ONZPR 2022).

Summary of reason for exclusion

MPI does not consider *Opogona sacchari* to be a hazard on pineapple fruit. We excluded it from this IRA because:

- it is unlikely to be associated with pineapple fruit as per the commodity description, and
- there is not enough evidence that *Opogona sacchari* is present in any of the exporting markets.

Supporting information

We conducted an online search of scientific literature using Google and Google Scholar using the search terms "*Opogona sacchari*", "*Opogona sacchari* AND *Ananas comosus*", "*Opogona sacchari* AND piña", "banana moth".

Opogona sacchari is unlikely to be associated with pineapple fruit as per commodity description because:

- *Opogona sacchari* larvae mainly attack pineapple planting material such as slips, suckers and crown (Vorsino et al. 2005; Wright 2012 in Sipes and Wang 2017), which are not part the commodity. However, at high infestation levels, larvae can attack the maturing pineapple fruit by boring into the rind (Vorsino et al. 2005), causing gummosis (carbohydrate-rich excretions), which is easily detectable visually. Fruit with gummosis is rejected in the packhouse (Vorsino et al. 2005; Sipes and Wang 2017).
- *Opogona sacchari* attacks plant tissue that is already damaged and then spreads to healthy plant tissue (Heppner et al. 1987). In Barbados, *O. sacchari* was most abundant in dead or dying stumps and dead sugar canes after they had been attacked by *Diatraea saccharalis* (Lepidoptera: Crambidae), suggesting that *O. sacchari* is an opportunistic pest (Davis and Peña 1990).
- We found no information on the location of egg deposition specifically on pineapples. On other plants, eggs are laid singly or in groups on unexpanded leaves, stems and bark (Davis and Peña 1990; EPPO 2006; CABI 2020).

There is insufficient evidence that *Opogona sacchari* is present in any of the exporting markets. There are unvalidated reports of detections on nursery stock from Costa Rica, Taiwan and Indonesia.

- *Opogona sacchari* has been detected in Chile on imported nursery stock (plants for planting) of *Dracaena fragans massangeana*, *Chamaedorea elegans* and *Phoenix roebelenii*. According to SAG (2019), these plants were traced back to Costa Rica, but this has not been confirmed by MPI. There is some uncertainty regarding the circumstances of *O. sacchari* detections because it is not known whether the plants were kept outdoors or were exposed to other plants, which could have been a source of contamination (SAG 2019).
- PestNet (2022) posted a report of larvae intercepted on *Yucca elephantipes* and *Dracaena* plants imported from Costa Rica, Taiwan and Indonesia, which members andecdotally considered to be *O. sacchari*.

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Appendix 2.10 *Carpophilus mutilatus* (confused sap beetle)

Scientific name: *Carpophilus mutilatus* Erichson, 1843
Order: Coleoptera **Family:** Nitidulidae
Synonyms/other names: *Carpophilus luridus* Murray, 1864 (synonymy from Brown 2009)
Other names: Flower beetle

Taxonomic notes

Carpophilus mutilatus is a member of the *C. dimidiatus* complex. The members of this complex are very difficult to distinguish. DiLorenzo et al. (2021) state, "There are currently no known external characters to reliably distinguish members of the *dimidiatus* complex from one another." Other members of the complex are reported from New Zealand, e.g. *C. dimidiatus* (NZOR 2022).

New Zealand status

- *Carpophilus mutilatus* is not known to be present in New Zealand. (NZOR 2022) and BiotaNZ (2022) state it has been recorded in error.
- *Carpophilus mutilatus* is reported to be present in New Zealand in PPIN (2022), but the record has been refuted (see note below).
- *Carpophilus mutilatus* is a regulated pest for New Zealand (ONZPR (2022).

Note: Leschen and Marris (2005) state, "This species was described from western India and the first record of this species in New Zealand was by Hutton (1904). We have examined specimens that were intercepted from produce originating from Australia. We find no evidence of establishment of this species in New Zealand, contrary to the findings of Archibald and Chalmers (1983). *Carpophilus mutilatus* did not fit the criteria of an established species as indicated in the introduction. There was a PPIN record for the species but we were unable to locate that specimen in borrowed material and we could not validate the record."

