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Import Risk Analysis: Fresh Island cabbage leaves (*Abelmoschus manihot*) from Cook Is., Fiji, Samoa, Tonga, Vanuatu

FINAL

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From Cook Is., Fiji, Samoa, Tonga, Vanuatu.

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Approved for review/public consultation/general release

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Background
This Risk Analysis was initiated by a new market access request from 5 Pacific countries for the importation of fresh island cabbage leaves (*Abelmoschus manihot*, Malvaceae) to New Zealand from Cook Is., Fiji, Samoa, Tonga and Vanuatu. New Zealand currently imports only frozen island cabbage leaves from Fiji.

Island cabbage is a hibiscus-like leaf crop of highly variable leaf shape typically cooked and eaten much like spinach. The commodity is defined as**:** "the harvested individual leaves of cultivated *Abelmoschus manihot* (L) Medik., trimmed at the stem end of the petiole to exclude any part of the stem, flowers, seed pods or roots; cleaned, packed and transported to New Zealand, for consumption."

Exported leaves will include those from commercial farms and surplus harvest from individuals. Therefore it is unlikely there will be any regulated in-field pest and pathogen control.

Hazard identification
This process identified 198 organisms associated with island cabbage (Appendix 1). Of these, 74 were assessed further based on their association with the commodity and presence in one or more of the five countries, and 124 organisms were excluded based on specific criteria (Appendix 2).

- 74 organisms were allocated to groups according to certain criteria:
- 14 organisms were selected to be assessed as examples of the groups (Chapters 5-10);
- 3 arthropod species known to be in New Zealand were evaluated for the risks they posed as vectors of pathogens (Appendix 3);
- the risks posed by 3 undescribed viruses were evaluated (Appendix 4)

Risk assessment
This risk analysis considers the following:

- Because procedures tend to vary between countries, the packhouse procedure (section 2.1.1.1) **is excluded in assessing the risk** but is discussed in risk management options for each risk group;
- Island cabbage leaves will be **imported with no stem attached, (see Scope, section 1.2)** thus managing risks associated with illegal propagation. **This is considered in assessing the risk;**
- Fresh island cabbage leaves are likely to be purchased and consumed the same day, as it is a product of cultural value, is highly perishable and will not be of sufficient quality after 2 or 3 days. This will contribute to reducing the likelihood of exposure. **This is considered in assessing the risk.**

Conclusions
Of the 14 organisms that underwent risk assessment, 12 were assessed to be risk organisms on the fresh island cabbage pathway (see Table 1, organisms in bold lettering). Risk management options are given for these organisms.

The overview of potential risk management options (Chapter 4) concluded that treatments for risk management of fresh island cabbage leaves are very limited.

- Most quarantine treatments available in the Pacific are not feasible as they are likely to damage the commodity;
- The current wash-wipe-inspection protocol for taro/tarua leaves has been proposed
- Interception data from taro and tarua leaves shows the current wash-wipe-inspection protocol is not achieving of a quarantine standard
- Visual inspection at the border is usually an audit of systems, but may need to be considered as an additional biosecurity measure for this commodity
- The efficacy of visual inspection is variable
- The proposed option (wash-wipe-inspection) and visual inspection at the border is likely to manage a proportion of the risk and result in a small residual unmanaged risk.

Table 1. Summary of hazard groups associated with fresh island cabbage leaves (*Abelmoschus manihot*)

(continued overleaf)

Group	Characteristics of the group	Organisms that were assessed in the group, organisms in **bold** were assessed as **risks**	Unassessed hazards* in the group
A. mobile arthropods that are cryptic and/or small (Chapter 5)	*Abelmoschus manihot* used for development; At least one life stage associated with the commodity; At least one life stage likely to be relatively hard to detect during harvest, sorting and inspection, and may move off or be shaken off the commodity.	***Aphis fabae*** -bean aphid (aphid nymphs and adults) ***Haritalodes derogata*** - cottonleaf roller (moth larvae)	*Bemisia tabaci* (Nauru biotype), *Arsipoda tenembriensis, Empoasca quadripunctata, Planococcus minor, Tetranychus* sp., *Thrips* sp., *Unaspis citri,*
B. sessile arthropods that are cryptic and/or small (Chapter 6)	*Abelmoschus manihot* used for development; At least one life stage associated with the commodity; At least one life stage likely to be difficult to detect during harvest, sorting and inspection and will remain on the commodity through the entire duration of the life stage.	***Aleurodicus dispersus*** - spiralling whitefly (whitefly eggs and nymphs) ***Maconellicoccus hirsutus*** - pink mealybug (eggs, nymphs) *Pseudaulacaspis pentagona*- white peach scale (eggs, nymphs and adult female scale)	*Bemisia tabaci* (Nauru biotype), *Anomis lyona, Coccus capparidis, Planococcus minor, Tetranychus* sp., *Thrips* sp., *Unaspis citri*
C. arthropods that feed internally (Chapter 7)	*Abelmoschus manihot* used for development; At least one life stage associated with the commodity; At least one life stage likely to be difficult to detect in island cabbage leaves until they emerge.	***Aphelenchoides besseyi*** - rice leaf nematode (foliar nematodes) ***Earias vittella*** - aibika tip borer (moth larvae)	No other hazard organism identified

Group	Characteristics of the group	Organisms that were assessed in the group, organisms in **bold** were assessed as **risks**	Unassessed hazards* in the group
D. arthropods that are obvious and/or large (Chapter 8)	*Abelmoschus manihot* used for development; At least one life stage associated with the commodity; At least one life stage likely to be relatively conspicuous during harvest, sorting and inspection.	*Adoretus versutus*- rose beetle (adult beetles) ***Achatina fulica*** - giant African snail (juvenile snails) *Amblypelta cocophaga cocophaga*- coconut bug (nymphs and adult bugs)	*Anomis lyona, Apirocalis cornutus, Brachylybas variegates, Colgar tricolour, Elytrurus griseus, Euricania disciguttata, Harmonia arcuata, Lampromicra* sp., *Leptoglossus gonagra, Micraspis lineola, Nysius* sp., *Phaenacantha* sp., *Phanoptera brevis, Sphaerorhinus aberrans, Tectocoris diophthalmus, Tiracola plagiata, Valanga* sp., *Xanthodes transversa*
E. hitchhiker organisms (Chapter 9)	No direct biological association with the commodity i.e. does not use *Abelmoschus manihot* for development. Association is opportunistic. Often highly mobile and can leave the commodity at any given opportunity.	***Solenopsis geminata*** - tropical fire ant (ant workers and queens)	*Anoplolepis gracilipes*, *Cardiocondyla nuda*, *C. wroughtonii*, *Crematogaster* sp., *Monomorium destructor, M. floricola, M. minutum, M. monomorium* , *Monomorium* sp., *Nylanderia bourbonica, N. minutula, Nylanderia* sp., *N. vaga, Paratrechina longicornis, Pheidole fervens, P. oceanica, Pheidole* sp. *P. umbonata, Ponera loi, Ponera* sp., *Solenopsis geminata, Tapinoma melanocephalum, Tapinoma* sp., *T. simillimum, Triglyphothrix obesa* ssp. *striatidens*
F. fungal pathogens that are spread by wind and/or rain (Chapter 10)	*Abelmoschus manihot* used for development Transmitted to and from plants by wind or rain. Micro-organisms whose presence can only be detected on *A. manihot* plants using specific tests or if there are visual symptoms	***Choanephora cucurbitarum*** - wet rot disease ***Choanephora infundibulifera*** - choanephora blight ***Oidium abelmoschi*** - powdery mildew ***Pseudocercospora abelmoschi*** - leaf spot	No other hazard organisms identified
G. systemic pathogens that are spread by arthropod vectors (Appendix 4)	Micro-organisms such as viruses that are associated with *Abelmoschus manihot* Presence can only be detected using specific tests or if there are visual symptoms.	Undescribed viruses	No other hazard organisms identified

* Grouping is not absolute, and some organisms fit into more than one group at different life stages.

1 Risk analysis background and process

1.1 Background

This risk analysis has been developed in response to a market access request from 5 Pacific Island countries (Cook Islands, Fiji, Samoa, Tonga and Vanuatu) for the fresh leaves of "island cabbage" (*Abelmoschus manihot*).

Island cabbage is a popular leaf vegetable in the Pacific which is typically cooked and eaten like spinach.

Currently Fiji is exporting fresh island cabbage leaves to Canada and blanched, then frozen island cabbage leaves to New Zealand, Australia, Hawaii, and USA. Tonga also exports small quantities of frozen leaves to New Zealand (Fa'anunu 2009).

Closely related products that are imported from the Pacific include fresh roselle leaves (*Hibiscus sabdariffa*) and fresh okra pods (*Abelmoschus esculentus*), the end use of both is "cooked and consumed".

1.2 Scope of this risk analysis

This Import Risk Analysis covers the importation of fresh island cabbage leaves cultivated in identified Pacific countries into New Zealand. For the purposes of this risk analysis "island cabbage" is defined as **"the harvested individual leaves of cultivated *Abelmoschus manihot* (L.) Medik., trimmed at the stem end of the petiole to exclude any part of the stem, flowers, seed pods or roots; cleaned, packed and transported to New Zealand, for consumption."**

The exporting countries are:

- Cook Islands
- Fiji
- Samoa
- Tonga
- Vanuatu

The leaves may have been grown anywhere in any of the exporting countries and may not necessarily be the produce of commercial farmers. A common practise in the Pacific is for individuals to grow such crops in their backyards and supply the surplus to a market or packhouse for sale. Therefore it is assumed that there is little or no in-field treatment for pest and disease control.

The scope of this analysis includes:

- identification of hazard organisms associated with island cabbage
- assessment of the risks of the identified hazards; this includes likelihoods of entry, exposure establishment and likely consequences for each group example hazard organism
- analysis of the identified risks against possible mitigation options
- peer review of the draft analysis

The identified options for measures will form the basis of a Risk Management Proposal and new Import Health Standard for importing fresh island cabbage leaves from the Cook Is, Fiji, Samoa, Tonga and Vanuatu into New Zealand.