Hosts and geographical distribution

Adult and larval sap beetles live and develop in organic matter, including ripe and rotting fruit, decaying plant tissues and stored products. They are generally associated with a wide range of plant species (Wakil et al. 2015). *Carpophilus mutilatus* has been reported from breadfruit, citrus, coconut, corn, cycads, grapes, island chestnuts, lentil seeds, *Pandanus*, quince, papaya, peppers, mangoes, melons, passionfruit, pipfruit, sugarcane, *Calophyllum, Helianthus* and *Hibiscus* (Crosby and Choquenot 2005; Marler and Muniappan 2006; Brown 2009).

Carpophilus mutilatus is thought to be native to Central and South America, and has been found in many countries, including Bangladesh, India, Israel, Philippines, Saudi Arabia, Czechia, Denmark, France, Germany, Italy, Lithuania, Malta, Sweden, Antigua and Barbuda, the USA, and Australia (Mostafa et al. 2017; CABI 2019). This species is also reported widely through the Pacific region, including the Caroline Islands, Cook Islands, Fiji, Gilbert Islands, Guam, Hawai'i, Marianna Islands, Marshall Islands, Nauru, New Caledonia, Samoa, Society Islands, Solomon Islands and Vanuatu (Brown 2009).

Given the similarity of *C. mutilatus* to other *Carpophilus* species (particularly *C. dimidatus*) and the historical confusion over identification (Leschen and Marris 2005; Brown 2009), there is a moderate level of uncertainty regarding the host ranges and geographical distribution of these species.

Summary of reasons for exclusion

Carpophilus mutilatus is not considered to be a hazard on fresh pineapple fruit. MPI has not assessed the risk of *C. mutilatus* further. *Carpophilus mutilatus* has been identified once at the New Zealand border on imported pineapple fruit. However:

- Like other sap beetles, *C. mutilatus* is generally associated with overripe, damaged, rotten and/or dried fruits and vegetables; and
- We found no reports of *C. mutilatus* causing impacts on fresh pineapple, despite its wide geographical distribution.

Supporting information

We collected evidence for this PRA exclusion note using various combinations of "*Carpophilus mutilatus*", "confused sap beetle/flower beetle" and "pineapple/*Ananas comosus*" as search terms on Google, Google Scholar, CNKI and CAB Abstracts. We reviewed the first 100 search results (10 webpages) of each specific search combination. We also collected information on '*Carpophilus'* AND 'pineapple/*Ananas comosus*' and 'sap beetle AND pineapple/*Ananas comosus*' in the searches.

Carpophilus mutilatus is unlikely to be commonly associated with this fresh pineapple commodity.

- We found no evidence that fresh pineapple is a host of *C. mutilatus*.
    - In common with other *Carpophilus* beetles, *C. mutilatus* is generally associated with stored fruit products, or fruits and other plant parts that are ripening or decomposing (James et al. 1995; Wakil et al. 2015).
- We found no evidence that *Carpophilus* beetles are directly associated with fresh pineapple fruit.
    - There are no reports in the last 30 years describing an infestation of any *Carpophilus* beetles on fresh pineapple. The records of pineapple hosting *C. hemipterus* and *C. obsoletus* in some reports (Bartholomew and Malézieux 1994; Leschen and Marris 2005; Wakil et al. 2015) are likely interpreted from old reports, which may only record the *Carpophilus* beetles present in pineapple orchards or infesting trash or overripe pineapple fruit, rather than fresh fruit.
    - Schmidt (1935) reported six species of sap beetles in the pineapple fields of Hawaiʻi, of which *C. hemipterus* and *C. humeralis* were the most common. Laboratory feeding tests of these two species on fruits, however, showed that beetles could not burrow into green pineapple skin even when starved. For ripe pineapples, the author stated, "in all cases where the fruit as a whole remained sound the beetles did not penetrate it."
    - Covas and Gaud (1983) reported that pineapple gummosis (which is generally mainly caused by insect damage in the field) could aid *C. humeralis* to burrow into fruits. However, gummosis is a quality defect, and any pineapples with gummosis would be excluded from the pathway.
    - The feeding behaviours of *Carpophilus* beetles (e.g. host selection) are affected by microorganisms (e.g. yeasts) on ripening and rotting fruit (and producing fermentation volatiles) (Zilkowski et al. 1999; Bartelt and Hossain 2006; Baig et al. 2020).