1.3 The risk analysis process

The following briefly describes the MAF Biosecurity New Zealand process and methodology for undertaking import risk analyses. For a more detailed description of the process and methodology please refer to the Biosecurity New Zealand Risk Analysis Procedures (Version 1 12 April 2006) which is available on the Ministry of Agriculture and Forestry web site (MAF, 2006).

The risk analysis process leading to the final risk analysis document is summarised in figure 1.

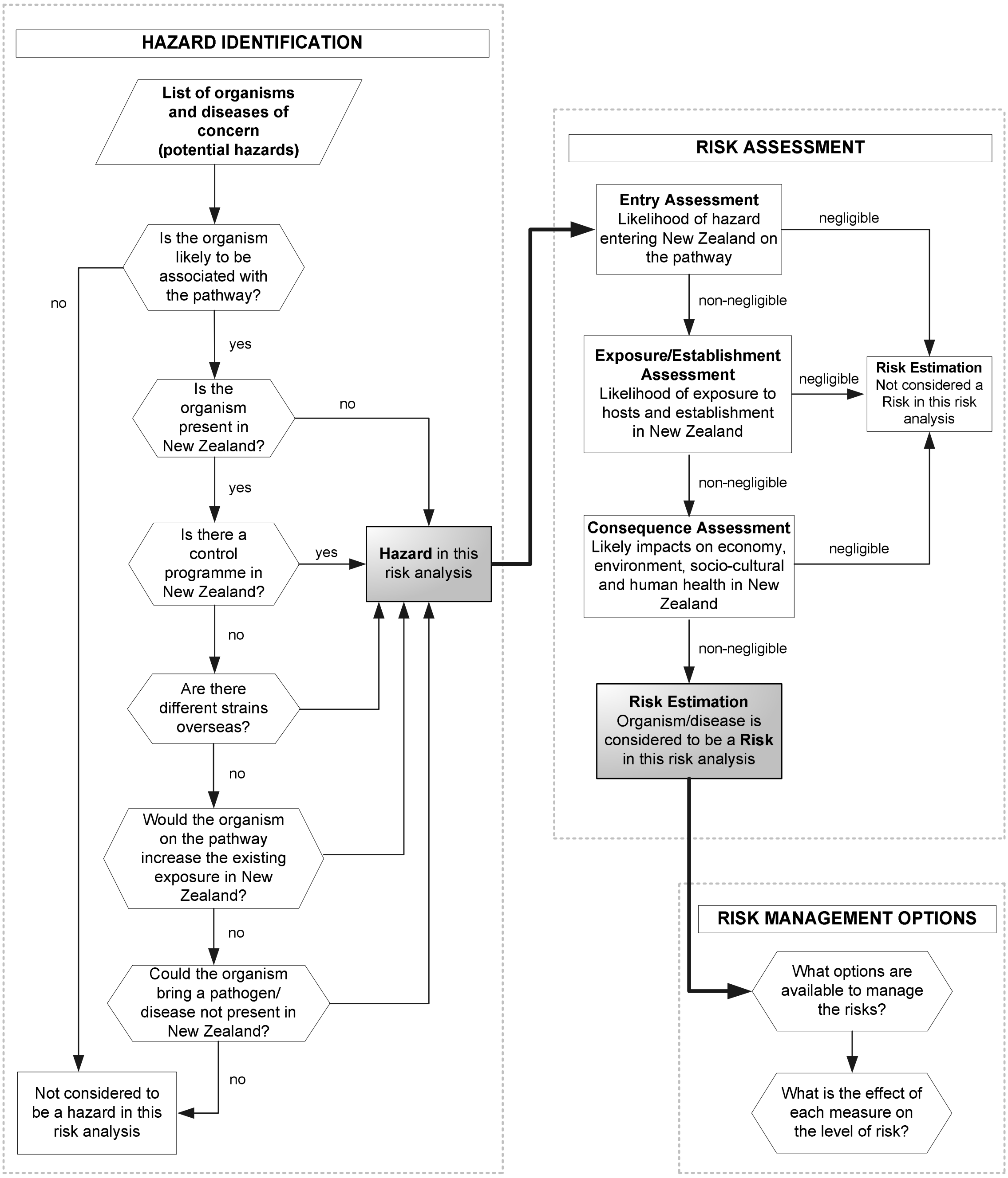

Figure 1. Diagrammatic representation of the risk analysis process

The process outlined in figure 1is further explained in the following sections.

1.3.1 Commodity and pathway description

The first step is to describe the commodity and entry pathway of the commodity. This includes relevant information on:

- the country of origin, including characteristics like climate, relevant agricultural practices, phytosanitary system;
- pre-export processing and transport systems;
- export and transit conditions, including packaging, mode and method of shipping;
- nature and method of transport and storage on arrival in New Zealand;
- characteristics of New Zealand's climate, and relevant agricultural practices.

This information provides context for the assessment of the hazard organisms.

1.3.2 Hazard Identification

Hazard identification is conducted prior to the risk assessment stage. It is basically equivalent to "pest categorisation" in the system used under the International Plant Protection Convention (IPPC) system (FAO 2007). This process begins with the collation of a list of organisms and diseases that might be associated with the commodity in the country of origin and are potentially capable of causing harm (potential hazards). Potential hazards are then screened using the steps listed in the hazard identification section of figure 1 and information on the biology and distribution of the organism or disease.

The hazard identification process identifies the organisms or diseases that are likely to be associated with the commodity from the exporting country, and which have the potential to cause harm to New Zealand (hazards).

Hitchhiker organisms, which have no biological host association with a commodity, are sometimes considered to be hazards where there are other sources of evidence for their likely association with a commodity, and where they meet the other criteria to be considered hazards.

During the hazard identification process, organisms and diseases are sometimes grouped on their biology and likely susceptibility to risk management measures. The groups are not absolute and some organisms fit into more than one group at different life stages.

Chapter 3 describes hazard identification process undertaken for this risk analysis and lists the main information sources.

1.3.3 Assessment of risks

Risk assessments are undertaken for one or more example species in each group identified during the hazard identification. This approach enables an understanding of the biosecurity risks associated with the commodity, especially where there is limited information on which to base a risk assessment. Example species were selected on the basis of availability of information on their ecology and biology, and to cover the range of likely mechanisms for association with island cabbage leaves.

Risk assessment is the evaluation of the likelihood of entry, exposure and establishment of a hazard organism, and the environmental, economic, human and/or animal health and socio-cultural consequences of the entry within New Zealand. The aim of risk assessment is to identify hazards which present an unacceptable level of risk, for which risk management measures may be considered. The risk assessment is qualitative, and descriptors (negligible, low, moderate, high) are used in assessing the likelihood of entry, exposure, establishment and spread, and the economic, environmental, socio-cultural and human health consequences. These descriptors are defined in the Risk Analysis Procedure manual (BNZ 2006).

1.3.4 Assessment of uncertainties

In this aspect of the risk analysis process the uncertainties and assumptions identified during the preceding hazard identification and risk assessment stages are stated within the text. An analysis of these uncertainties and assumptions can then be completed to identify which are critical to the outcomes of the risk analysis. Critical uncertainties or assumptions can then be considered for further research with the aim of reducing the uncertainty or removing the assumption.

Where the risk assessment has significant uncertainty, this is stated in the conclusion of the risk assessment. In these cases, the Risk Analysis Procedure manual (BNZ 2006) notes a precautionary approach to managing risk may be adopted. In these circumstances the measures should be reviewed as soon as additional information becomes available[1] and be consistent with other measures where equivalent uncertainties exist.

1.3.5 Management options

For each organism classified as a risk, a risk management step is carried out, which identifies the options available for managing the risk and considers the efficacy of those options in relation to the risk. In addition to the options presented, unrestricted entry or prohibition may also be considered for each risk organism. Recommendations for the appropriate phytosanitary measures to achieve the effective management of risks are not made in this document. These will be determined when the Risk Management Proposal (RMP) and Import Health Standard (IHS) are drafted.

As obliged under Article 3.1 of the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement), the measures adopted in IHSs will be based on international standards, guidelines and recommendations where they exist, except as otherwise provided for under Article 3.3 (where measures providing a higher level of protection than international standards can be applied if there is scientific justification, or if there is a level of protection that the member country considers is more appropriate following a risk assessment).

1.3.6 Review and consultation

Peer review is a fundamental component of a risk analysis to ensure the analysis is based on the most up to date and credible information available. Each analysis must be submitted to a peer review process involving recognised and relevant experts from New Zealand or overseas. The critique provided by the reviewers is reviewed and where appropriate, incorporated into the analysis. If suggestions arising from the critique are not adopted the rationale must be fully explained and documented.

1 Article 5.7 of the SPS Agreement states that "a Member may provisionally adopt sanitary …. measures" and that "Members shall seek to obtain additional information …. within a reasonable period of time." Since the plural noun "Members" is used in reference to seeking additional information a co-operative arrangement is implied between the importing and exporting country. That is the onus is not just on the importing country to seek additional information.

The conclusions of the risk analysis will be summarised in a risk management proposal that accompanies the draft IHS for consultation. The risk analysis provides additional technical detail should submitters wish to see a more detailed scientific analysis of the biological risks.

All submissions received from stakeholders will be analysed and compiled into a review of submissions. The Risk Analysis, Risk Management Proposal and draft Import Health Standards will be modified where appropriate depending on the outcome of consultation.

References for Chapter 1

FAO (2007) International Standards for Phytosanitary Measures (ISPM) no.2: Framework for Pest Risk Analysis. Food and Agriculture Organisation. available online at https://www.ippc.int/file_uploaded/1179929048771_ISPM02_2007_E.pdf

MAF (2006) Biosecurity New Zealand risk analysis procedures. Ministry of Agriculture and Forestry, New Zealand, 201 pp. Available online at http://www.biosecurity.govt.nz/files/pests-diseases/surveillance-review/risk-analysis-procedures.pdf

Figure 2. Island cabbage plant, 6 months old, on a farm in Fiji

2 Commodity and pathway description

This chapter provides information on the commodity that is relevant to the analysis of biosecurity risks and common to all organisms or diseases potentially associated with the commodity. It also provides information on New Zealand's climate and geography to lend context for assessing the likelihood of establishment and spread of hazard organisms.

2.1 Commodity description

Taxonomy

Scientific name:	*Abelmoschus manihot* (L.) Medikus
Other relevant scientific names:	*Hibiscus manihot* L.
Family:	Malvaceae
Common names:	island cabbage
Cook Is.:	raukau viti
Fiji:	bele
Samoa:	lau pele
Tonga:	pele
Vanuatu:	aelan cabis

The taxonomy of *Abelmoschus manihot* is complex, with numerous varieties within the Pacific and south-east Asia, therefore the reader is directed to Preston (1998) for further information.

Physical description

Abelmoschus manihot is a fast growing, erect, branched, perennial shrub, reaching up to 5m in height. The leaves are alternate and are extremely variable in shape, size and outline, even on one plant. In outline leaves can be round to broadly oval, cordate (heart-shaped) or sometimes hastate (triangular as in an arrow head) at the base, sometimes entire but mostly 3-7 lobed or parted, 3-30cm in diameter. Leaf segments also vary in shape (see figure 2). The petioles can be a few centimetres to about 25cm long. In colour the leaves can be bright green to reddish-green or purplish. Flowers are hibiscus-like, pale yellow with a dark purple centre. Fruits are beaked, oblong and with a dehiscent capsule containing numerous pubescent seeds.

Origins and use

Island cabbage is considered to have originated from South and Southeast Asia, and appears to have spread from New Guinea to the Solomon Islands to Vanuatu, Fiji and the rest of the Pacific (in Preston 1998). Island cabbage is open pollinated[2] and there are numerous varieties of it throughout the Pacific. In Vanuatu there are more than 70 varieties being tested by the Department of Agriculture and Rural Development (Fa'anunu 2009)
The diversity of forms is matched by the diversity of vernacular names, for instance, Preston (1998) lists more than 35 names from Vanuatu and 8 from Fiji.

Island cabbage is a very popular green leaf vegetable in Vanuatu, Fiji and Tonga, although it is less popular in Samoa and the Cook Islands. The leaves are commonly cooked and eaten much like spinach. In all five countries it is known by its leaf form and leaf colour rather than by named varieties.

2. Open pollinated flowers can produce seeds that give rise to offspring identical to the parent plant.

The three most common forms grown for their palatability, softness and less fibrous texture are described by Fa'anunu (2009) as:

i. roundish green leaf (sometimes referred to as white), very soft, good texture and taste when cooked;
ii. More lobed and palmately shaped leaves which tend to be more tough and fibrous when harvested late;
iii. a hybrid of reddish-green round leaves

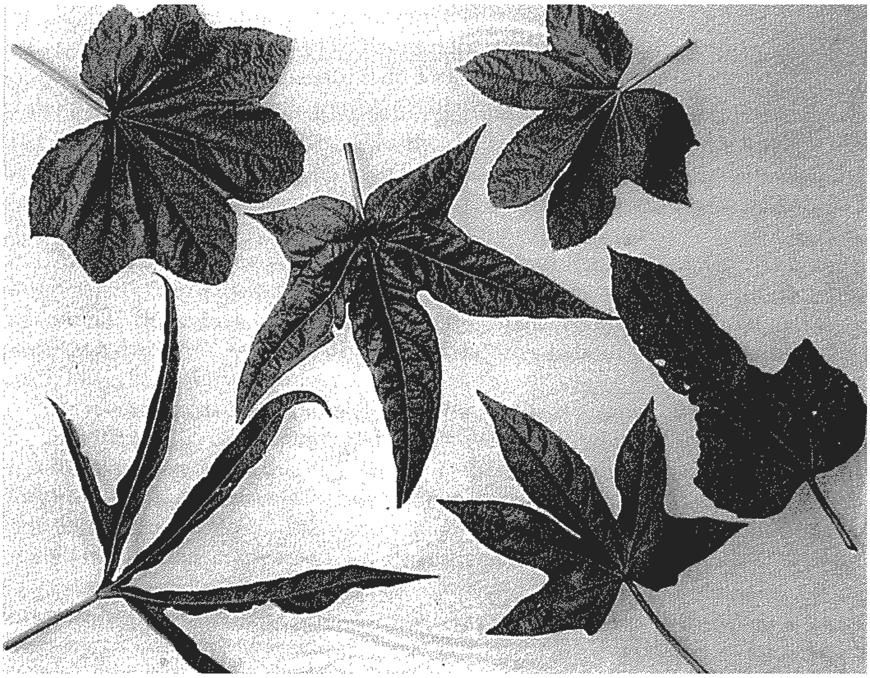

Figure 3. Diversity of leaf form in island cabbage (*A. manihot*) (Preston 1998)

Figure 4. Various leaf forms within one crop, and in some cases on one plant, Fiji

2.2 Pathway description

Overview of pathway

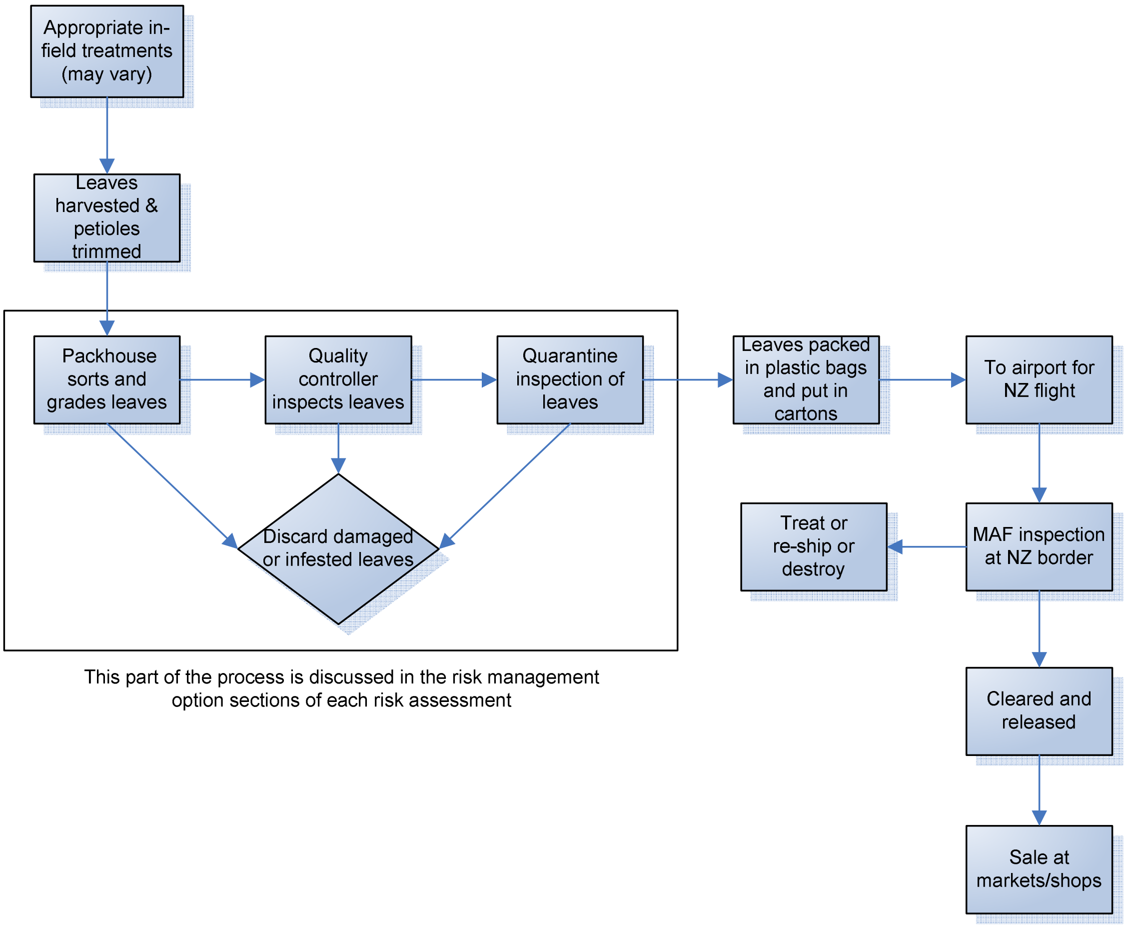

Figure 5. Overview of the island cabbage import pathway from field to overseas market

2.2.1 Pre-export process

Pre-harvest operation

Growers in the Pacific Islands countries are not currently registered for produce other than commodities that are fruit fly hosts. However, it is assumed government extension services can provide information about the requirements for export, such as in-field spraying at particular times for particular pests or pathogens. This product is not likely to come exclusively from commercial growers. Back-yard surplus is likely to be included in exported produce and this is unlikely to have had any form of treatment for pests and diseases.

Harvesting

This is either by cutting off the terminal stem 6-8 leaves below the terminal bud, or by breaking off individual leaves from the stem. The former process encourages further growth and is commonly used for home and local market harvests. The latter method of harvest is for home use and for export use.

Transport from farmer to pack-house

This is currently unknown but could be by various means to the pack-houses.

Pack-house procedures

The process that is undertaken in Fiji and Tonga for taro and tarua leaves is described here. It is likely a similar method will be adopted by all the countries wishing to export island cabbage leaves to New Zealand. However given that procedures tend to vary between countries it is uncertain exactly what procedures will be used. Therefore this process will not be considered in assessing risk, but will be discussed under risk management options.

Leaves arriving at the pack-house are sorted and graded. Leaves are washed in a tub of chlorinated water and wiped with a soft cloth or sponge to remove any contaminants. They are then dried by fan-generated air movement. A quality controller inspects the leaves and then they are inspected by a quarantine officer. Leaves are packed into plastic bags with holes in them then these bags are packed into cardboard cartons with holes in the sides.

Transport to New Zealand

As island cabbage leaves are highly perishable they will be flown to New Zealand. Flights from the exporting countries usually take about 4 hours.

2.2.2 Post New Zealand border

Distribution, use and disposal in New Zealand

Island cabbage is expected to be sold for human consumption at Polynesian markets and shops in the Auckland region. Unsold produce or produce that is undesirable is likely to be disposed of in rubbish bins, or taken for composting or landfill.

Island cabbage imported from the Pacific Islands is likely to enter New Zealand all year round although there is likely to be a greater volume between November and April. From the border, leaves would be transported to Auckland, either to wholesalers or retailers, and from there to individual consumers and possibly the food service industry. Retailers are more likely to be located in urban areas than wholesalers.