- *Carpophilus mutilatus* has been identified only once on fresh pineapple pathway at the New Zealand border.
    - *Carpophilus* beetles have been intercepted at the New Zealand border more than 854 times on fresh produce pathway, while 69 times on fresh pineapple with only one record associated with *C. mutilatus* (consignment C2020/876697) (LIMS 2022).
    - At the New Zealand border, *C. mutilatus* has only been identified six times on fresh produce: on kava sticks, capsicum (consignment C2008/185844), onion, garlic and pomegranate (LIMS 2022).
    - *Carpophilus mutilatus* has not been detected at the European Union border. *C. hemipterus* has been intercepted on fresh pineapple and apple, but other intercepted species of *Carpophilus* beetles were only associated with stored products (EPPO 2022).

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Appendix 2.11 *Metamasius hemipterus* (West Indian sugarcane borer)

Scientific name: *Metamasius hemipterus* (Linnaeus)
Order: Coleoptera **Family:** Dryophthoridae
Other names: *Metamasius sericeus*, rotten cane stalk borer, silky cane weevil, weevil borer

Taxonomic notes

There are three recognized subspecies of this weevil; *M. h. hemipterus* (L.) is distributed southwards from Puerto Rico through the Lesser Antilles and into most of South America; *M. h. sericeus* (Olivier) is found in the Greater Antilles and Central America south from Nicaragua to western Colombia and Ecuador; while *M. h. carbonarius* (Chevrolat) occurs from Mexico south to El Salvador and Honduras (Vaurie 1966). Recent , molecular data suggest that *M. h. hemipterus* could be elevated to a separate species, and *M. h. sericeus* and *M. h. carbonarius* could be treated as the same species (Palmieri et al. 2022). The biology of the three subspecies currently recognized is very similar (Giblin-Davis et al. 1994).

New Zealand status:

- *Metamasius hemipterus* is not known to be present in New Zealand.
    - *Metamasius hemipterus* is not listed in NZOR (2022).
    - *Metamasius hemipterus* is not listed in PPIN (2022).
    - *Metamasius hemipterus sericeus* is not present in New Zealand (PPIN 2022).
    - There is no entry for *M. hemipterus* in BiotaNZ (2022).
    - *Metamasius hemipterus* is a regulated and unwanted organism (ONZPR 2022).
    - *Metamasius hemipterus sericeus* is a regulated and unwanted organism (ONZPR 2022).

Summary of reason for exclusion

MPI does not consider *Metamasius hemipterus* to be a hazard on pineapple fruit and excluded it from this IRA because pineapple fruits infested by *M. hemipterus* do not meet the commodity description.

Supporting information

The search terms [“*Metamasius hemipterus*” AND “Pineapple” OR “*Ananas comosus*”] were used in Google and Google Scholar. The first 50 results were checked both in English and Spanish language.

Pineapple fruits infested by *M. hemipterus* do not meet commodity description.

The occasional presence of *M. hemipterus* on pineapple plants causes visible damage to the plants before the fruit is produced and eventually attacked.

- *Metamasius* spp. (e.g. *M. hemipterus, M. callizona, M. dimidiatipennis*) weevils are reported as occasional production pests of cultivated pineapples (Frank and Cave 2005; Rodríguez-Rodríguez 2010; Thorn et al. 2019).
- The pineapple plants attacked by *Metamasius* weevils are visibly damaged (Rodríguez-Rodríguez 2010).
- On pineapple plants, *M. hemipterus* adults (9-14 mm long (CAPS 2013)) live, feed and lay their eggs (1.7 mm long[1]) in the central leaves. Larvae (3.2 to 4.5 mm wide,

15–17 mm long (CAPS 2013)) are mostly found in the lower stalk of the plant and prefer to pupate in the peduncle.

- Adults of *M. hemipterus* feed on the apical meristem of the pineapple plant, and focus on tender leaves (Rodríguez-Rodríguez 2010). Adults can also feed on the pineapple flowers, and can also damage the skin of the pineapple fruits, causing deep scratches, gummosis, and damage and deformation of the fruit (Rodríguez-Rodríguez 2010). Adults of *M. hemipterus* prefer to feed on the crown than on the fruit (Rodríguez-Rodríguez 2010). If adults feed on fruits, they prefer damaged and overripe ones (Rodríguez-Rodríguez 2010).

If the pineapple fruit is attacked, it shows obvious external symptoms.

- Only occasionally, adult *M. hemipterus* attack developing pineapple fruits. Depending on the timing of the weevil attack, the fruit grows without crown, or with visible holes (Rodríguez-Rodríguez 2010). The damage makes the fruit unsuitable for export (Rodríguez-Rodríguez 2010).
- The larvae of *M. hemipterus* cause linear galleries in the leaves and stem when they feed. A similar damage can be seen in the fruit if the larva reaches it through the peduncle (Rodríguez-Rodríguez 2010). Larval galleries can structurally weaken stems and crowns of the plant hosts causing them to break (Thorn et al. 2019). The damage to the fruit is obvious and externally visible (Rodríguez-Rodríguez 2010).

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Appendix 2.12 Sybra alternans

Scientific name: *Sybra alternans* (Wiedemann, 1823)
Order: Coleoptera **Family:** Cerambycidae
Other scientific names: *Lamia alternans* Wiedemann, 1823; *Atelais angustata* Pic, 1926; *Sybra fuscovittata* Aurivillius, 1927; *Sybra carolina* Matsushita, 1935; *Sybra ochreovittata* Breuning, 1939; *Sybra alternans* m. *discomaculata* Breuning, 1950; *Falsoropica javaensis* Breuning, 1982.

Taxonomic note: Synonomy provided is from Skale and Weigel (2016)

New Zealand status:

Sybra alternans is not known to be present in New Zealand:

- There is no entry for *S. alternans* in NZOR (2022), ONZPR (2022) or BiotaNZ (2022).
- "*Sybra altenanus*" (Coleoptera: Cerambycidae) is listed as "not assessed" in ONZPR (2022). This is likely to be a misspelling since no matching published name was found.

Summary of reason for exclusion

Sybra alternans is not considered to be a hazard on pineapple fruit as per the commodity description and is excluded from this IRA. This is because no comprehensive evidence for commodity association has been found in published literature. The only host association report that was found is from a survey of insects that visit ripe and wounded fruit or that emerge from rotten fruit in a pineapple orchard (Sakimura and Linford 1940).

Supporting information

The evidence for the association is weak as there is only a single report found. The report does not mention lifestage.

- No detailed information on the biology of *S. alternans* was found in searches of the published literature. Brief notes found indicated that *S. alternans* larvae are generalists having found feeding on banana fruit (Chen et al 2001), dead plant tissues (e.g., decaying bark, Sweazy 1950) and fungus infected plant material (e.g.,in *Vachellia farnesiana* seed pods infested with *Aspergillus*, Dexter 1960).
- *Sybra alternans* was found in association with ripe pineapple fruits that had been placed in groups on pineapple plants in the field. Further collections were obtained through sweep netting during night (Sakimura and Linford (1940).
- A number of authors list pineapple as one of the hosts but no direct evidence was provided (Chen et al. 2001; Mondaca et al. 2016; Rafil et al. 2018), while some authors (Chen et al. 2001) cite Sakimura and Linford (1940) as reference for host association.
- Gressitt (1956) and Gressitt and Davis (1972) do not list pineapple as a host, and list dead branches as the major host.
- Stein and Haraguchi (1984) list "pulverised dried [woody] material" as a suitable diet for rearing the beetle. This diet was successfully used by Keena (2017).
- Swezey (1950) reported that beetle emergence occurred from cut branches of *Artocarpus altilis* (breadfruit).

A literature review was undertaken, using only the search term [*Sybra alternans*] or synonoms listed above. Other than (Chen et al. 2001; Mondaca et al. 2016; Rafil et al. 2018) no relevant results were found. CABI returned no relevant results with the above search terms. The internal MPI databases LIMS/PPIN returned no results.

New Zealand actively imports pineapple from countries where *S. alternans* is known from (e.g, 47 consignments from Philippines in 2020 (QuanCargo 2021)), but *S. alternans* has not been identified at the New Zealand border.