Some contaminating organisms (*e.g.* very mobile insects) may be exposed to suitable hosts at almost any point in the distribution pathway, but for the majority the final disposal location of leaf waste is the point at which exposure is most likely to occur.

Culled and unsold leaves or uneaten leaves may be disposed of by wholesalers, retailers, food services (*e.g.* restaurants, market fast-food vendors, hospitals) and consumers. The main domestic disposal pathways are disposal in bagged waste into landfill, disposal into sewage through a sink disposal unit, and disposal in garden compost (Ventour 2008, Hogg *et al*. 2010). Domestic disposal could also include public rubbish bins or random disposal in parks/roadsides. Industry (wholesale and retail) disposal pathways for culled and unsold leaves may include distribution to rural areas for animal food.

Some methods of disposal are higher risk than others. Organisms contaminating remains disposed of as bagged waste into landfill, or into sewage via sink disposal units would have a negligible likelihood of exposure. Those on leaves disposed of into domestic compost (particularly open compost), into gardens, into orchards near packhouses, into rural areas as food or randomly by the roadside would have a higher likelihood of exposure to a suitable host. A further risk scenario is transfer to house plants in households, offices or supermarkets.

Domestic waste: A survey in the United Kingdom found that about 12% of food waste is disposed at home through either composting, as animal feed, or down the sink; the remaining 88% is collected by local authorities (Ventour 2008; 20,000 households). This survey also reported that between 15 and 25% of households' compost waste at home. A similar survey in New Zealand found that (approximately) 13% of household organic waste is composted, 13% is disposed of in sink disposal units and 71% is landfilled (Hogg *et al.* 2010). In 1993, a small survey showed that about 30% of New Zealand households used composting as a primary disposal method (specifically of fruit waste) and another 5% disposed of it in the garden (Viggers 1993; 846 respondents). Viggers (1993) additionally estimated that in December 1992, in any week about 7.5% of the population over 12 years old was likely to drop fruit waste on roadsides or on the ground in New Zealand. This was classified as a high risk disposal method.

Industry (wholesale and retail) waste: A survey of commercial fruit waste (whole fruit and fruit remains/peels) and disposal in New Zealand and found that approximately 20.3% of retail (supermarkets, dairies and groceries) and 6.9% of non domestic outlets (hospitals, rest-homes, restaurants etc.) used high risk methods (garden compost, other and unknown) to dispose of waste (Wigbout 1991; 894 respondents). Wholesale fruit disposal pathways and practices were not covered. 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 (I. Wallace, Nashi NZ Inc., pers. comm. to MAFBNZ, September 2009). In California, disposal of large numbers of culled imported Mexican avocados at packhouses in close proximity to avocado trees has been identified as a potential entry pathway for diaspidids (Morse *et al.* 2009).

While little is known about industry pathways and practices such as the disposal of culled and unsold vegetables by wholesalers and retailers, domestic surveys suggest that the majority of household organic waste is disposed of via landfill; that household organic waste is more commonly disposed of as compost in New Zealand than in the UK, and that the amount that is composted in New Zealand has decreased over the last two decades.

Although the majority of domestic disposal is via low risk methods, the amount of organic waste, particularly uneaten fruit and vegetables is surprisingly high. Ventour (2008) calculated all fruit waste (avoidable and unavoidable, *i.e.* peelings, cores *etc.*) to be 1,100,300 tonnes p.a. in the UK. Roughly half of this (550,800 tonnes) was "avoidable" waste; individual items of fruit thrown away whole and untouched. Ventour (2008) calculated that 2.9 billion (=1000 million) whole items of fruit and 1.9 billion whole vegetables are thrown away each year. 26% (by weight) of fruit and 19% of vegetables purchased for domestic consumption were thrown away whole and uneaten (avoidable waste). In New Zealand Hogg *et al.* (2010) estimated that each household throws away 248 kg of food waste per year, a similar figure on a per capita basis to that estimated from the UK. The New Zealand study did not break food waste into categories but it is assumed that a similar proportion would be fruit waste.

Although there is little information available regarding the amount of waste produced by industry, Wigbout (1991) showed that New Zealand retail outlets discarded between 0.86% and 13.3% of fruit, while non-domestic consumers discarded between 0.63% and 42% of fruit (the amount of waste was highly dependent on the type of fruit).

However, it is assumed that the proportion of island cabbage leaves disposed of prior to cooking is likely to be less than the vegetables and fruit proportions quoted above. The reasons for this are that it is a highly perishable food item and so it is expected only whole, undamaged leaves will be packaged for export; the whole leaf and petiole that is imported is eaten therefore not generating any trimmed (unavoidable) waste; it is highly favoured in most of the islands and is therefore likely to be cooked and consumed immediately.

Summary of waste disposal

- there is little information available regarding industry pathways and practices such as the disposal of culled and unsold fruit by wholesalers and retailers
- the majority of domestic disposal appears to be by very low risk methods – almost 85% of household organic waste is via landfill or in sink disposal into sewage
- however, the amount of household organic waste is surprisingly large. The amount disposed of by composting can be calculated (approximately 13% of around 248 kg of food waste per year, or about 20 kg per household). The amount of this material that is both imported and infested with risk organisms is likely to be extremely low.
- But, the proportion of island cabbage leaves disposed of prior to cooking is assumed to be lower again than the amounts quoted above for food.
- Overall, the likelihood of exposure of different categories of contaminating organisms via the fresh produce pathway remains an area of significant uncertainty.

2.3 Climate in exporting countries

There are variations in the climate between the five countries due to land and ocean mass. However, they all enjoy a tropical maritime climate without great extremes of heat or cold. All five countries experience the same distinct wet season from November to April and dry season from May to October. They are all vulnerable to cyclonic periods during the wet season.

Table 2. Distribution of average temperatures, rainfall and relative humidity for the exporting countries (Fa'anunu 2009)

Country	Average temperature (˚C)	Average rainfall (mm)	Average relative humidity (%)
Cook Islands	21-28	2000	84
Fiji	18-32	1500-6000	65-90
Samoa	19-32	2000-5000	70-91
Tonga	18-30	1673-2453	80.6
Vanuatu	21-27	1500-4000	75-80

Island cabbage thrives in these warm climates. It responds well to the even rainfall with fast, lush green growth. It does not do as well in dry sites which results in fibrous, leathery leaves.

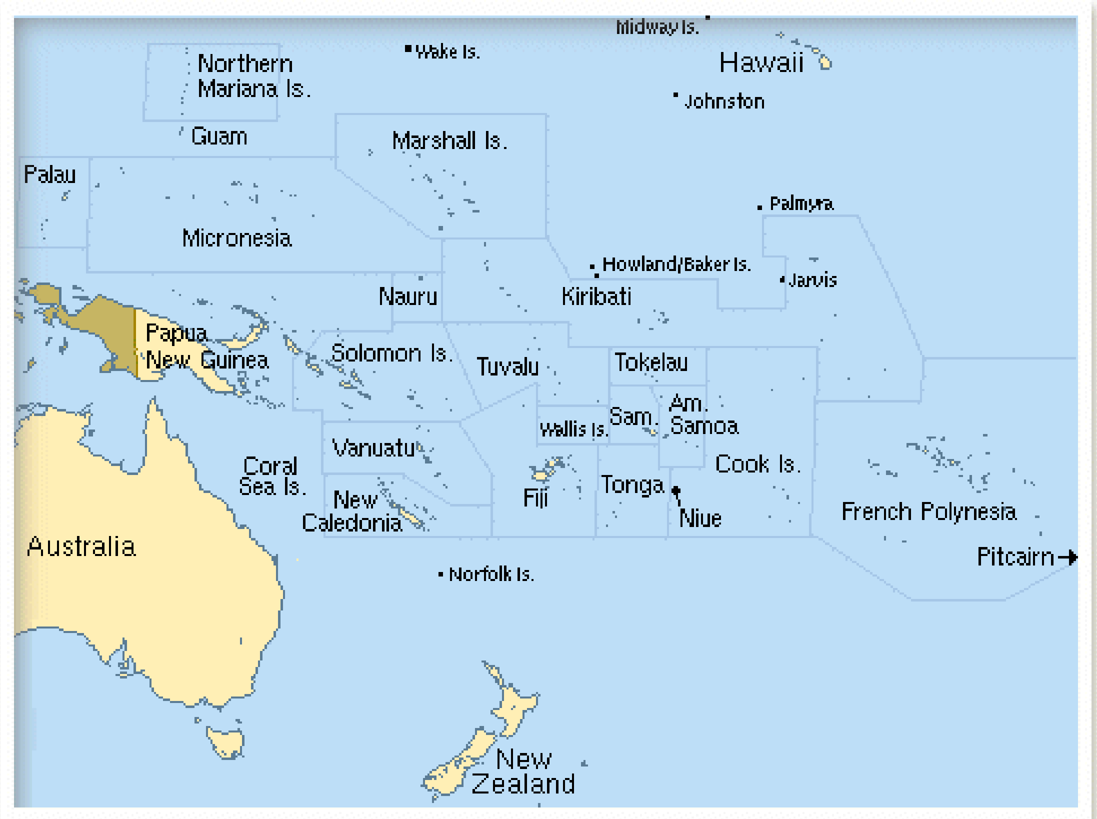

Figure 6. Map of the Pacific Islands showing the location of the exporting countries in relation to New Zealand. The equator runs just above Nauru.

2.4 The New Zealand *Abelmoschus* and *Hibiscus* industry

2.4.1 Production

There is no known industry in New Zealand for the production of *Abelmoschus manihot*. It is not known to be grown in New Zealand (NZPlants 2011). The closest related plant that is commercially cultivated would be *Hibiscus* plants for nursery/garden centre sale. There is some cultivation of *A. esculentus* (okra) in New Zealand but it is likely this is not an industry. Illegally imported okra seed has been confiscated in recent times (MAF-IDC Plants and Environment Investigations Monthly Report 04-2011)

Various ornamental Malvaceae are grown commercially, including *Abutilon* species, *Alcea*, *Althaea*, *Lavatera*, *Malva* and the natives *Hoheria* and *Plagianthus* species

2.4.2 New Zealand Malvaceae

The New Zealand Malvaceae is represented by three genera, *Hoheria* (endemic), *Plagianthus* (endemic) and *Hibiscus* (native).

There are six species of *Hoheria - H. populnea, H. sexstylosa, H. lyallii, H. glabrata, H. equitum* and *H. angustifolia*; two species of *Plagianthus* - *P. regius* and *P. divaricatus*; and two species of *Hibiscus – H. richardsonii* and *H. diversifolius* subsp. *diversifolius* (NZPCN 2011). The species potentially at risk from tropical and subtropical imported organisms are more likely to be those distributed throughout the north of the north island. These include (with conservation threat status in [brackets]):

- *Hoheria equitum* Heads 2000 – [naturally uncommon], restricted distribution to Poor Knights Islands and Hen and Chicken Islands
- *Hoheria populnea* A.Cunn. – [not threatened], natural distribution was North Cape to Waikato and Coromandel, however this has become a popular garden and amenity plant, has cultivars of it, and is distributed throughout New Zealand.
- *Hoheria sexstylosa* Colenso – [not threatened], natural range is Northern Waikato, Coromandel Peninsula to South Coast Wellington and Wairarapa
- *Hibiscus richardsonii* Lindl. – [nationally critical], strictly coastal, Te Paki (Northland) to Hicks Bay (East Coast) including Great Barrier and Mayor Islands
- *Hibiscus diversifolius* var. *diversifolius* - [nationally endangered], restricted distribution to the northernmost extremity of the North Island, in coastal wetlands and streamsides
- *Plagianthus regius* and *P. divaricatus* – [non threatened] and widespread

2.4.3 Imports of similar commodities

New Zealand currently imports frozen island cabbage leaves from Fiji and sometimes Tonga, fresh roselle leaves (*Hibiscus sabdariffa*) and fresh okra pods (all for consumption) from the Pacific.

2.5 New Zealand climate

General

New Zealand is situated in the South Pacific and ranges from 34˚ 00' S and 166˚ 00' E to 48˚ 00' S and 179˚ 00'E. It has a maritime climate which varies from warm subtropical in the far north to cool temperate in the far south, with severe alpine conditions in the mountainous areas. Mountain chains extending the length of New Zealand's South Island provide a barrier for the prevailing westerly winds, dividing the country into two separate climatic regions. The West Coast of the South Island is the wettest and the area to the east of the mountains, just over 100 km away, is the driest (NIWA 2007).

Annual rainfall in most parts of the country is between 600 and 1600 mm, with a dry period during the summer. At four locations on the west coast of the South Island (Westport, Hokitika, Mt Cook and Milford Sound) mean annual rainfall was between 2200 mm and 6800 mm for the period 1971-2000 (NIWA 2007). Rainfall is higher in winter than summer in the northern and central areas of New Zealand, whereas for much of southern New Zealand rainfall is lowest in winter. Mean annual temperatures range from 10°C in the south to 16°C in the north. The coldest month is usually July, and the warmest month usually January or February. Inland and to the east of the ranges the variation between summer and winter temperatures is up to 14°C. Temperatures also drop about 0.7°C for every 100 m of altitude (NIWA 2007).

Sunshine hours are relatively high in places sheltered from the west and most of New Zealand would have at least 2000 hours annually. Most snow falls in the mountain areas. Snow rarely falls at the coast of the North Island and west of the South Island, although the east and south coasts of the South Island may experience some snow in winter. Frosts can occur anywhere, and usually form on cold nights with clear skies and little wind (NIWA 2007).

The northern North Island

The northern part of New Zealand is the most climatically suitable for the establishment of new pests and pathogens coming from sub-tropical/tropical countries such as the Pacific Islands. However, organisms vary in their climatic tolerances and ability to adapt so other areas of New Zealand cannot be completely excluded.

The northern North Island includes Kaitaia, Kerikeri, Whangarei, Auckland (New Zealand's largest city), and Tauranga (see figure 5 for map of regions). The latter two cities both contain large active sea ports. Kerikeri is a well known orcharding town with many varieties of *Citrus* fruit grown there. Avocado, kumara, macadamia and tamarillos are the other main crops grown there (HortResearch 2005; Plant and Food Research 2010). This is a sub-tropical zone, with warm humid summers and mild winters. Typical summer daytime maximum air temperatures range from 22˚C to 26˚C, but seldom exceed 30˚C. Winter daytime maximum air temperatures range from 12˚C to 17˚C (NIWA 2007).

The Auckland region produces a variety of crops including *Citrus* species such as mandarins and lemons, strawberries, herbs, Asian vegetables, brassicas, chestnuts, greenhouse crops, lettuce, olives, onions, persimmons, pumpkin and silverbeet (HortResearch 2005; Plant and Food Research 2010). Auckland has the highest rate of naturalised plants of any city in New Zealand. The prime reasons for the high numbers of plant species are considered to be the moderate climate favouring species from many climatic zones, and availability of habitats (Esler 1988).

Auckland also has the largest population in the country, with the greatest influx of incoming goods and people and contains the largest sea and air ports. Therefore it is likely to be one of the first places risk organisms could establish.

The Bay of Plenty region produces feijoas, *Citrus*, avocado, asparagus, tamarillos and kiwifruit (HortResearch 2005; Plant and Food Research 2010).

2.5.1 Map of New Zealand

The following map (7) is used here to give the reader an idea of the location of some of the regions and their corresponding latitudes and longitudes mentioned in this document. The Crosby Codes were not used in this risk analysis as full names are considered easier to read.

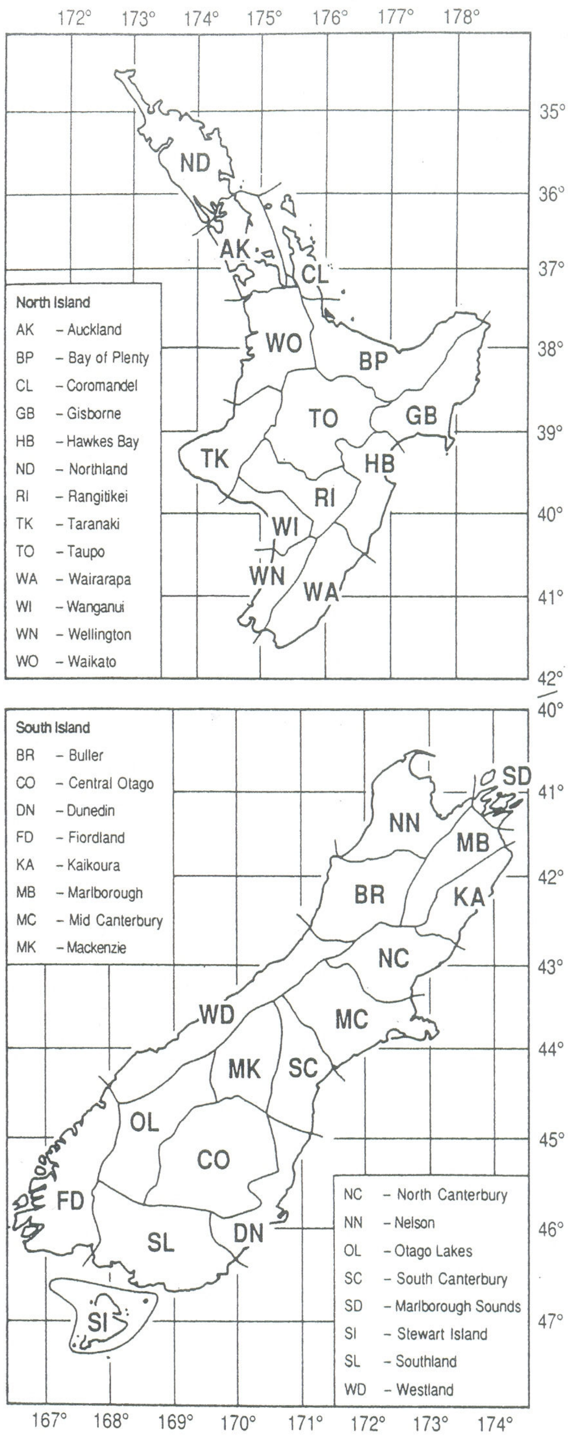

Figure 7. Map of New Zealand portraying Crosby Codes for New Zealand and presenting latitudes/longitudes (from Fauna of NZ Series).

2.6 Conclusion for Chapter 2

This risk analysis considers the following:

- Because procedures tend to vary between countries **the packhouse procedure** (section 2.1.1.1) **is excluded in assessing the risk** but is discussed in risk management options for each risk group;
- **Island cabbage leaves will be imported with no stem attached**, (see Scope, section 1.2) thus reducing risks associated with illegal propagation. **This is considered in assessing the risk**;
- Fresh island cabbage leaves are **likely to be purchased, cooked and consumed the same day**, as it is a product of cultural value, is highly perishable and will not be of sufficient quality for consumption after 2 or 3 days. This will contribute to reducing the likelihood of exposure. **This is considered in assessing the risk**
- The northern part of New Zealand is the most climatically suitable for the establishment of new pests and pathogens coming from sub-tropical/tropical countries such as the Pacific Islands. However, organisms vary in their climatic tolerances and ability to adapt so other areas of New Zealand cannot be completely excluded.

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3 Hazard identification

3.1 Identification of hazards

A list of organisms likely to be associated with island cabbage leaves from the Pacific Islands was compiled using:

- The report by Fa'anunu (2009)
- The publication: Preston (1998)
- Information derived from literature searches, including but not limited to: CAB Abstracts, Google Scholar, Farr et al (1989), Waterhouse 1997
- Database searches, including but not limited to: Farr et al (1989), Migeon and Dorkeld (2006), CPC (2010), Scalenet (2010), Pacific Island Pest List Database (2010), ICTVdB (2010), ANIC (2010), AFD (2010), FPI (2010), NZFungi (2010).
- Internet searches
- A review of organisms intercepted on closely related plant species (*Hibiscus sabdariffa* and *Abelmoschus esculentus*) imported from the Pacific Islands (Analysis and Profiling Interception database; Quancargo database)

Organisms on the list were screened and were classed as hazards if they were:

- likely to be present on the importation pathway (fresh island cabbage leaves from Cook Is, Fiji, Samoa, Tonga and Vanuatu for consumption)
- not known to be present in New Zealand

In addition, organisms that were present on the importation pathway, but present in New Zealand were given further consideration if they met any of the following criteria:

- vectors of pathogens or parasites that are not present in New Zealand
- known to have strains that do not occur in New Zealand
- of restricted distribution in New Zealand
- under official control in New Zealand
- differ genetically from those that occur in New Zealand in a way that may present a potential for greater consequences in New Zealand, either from the organism itself or through interactions with existing organisms in New Zealand
- the nature of the imports would significantly increase the risk.