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Appendix 3 Transit conditions

The following markets are likely to export pineapples via air freight at room temperature:

- Fiji
- New Caledonia
- Vanuatu
- Samoa
- Tonga
- Cook Islands
- Australia (sometimes air freight but sometime sea cargo)

The following markets are likely to export pineapples as sea cargo:

- Costa Rica
- Ecuador
- Indonesia
- Malaysia
- Panama
- The Philippines
- Thailand
- Sri Lanka
- Taiwan
- Papua New Guinea
- Australia (sometimes air freight but sometime sea cargo)

Recommended cold storage conditions for pineapple are temperature at 7–13°C and relative humidity at 85–90% moisture, and the approximate storage life under these conditions is 14 – 28 days(Camelo 2004). Colder than 4°C fruit fail to continue ripening and show severe chilling injury (Camelo 2004).

Estimated shipping duration and the fastest estimated shipping duration from exporting markets are shown in App.Table 1 and App.Table 2.

APP. Table 1 Estimated shipping times from targeted markets to New Zealand (information sourced from Freight (2021)).

Markets	**shipping times / schedule**					
	Auckland	Lyttelton	Nelson	Port Chalmers	Tauranga	Wellington
Asia						
Indonesia (Belawan)	3w–4w	3w–4w	4w	3w	3w–4w	3w–4w
Indonesia (Surabaya)	4w–5w	4w	5w	4w	3w–5w	4w–5w
Malaysia (Port Klang)	2w–3w	3w	3w–4w	2w–3w	3w	3w–4w
The Philippines (Manila)	2w–3w	3w	3w–4w	2w–3w	3w	3w–4w

Thailand (Port of Bangkok)	3w–4w	4w	4w	4w	3w–5w	3w–4w
Sri Lanka (Port of Colombo)						
Taiwan (Kaohsiung)	5w	5w	6w–7w	7w	4w	4w–5w
Central America						
Costa Rica (Puerto Caldera)						
Ecuador (Andiport)						
Panama						
Oceania						
Papua New Guinea (Port Moresby)						
Australia (cityies)						
Adelaide	1w–2w	2w	2w	3w	1w–3w	2w
Brisbane	4d–2w	1w–2w	1w–2w	1w–2w	5d–2w	1w–2w
Melbourne	5d–3w	2w	1w–2w	2w–3w	4d–1w	1w–2w
Fremantle	3w–4w	3w–4w	3w	3w–4w	3w–4w	3w
Sydney	3d–3w	1w–2w	1w	2w	2d–2w	5d–1w

APP.Table 2: Fastest estimated shipping times from exporting markets to New Zealand (calculated used the information from Ports.com (2021)).

Markets	**shipping times / charter (day)**		
	Auckland	Lyttleton	Wellington
Asia			
Indonesia (Belawan)	13.1	14.1	13.8
Indonesia (Surabaya)	12	13	12.6
Malaysia (Port Klang)	12.6	13.6	13.2
The Philippines (Manila)	11.3	12.3	11.9
Thailand (Port of Bangkok)	13.6	14.7	14.3
Sri Lanka (Port of Colombo)	14.8	15.9	15.5
Taiwan (Kaohsiung)	12.1	13.1	12.7
Central America			
Costa Rica (Puerto Caldera)	34.4	34.3	34.5
Ecuador (Andiport)	35.1	27.8	35.2
Panama	33.3	33.1	33.4
Oceania			
Papua New Guinea (Port Moresby)	5.6	6.6	6.3
Australia (cities)			
Adelaide	4.2	4.5	4.3
Brisbane	3.2	4.2	3.8
Melbourne	3.4	3.9	3.5
Fremantle	6.6	6.5	6.7
Sydney	2.8	3.8	3.4

Note: Based on the estimated transit time of a charter vessel traveling the most direct shipping route at a speed of 20 knots.

References for Appendix 3

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Appendix 4 Glossary and abbreviations

Term or abbreviation	Definition
BRAD	Biosecurity Risk Analysis Database. MPI internal database that records the regulatory status and other information about plant pests.
CMI	Climate (or composite) match index, a value that indicates the similarities between a location overseas and New Zealand (Phillips et al. 2018).
commercial production	Definition for the purposes of risk assessment: a process/system where activities, such as in-field monitoring, in-field pest control activities, harvesting, cleaning, sorting and grading have been undertaken to produce a commodity that is free of defects such as broken skin, rot and damage. Depending on the systems in place, these activities can be undertaken at any stage from the point of planting to the point of export.
commodity description	The commodity description defines the form of the commodity that is covered by the IRA, e.g. the commodity species and the countries under consideration. The commodity description may also include commercial production and/or grading requirements or other commodity quality specifications.
conditional non-host	Fruit or vegetable at a specified maturity and specified physical condition that cannot support the complete development of a particular pest species.
CPC	*Crop Protection Compendium*. A CABI database that provides information about crop pests.
disease	A disorder of structure or function in a plant, especially one that affects a specific location and is not simply a direct result of physical injury.
endemic	An animal, plant, pest, or disease that is native to and is not naturally found outside a defined geographical area.
establishment	Perpetuation, for the foreseeable future, of an organism or disease within an area after entry.
ERS	Emerging Risk System, an MPI workflow system that allows MPI to receive, process and store information about new biosecurity risks and to manage those risks in a timely fashion.
exposure	The process of the hazard organism moving from the commodity it arrived on to another host (also called "transfer").
exotic	This word has different meanings in different fields, but in this document, it is defined as an animal, plant, pest or disease that is not indigenous to New Zealand.
hazard	A hazard is a pest (including arthropods and pathogens) or disease that is not present in the PRA area, e.g. New Zealand (or is present but still represents a biosecurity risk, e.g. is capable of

	vectoring pathogens not present in the PRA area), has the ability to establish and cause harm in the PRA area and is associated with the entry pathway (commodity/country of origin) under consideration.
indigenous	Native; organism originating or occurring naturally in a specified area.
inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present and/or to determine compliance with phytosanitary regulations (FAO 2012).
introduced	Not indigenous, not native to the area in which it now occurs, having been brought into this area directly or indirectly by human activity.
IPPC	International Plant Protection Convention, a 1951 multilateral treaty overseen by the Food and Agriculture Organization that aims to secure coordinated, effective action to prevent and to control the introduction and spread of pests of plants and plant products.
ISPM	International Standards for Phytosanitary Measures, international standards adopted by the Conference of the Food and Agriculture Organization, the Interim Commission on phytosanitary measures or the Commission on phytosanitary measures, established under the IPPC.
IHS	Import Health Standard (See "Import Health Standard" for a definition.)
Import Health Standard	An import health standard (IHS) is a document issued under section 24A of the Biosecurity Act 1993. It states the requirements that must be met before risk goods can be imported into New Zealand.
IRA	Import Risk Analysis, an administrative process through which quarantine policy is developed or reviewed, incorporating risk assessment, risk management and risk communication.
MPI	Ministry for Primary Industries, New Zealand
non-host	Fruit or vegetable that will not support the complete development of a particular pest species regardless of the stage of maturity and physical characteristics.
NPPO	National Plant Protection Organisation, official service established by a government to discharge the functions specified by the IPPC.
NZOR	New Zealand Organisms Register, an actively maintained compilation of all organism names relevant to New Zealand: indigenous, endemic or exotic species or species not present in New Zealand but of national interest.
ONZPR	Official New Zealand Pest Register. MPI database that records organisms that may be associated with plants or plant products that are imported into New Zealand. Plant and plant product

	importers can use ONZPR to find out the quarantine status of a species – regulated or non-regulated.
pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products.
pest-free area	An area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained.
pest-free place of production	A place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period.
PFA	Pest-free area (See "Pest-free area" for a definition.)
PFPP	Pest-free place of production (See "Pest-free place of production" for a definition.)
PPIN	Plant Pest Information Network database (MPI), a record of organisms collected in New Zealand and identified by MPI's Plant Health and Environment Laboratory.
PRA	Pest Risk Assessment or Pest Risk Analysis
QuanCargo	New Zealand border transaction database, detailing commercial consignments and interceptions of pests made by quarantine inspection (MPI).
quarantine pest	A pest of potential economic importance to the area endangered thereby, e.g. New Zealand, and not yet present there, or present but not widely distributed and being officially controlled.
systems approach	The integration of different pest risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of phytosanitary protection. Measures can be undertaken at any stage from the point of planting to the point of export.
vector	An organism or object that transfers a pest, parasite, pathogen or disease from one area or host to another.