The results of this process are contained in Appendices 1, 2, 3 and 4. The list, although extensive, is not exhaustive. While it includes most organisms likely to be carried on fresh island cabbage leaves from Cook Is., Fiji, Samoa, Tonga and Vanuatu, there may be information on additional organisms in sources that were not consulted, or which are not accessible.

In the process of identification of hazards associated with fresh Island cabbage leaves for consumption, 198 organisms (arthropods and pathogens) known to be associated with *Abelmoschus* species were tabulated in Appendix 1.

- of these 198 organisms, 74 were assessed further on the basis of association with the commodity and presence in either one or more of the following countries: Cook Is, Fiji, Samoa, Tonga and Vanuatu
- these 74 organisms were allocated to groups and 14 species selected to be examples of the groups (see 3.2)
- 124 organisms were excluded from further assessment (see Appendix 2)

- the risk posed by 3 arthropod species recorded from New Zealand, but known to be vectors of various pathogens is examined in Appendix 3
- the risk posed by 3 undescribed viruses reported from island cabbage in the Pacific is discussed in Appendix 4
- the risks posed by the 14 example organisms are assessed in Chapters 5 to 10 inclusive

3.2 Grouping

The final stage of hazard identification is grouping potential hazard organisms and the selection of example species. Because of the similarities in biology and the nature of association, it is assumed that risk management for the example species will also manage the risks of other organisms in this group, including any that have yet to be identified. Grouping requires an understanding of the biology of the grouped hazards and the potential measures, so that organisms can be grouped appropriately and to ensures any measures that may be implemented are appropriate for all the organisms in that group.

The groupings that are used in this risk analysis are:

Hazard Group A	mobile arthropods that are cryptic and/or small (Chapter 5)
Hazard Group B	sessile arthropods that are cryptic and/or small (Chapter 6)
Hazard Group C	arthropods that feed internally (within the leaf) (Chapter 7)
Hazard Group D	arthropods that are obvious and/or large (Chapter 8)
Hazard Group E	hitchhikers (Chapter 9)
Hazard Group F	fungal pathogens that are spread by wind or rain (Chapter 10)
Hazard Group G	systemic pathogens that are spread by insect vectors (Appendix 4)

3.3 Organism interception records

Organisms intercepted on imported goods at the border or post border are sometimes identified and recorded, usually during the biosecurity clearance process or as part of a monitoring survey. These records are extremely valuable because they demonstrate an actual rather than a theoretical association with a pathway for both live and dead organisms.

However there are significant limitations to their use, and both relative and absolute numbers of interception records are largely meaningless. Some of the reasons interception data cannot be used quantitatively are:

- not every organism on a pathway is detected. The level of detection of contaminants was tested on four pathways into the USA by Work *et al.* (2005). They estimated that even rigorous quarantine inspections probably only find 19-50% of associated species, depending on the pathway. These results were limited to insect species, probably due to the difficulty involved in detecting pathogens and other very small non-insect arthropods (such as mites) by visual examination. Work *et al.* (2005) also found that, although interception rates were highest in refrigerated maritime cargo (which includes fresh produce); the detection rate was poor on this pathway compared to the other cargo pathways. Detection rates are likely to vary greatly depending on the nature of the commodity and the biological characteristics of the taxa involved *e.g.* cryptic behaviour and body size. The sampling protocols used are also influential (*e.g.* Venette *et al*. 2002, Barron 2006).

- not every organism detected is recorded or identified
- the same interception may be recorded in multiple locations and duplications can occur
- search effort and the levels of identification done can vary (for example many interception records come from surveys)
- the level and reliability of identifications can vary
- the viability or life stage of an organism may not be recorded, or may be inaccurately recorded.

As there is no existing trade in fresh *Abelmoschus manihot* from the Pacific to New Zealand, no specific interception data are available. For particular potential hazard organisms, information from interception records on closely related commodities (*Abelmoschus esculentus* and *Hibiscus sabdariffa*) from the Pacific has been considered. Additionally information on hitch hiking organisms has been considered by assessing physically similar commodities and similar production systems. It is recognised that factors such as different production systems, different pest population levels etc. will have a strong influence on the likelihood of an organism being present on a particular commodity/country combination. However these similar pathways do provide some relevant information for island cabbage.

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4 Overview of potential risk management options

4.1 Introduction

Risk management in the context of risk analysis is the process of identifying measures to effectively manage the risks associated with the commodity under consideration. Since zero-risk is not a reasonable option, the guiding principle for risk management should be to manage risk to achieve the required level of protection that can be justified and is feasible within the limits of available options and resources.

Recommendations for the appropriate phytosanitary measures to achieve the effective management of risks are not made in this document. These will be determined when the Risk Management Proposal (RMP) and Import Health Standard (IHS) are drafted.

There are two areas in this document that discuss options for managing risk. This chapter looks at what options are available for the commodity and gives some general efficacy information. At the end of each individual pest risk assessment, factors relating to the efficacy of risk management are discussed in relation to the pest or group of pests. As the available information on efficacy is not always specific, factors that make a particular option more effective or less effective are discussed. Measures may be considered by themselves or in combination with other measures as part of a systems approach to mitigate risk.

Most exported fresh produce is produced commercially using pest management systems designed to reduce the likelihood of the commodity being infested with hazard organisms and pathogenic agents before export. It is expected that most fresh produce exported from overseas to New Zealand will follow such standards, therefore in most risk analyses, aspects of the production system are not considered as specific risk management options.

However in this risk analysis, some steps are considered as risk management options that would normally be considered within the commodity description, as discussed in section 2.2.1. This risk analysis needs to consider the following in discussing risk management options:

- There is currently no export system for fresh island cabbage leaves to New Zealand;
- Production of island cabbage is not regulated and therefore it is unlikely there will be formal pest management systems in place in the field in every instance;
- The most likely point in the pathway where risk mitigation is able to occur prior to export is at the packhouse;
- Post harvest treatments for fresh island cabbage leaves are very limited, and therefore washing and wiping of leaves is the primary option considered.

4.2 Discussion of risk management options

4.2.1 Heat disinfestation treatments

High temperature Forced Air (HTFA); Hot water Immersion (HWI); blanching

The scope of the risk analysis is fresh leaves only. All potential heat treatments will cook the leaves, rendering them unsaleable and no longer a fresh commodity. Therefore heat treatments are not feasible risk management options for fresh island cabbage leaves.

4.2.2 Cold disinfestation treatments

Cold treatments require the produce to be kept at a set temperature, usually 0-3 degrees C (Mangan & Hallman 1998), for two to three weeks. Island cabbage is highly perishable and is unlikely to keep beyond 3-4 days at usual refrigeration.

4.2.3 Irradiation

Under regulations managed by Food Standards Australia New Zealand (FSANZ), irradiated food is not permitted to be sold in New Zealand unless it has been through a pre-market safety assessment process conducted by FSANZ. Island cabbage leaves have not been assessed under this system. There are no irradiation facilities in the Pacific Islands, and it is unlikely this commodity has been tested for safety assurance, tolerance and efficacy of the treatment.

4.2.4 Methyl bromide

Fumigation treats both internal and external infestations including those that are not visible through standard visual inspection. Factors affecting mortality include:

- temperature; lower doses are generally required at higher temperatures due to the organisms' increased metabolic activity
- life stage; the treatment regime must kill the most tolerant life stage that is associated with the commodity
- resistance within populations

Fumigation with methyl bromide is a measure that is unlikely to be satisfactory for treatment of island cabbage. The requirement to heat the gas is likely to wilt the commodity rendering it unsaleable.

Additionally, methyl bromide is being phased out of use as a biosecurity treatment. The Montreal Protocol on Substances that Deplete the Ozone Layer is an international agreement designed to protect the stratospheric ozone layer. It stipulates that the production and consumption of compounds that deplete ozone in the stratosphere: chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform are to be phased out by 2000 (2005 for methyl chloroform). Scientific theory and evidence suggest that, once emitted to the atmosphere, these compounds could significantly deplete the stratospheric ozone layer that shields the planet from damaging UV-B radiation. The use of methyl bromide as a quarantine treatment to eliminate quarantine pests has been exempt from the phase-out requirements, but as a signatory to the protocol, New Zealand is committed to reducing its use.

4.2.5 Washing, wiping, visual inspection

The 'washing, wiping and inspection' process currently used in the Pacific for the export of taro and tarua leaves is described briefly in section 2.2.1., as it is likely to be similar to that used for island cabbage leaves.

To give an indication of the likely efficacy the interception data for the past three years were examined. There have been 170 separate occasions of interceptions on taro leaves and tarua leaves between 26 March 2008 and 18 Feb 2011. These data are tabulated below to give an indication of some of the types of organisms that were intercepted and their relative frequency.

Table 3 shows the number of times in approximately a 3 year period that various types of organisms were intercepted on taro leaves (*Colocasia esculenta*) and tarua leaves (*Xanthosoma sagittifolium*) NB: these numbers do not reflect the number of individuals intercepted, they reflect the number of times organisms were detected on a proportion of lines that were inspected. It does not take into account organisms that were intercepted and not recorded (see section 3.3 where limitations regarding use of interception data are discussed). Fungi have previously been intercepted, but were not recorded in the period shown here.

Table 3. Number of occasions of interceptions

Type of organism	**Number of occasions of intercepts**	
	Taro leaves (26 Mar 08-18 Feb 2011)	**Tarua leaves** (15 May 08-11 Nov 2010)
Ants	5	4
Aphids	29	3
Beetles	5	3
Bugs	6 (mirids)	-
Dermaptera	1	1
Flies	7	3
Fungi	-	-
Mealybugs	8	2
Mites	8	-
Moths	37	12
Neuroptera	-	2
Planthoppers (delphacids and flatids)	10	-
Psyllids	1	-
Snail	1	1
Undetermined	2	4
Virus	-	1
Whitefly	14	4

Additionally, data on the number of lines of taro leaves and tarua leaves coming into New Zealand in a two year period (May 2009 - April 2011) were examined. The number of lines that required treatment or destruction because they were infested with quarantine pests were compared to the number of lines that did not require treatment. Of the lines that were inspected 27% were treated or destroyed (278 of the 1,030 inspected lines) (MAF 2011).

This indicates that the 'washing, wiping and inspection' protocol currently used is not achieving the level of risk management expected, or that is typically acceptable for, a quarantine measure. This has required New Zealand to take mitigation measures upon arrival of the leaves at the border. While the results do not directly indicate the efficacy for island cabbage, they suggest that either the protocol is likely to need some modification to achieve the level required, or may need to be combined with another measure.

The FAO (2004) advocates that harvested produce should be trimmed of stem and well washed to remove any superficial dirt, plant debris, pests and pathogens. The water should be clean and contain the appropriate concentration of sanitizers to minimise the transmission of pathogens from water to produce, from infected produce to healthy produce within a single batch, and from one batch of produce to another batch over time. Waterborne microorganisms, including post-harvest plant pathogens and agents of human illness, can be rapidly acquired and taken up on plant surfaces (FAO 2004).

The USDA-PPQ Treatment Manual (2007) states that water used for washing and rinsing, for heat treatments, and for cooling must be fortified with sodium hypochlorite (household bleach) and constantly maintained at a chlorine level not to exceed 200ppm.

In addition, some pests (see chapters 5, 8 and 9) are capable of recontaminating washed leaves. The use of running water and appropriate storage are two approaches likely to reduce recontamination.

4.2.6 Visual inspection at the New Zealand border

Visual inspection at the New Zealand border is normally considered to be a verification process to ensure that offshore risk management measures have been correctly applied. Given that there are limited risk management options for island cabbage, visual inspection at the New Zealand border is considered here as a potential risk management option.

The inspection sampling regime depends on the level of confidence required for the absence of a particular organism, the detectability of the organism and the homogeneity of distribution of the organism within the commodity consignment (ISPM No. 23, 2005). These factors will be considered in relation to individual hazard organisms in Chapters 5–10.

4.2.7 Assumptions and uncertainty

There is considerable uncertainty about the efficacy of risk management measures. Additionally there is little information available on the efficacy of measures against some specific hazards. Significant uncertainty and may result in a level of residual risk (the risk remaining after measures have been implemented) being associated with the pathway.

The use of interception data once trade has commenced is one method of monitoring efficacy, as records of live and dead organisms indicate the success of risk management measures and the likelihood of potential hazards surviving the import process. However, interception records can rarely be used quantitatively because of limitations in the identification and recording processes.

The risk analysis uses available information to assess risk and clearly sets out the major remaining uncertainties and assumptions in the risk assessment for each potential hazard. Review of interception records is a means of testing these assumptions. They are intended to be used as a review tool, not as a primary risk mitigation measure or as a tool to prove the efficacy of a suggested measure. Measures are only suggested to be viable if there is clear evidence for their efficacy, and this is not dependent on interception data once trade has began.

4.3 Conclusion for Chapter 4

The options for risk management of fresh island cabbage leaves are very limited.

- Most quarantine treatments available in the Pacific are not feasible as they are likely to damage the commodity;
- The current wash-wipe-inspection protocol for taro/tarua leaves has been proposed;
- Interception data from taro and tarua leaves shows the current wash-wipe-inspection protocol is not of a quarantine standard;
- Washing effectiveness may be increased if leaves are submersed in the water, wiped and rinsed under running chlorinated water to remove any superficial invertebrates or dirt;
- Visual inspection at the border is usually an audit of systems, but would need to be considered as an additional biosecurity measure for this commodity;
- The efficacy of visual inspection is variable;
- The proposed option (wash-wipe-inspection) and visual inspection at the border is likely to manage a proportion of the risk and result in a small residual unmanaged risk.

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5 Risk assessments for potential hazard organisms group A: mobile arthropods that are cryptic and/or small.

5.1 Group hazard identification

The biosecurity risk from this group of hazards is assessed using two examples: all life stages of the aphid *Aphis fabae* and the crambid moth *Haritalodes derogata*. It is assumed that because of the similarity in detectability, any risk management for these example species will also manage the risk from other organisms in this hazard group, including any that have yet to be identified.

The organisms classed as hazards identified in Appendix 1 that appear to have life stages meeting the criteria for this group are listed in the following table. The organisms in **bold** have been assessed in this chapter; the organisms not in bold have not been assessed. Not all identified hazards are necessarily risks on this pathway.

Table 4. Mobile hazard organisms which are likely to be cryptic or small

Taxonomy	Type of organism	Included hazards	Mobile cryptic or small life stage
Acarina	Mites	*Tetranychus* species	nymphs and adults
Coleoptera	beetles	*Arsipoda tenembriensis*	adults
Hemiptera	aphids	***Aphis fabae***	nymphs and adults
Hemiptera	'planthoppers'	*Empoasca quadripunctata*	nymphs and adults
Hemiptera	scale insects and mealybugs	*Coccus capparidis, Maconellicoccus hirsutus, Planococcus minor, Pseudaulacaspis pentagona, Unaspis citri*	crawlers
Hemiptera	whitefly	*Aleurodicus dispersus, Bemisia tabaci*	adults
Lepidoptera	moth larvae/ caterpillars	*Anomis lyona,* ***Haritalodes derogata,*** *Tiracola plagiata, Xanthodes transversa*	early instar larvae
Nematoda		*Aphelenchoides* sp.	juveniles and adults
Thysanoptera	Thrips	*Thrips* .sp.	nymphs and adults

5.2 *Aphis fabae* - bean aphid

Scientific name: *Aphis fabae s.l.* Scopoli, 1763 (Hemiptera: Aphididae)
Other scientific names: *see section 1.1.1.2 Taxonomy*
Common names: bean aphid, black bean aphid

5.2.1 Hazard identification

5.2.1.1 Description

Aphis fabae is a temperate climate, phloem-sap-sucking insect. Its colour is matt black, the males have striped abdomens and adults often have dorsal white wax markings. It ranges in size from 1.3 - 3.1mm (Blackman and Eastop 2000).

5.2.1.2 Taxonomy

Aphis fabae Scopoli consists of a complex of closely related host-plant-associated forms (Tosh *et al*. 2004). The original description covers a number of races, subspecies and closely related species, now sometimes collectively referred to as *Aphis fabae s.l.* Scopoli (*s.l.*, meaning "in the broad sense").

Five closely related taxa[3] are known from Northern Europe (the probable area of origin): *Aphis fabae s.str.* Scopoli (*s. str*., in the strict sense, also known as *A. fabae fabae*), *A. fabae cirsiiacanthoidis* Scopoli, *A. fabae euonymi* Fabricius, *A. fabae mordwilkoi* Börner & Janisch and *A. fabae solanella* Theobald[4] (van Emden & Harrington 2007). Additional subspecies have been described by various authors (CPC 2010, Favret 2010).

Descriptive keys are available to distinguish members of the *A. fabae* group (*e.g.* Thieme 1987; Müller & Steiner 1990), and host association can be used to some extent, although the host range of all taxa in the group appears to overlap (van Emden & Harrington 2007). However the limits of some taxa are not clear and molecular techniques are needed to distinguish all the members of the *A. fabae* complex from each other (Jörg & Lampel 1996).

Since no members of the complex are known to be present in New Zealand the taxon treated here is *Aphis fabae s.l.* and includes all races, subspecies and closely related species except where otherwise specified.

5.2.1.3 Exporting country status

Aphis fabae has been reported from Tonga (Englberger & Foliaki 1992 cited in Fa'anunu 2009 and Pacific Island Pest List Database 2010). It is not stated which race or strain of *Aphis fabae* this is.

5.2.1.4 New Zealand status

Aphis fabae (neither the type nor any of the other subspecies) is not known to be present in New Zealand. Not recorded in: Teulon *et al.* (2004); Macfarlane et al. (2010); PPIN (2011).

5.2.1.5 General geographic distribution

Aphis fabae occurs in North America (CPC 2010), Europe, South America, West Asia and Africa, but is not common in hotter parts of the tropics, the Mediterranean or the Middle East where *A. fabae solanella* tends to replace it (Blackman & Eastop 2000; van Emden and Harrington 2007).

5.2.1.6 Commodity association

Aphis fabae has been recorded from *Abelmoschus manihot* (island cabbage) in Tonga (Englberger and Foliaki 1992, cited in Fa'anunu 2009). The race or strain is not stated.

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3. In this risk analysis, these taxa are listed as subspecies, however some sources list some of them as species
4. *A. solanella* is often regarded as a separates species (*e.g*. Tosh *et al.* 2004, Thieme & Dixon 2004).

5.2.1.7 Plant association

Although host range is used to some extent in distinguishing members of the complex, the host range of all members of the group appears to overlap and some hosts seem to be acceptable to all of them (van Emden & Harrington 2007). The northern European members of the complex all carry out their sexual phase on the spindle tree *Euonymus europaeus*, except *A. f. mordvilkoi* which uses *Viburnum opulus* or *Philadelphus coronarius*. *A. euonymi* stays on *Euonymus* all year. *A. f. cirsiiacanthoidis* usually has its sexual phase on *Euonymus* but can use *Viburnum opulus.* In Europe the primary host of *Aphis fabae fabae* is *Euonymus europaeus* (spindle tree), sometimes the host is *Viburnum opulus.* Secondary hosts are *Beta vulgaris* (beetroot), *Phaseolus vulgaris* (common bean) and *Vicia faba* (broad bean) (van Emden and Harrington 2007).

CPC (2010) reports the following host associations for *Aphis fabae* (*s.l.*):
Cultivated plants: *Allium* spp., *Apium graveolens* (celery), *Asparagus officinalis* (asparagus), *Brassica* spp., *Capsicum* spp., *Citrus sinensis*, *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Cucurbita maximus* (giant pumpkin), *Lactuca sativa* (lettuce), *Lycopersicon esculentum* (tomato), *Pastinaca sativa* (parsnip), *Phaseolus coccineus* (runner bean), *Pisum sativum* (pea), *Solanum tuberosum* (potato), *Spinacia oleracea* (spinach), *Vitis vinifera* (grape) and *Zea mays* (maize).

Wild or ornamental plants: *Arctium lappa* (burdock), *Berberis vulgaris* (barberry), *Chenopodium album* (fat hen) *Cirsium* spp., *Cotoneaster*, *Euonymus japonicus* (Japanese spindle), *Helichrysum* spp., *Hosta* spp., *Lonicera* spp., *Lupinus luteus* (yellow lupin), *Rosa* spp., *Rumex* (dock), *Solanum* spp. (nightshade), *Urtica* spp., *Viburnum* spp.

All of these plants grow in New Zealand.

5.2.1.8 Plant parts affected

Young *A. fabae* colonies feed upon young shoots, older colonies are spread over most aerial parts of the plant and are often attended by ants (Blackman and Eastop 2000).
Most of the damage it causes is from direct feeding causing wilting and collapse, and honeydew excretion reducing the host plants photosynthesis capability (Cammell 1981).

A. fabae as a vector:
This aphid can vector "more than 30 plant viruses of beans, peas, beets, crucifers, cucurbits, potatoes, tomatoes, dahlia and tulips, which are non-persistent" (van Emden and Harrington 2007). It also vectors "the persistent *Bean leaf roll virus* (Ortiz et al 2005) Beet yellow net virus and potato leaf roll virus" (van Emden and Harrington 2007), none of which are recorded from Tonga (Pearson and Grisoni 2002). *A. fabae* is considered to be "usually of only minor importance in transmitting plant virus diseases" (Cammell 1981).

5.2.1.9 Potential for establishment and impacts

Aphis fabae is primarily a temperate species and so is potentially able to establish in New Zealand. It is a recognised plant pest and therefore has the potential for unwanted impacts.

5.2.1.10 Hazard identification conclusion

Given that *A. fabae*

- is associated with island cabbage leaves;
- is reported from Tonga;

- and is not recorded from New Zealand;
- is potentially able to establish and have unwanted impacts

A. fabae is considered a hazard on island cabbage leaves in this risk analysis.

5.2.2 Risk assessment

5.2.2.1 Biology

Life cycle for A. fabae in Britain. After Cammell (1981), unless otherwise stated.
The following is a simplified portrayal of a complex life cycle:
Aphis fabae is a polymorphic[5] aphid with a host-alternating life cycle. Eggs (4-6 per female) are laid in autumn-winter on spindle tree (*Euonymus europaeus*) - the primary winter host. In early spring eggs hatch to become large, fecund, wingless females (fundatrices) which then reproduce parthenogenetically. After about three generations winged females (spring migrants) are increasingly produced during the late spring-early summer and these leave spindle trees to continuously colonise a wide range of secondary hosts which include beets, beans and many weed species. Wingless females that bear live young are produced on these secondary hosts and further disperse and colonise. In early autumn the decreasing day-length and temperatures stimulate birth of winged females and males. Winged females are the autumn migrants that move back to spindle trees and produce wingless, sexual females. These females mate with the males and lay eggs on spindle trees thus starting the whole cycle again (Cammell 1981).

Embryos develop to an advanced state within the female nymph before she becomes an adult, and these embryos in turn have developing embryos of the next generation within them. Thus the generations are telescoped in to one another. Nymphs take one to two weeks to reach adulthood on nutritious summer hosts (Cammell 1981).

The average life span of an aphid is about one month, with a reproductive period of about 3 weeks under good environmental conditions (http://hortipm.tamu.edu/pestprofiles/sucking/bartaphid/baraphid.html).

Eggs are the predominant means of overwintering. However, in mild or warmer climates *A. fabae* may continue to reproduce parthenogenetically[6] on secondary hosts without having an annual sexual phase (Cammell 1981). In this case the overwintering stage is wingless virgins (HYPPZ 2010).

Dispersal is mostly wind-borne and is a function of the winged stages in the lifecycle, behavioural mechanisms and the nature of the wind (Cammell 1981).

Aphis fabae is known to be a temperate climate insect and is the dominant species in the *A. fabae* complex throughout northern Europe and Britain (Cammell 1981).

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5. Polymorphic – more than one morph or form each with a specific function necessary to the completion of each stage in the life cycle
6. Parthenogenesis- is a form of asexual reproduction by females, where growth and development of embryos occurs without fertilization by a male.

5.2.2.2 Entry assessment

Aphis fabae eggs are laid in bark crevices on spindle trees therefore they are not likely to be found on island cabbage leaves.

The likelihood of A. fabae eggs entering New Zealand on island cabbage leaves is considered to be negligible.

Although small, *A. fabae* is a black-coloured, strongly aggregating species and therefore should be reasonably visible during harvest. However, it is likely that low numbers of small sized aphids and/or alatae[7] that may be on the undersides of leaves, could escape detection during harvest/inspection. Dark coloured aphids and alatae have been intercepted previously on leaves coming in to New Zealand (MAFBNZ Interception database 2010).

Live aphids (juveniles and adults, apterae[8] and alatae) have also been intercepted in cut flowers, foliage and fresh produce after long flights (*e.g.* from India, Europe and the Pacific Islands) and so are able to survive transit conditions (MAFBNZ Interception database 2010).

Given that:

- *A. fabae* is a dark-coloured, aggregating species and therefore reasonably visible; but,
- Inspections may not detect low levels of *A. fabae* within bundles of leaves; and,
- aphids can survive long flights and transit conditions;

The likelihood of entry of juveniles and/or adults on island cabbage leaves is considered to be low

5.2.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

Winged aphids are likely to fly from a wilting host to a new host (see p164, van Emden and Harrington 2007)

Adult wingless aphids are known to walk across plant-to-plant bridges and across open ground to move from one host plant to a new host (Broadbent 1953; Ribbands 1963).

Aphis fabae is a more sedentary, gregarious species, and dispersal of the wingless form is considered more restricted compared with some aphids (Hardie 1980). Although Hardie (1980) showed that

7. Alate (*pl.* alatae) - winged
8. Apterous (*pl.* apterae) - without wings

adult, wingless *A. fabae* would leave crowded, nutritionally-reduced host plants for another host plant, the distance travelled appeared very small.

Host plants for *A. fabae* are widespread and common in New Zealand, with many occurring all year round, including *Lonicera* spp., *Cotoneaster* spp. and some *Rumex* spp., with others becoming abundant from spring to autumn, such as *Chenopodium album*, an annual weed (NZFlora 2010).

Given that:

- *A. fabae* is known to move from one host to another host;
- the distance *A. fabae* can walk is not known but may in some cases be sufficient to place the aphid on a new host;
- *A. fabae* is polyphagous, and;
- there are host plants available all year in New Zealand;

The likelihood of exposure to new hosts is considered to be low to moderate depending on the time of year.

5.2.2.4 Assessment of establishment and spread

Aphis fabae has established in parts of the world with climates similar to New Zealand and is unlikely to have climatic barriers to its establishment in New Zealand.

Parthenogenetic females are the most likely form of *A. fabae* to arrive. One female has the ability to produce 85-90 offspring (Cammell 1981). Within about 2 weeks maturing nymphs will begin to reproduce themselves. Telescoping generations allow for a rapid population build up in good conditions.

Natural dispersal is by wind-borne winged adults. *Aphis fabae* is known to disperse and significantly colonise host crops up to 30km from the source of infestation (Cammell 1981). In time, *A. fabae* is likely to spread throughout most of New Zealand as conditions are considered suitable. Both the pea aphid and blue-green lucerne aphid spread through most of New Zealand in less than one year (Cameron and Walker 1989 cited in: Teulon and Stufkens 2002).

Given that *A. fabae*:

- is a temperate climate species;
- reproduction is predominantly parthenogenetic, giving rise to females;
- there are sufficient hosts to sustain development

The likelihood of establishment and spread is considered to be moderate.

5.2.2.5 Consequence assessment

Economic consequences

Aphis fabae is a known pest of vegetable crops, particularly beans and beets, and is considered an economically important species in Britain and Europe. Damage is caused by large aggregations feeding on the phloem and xylem sap which severely weakens the plant and can cause plant death. The small size of aphids, their parthenogenetic reproduction, and high reproductive rate, telescoping generations, rapid dispersal and eruptive population dynamics means they are difficult to control (Cammell 1981; Teulon and Stufkens 2002).

Affected groups will be in the horticultural and nursery sectors. Growers are likely to be controlling for other crop aphids and so the costs of this species may be partially absorbed. However, it is unknown how the presence of *A. fabae* would impact on current IPM programmes and whether the phenology of this species would mean additional control is required.

Therefore, the economic consequences are considered to be in the range of low to moderate.

Environmental consequences

Large populations of introduced aphids have been seen on native plants, and some damage has been noted, but there are few documented reports (Teulon and Stufkens 2002). It is not certain how *A. fabae* would affect native environments, but given dispersal is wind-borne and can be over some distance it is likely some individuals will find their way into natural habitats from urban environments. Families and genera that *Aphis fabae* feeds on are represented in the native flora; *e.g.*.: *Helichrysum* spp and *Urtica* spp. It is likely there would be some predation of aphids by insectivores.

The environmental consequences are considered to be low.

Human health consequences

There are no recorded impacts on human health.

Socio-cultural consequences

Amenity plants and home gardens may be affected by the addition of another aphid species as some previously unaffected plants may be hosts for *A. fabae.* Broad beans, a known host for *A. fabae*, are a common home garden crop.

The socio-cultural consequences are considered to be low.

5.2.2.6 Risk estimation

The likelihood of entry and exposure is low-moderate, establishment is moderate, and potential consequences are low to moderate.

As a result the risk estimate for Aphis fabae is non-negligible and it is classified as a risk in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

5.2.3 Risk management options

Given the risk estimate for *A. fabae* associated with island cabbage is non-negligible, options for phytosanitary measures are considered and factors relating to efficacy are discussed.

5.2.3.1 Post harvest cleaning and visual inspection option (*A. fabae*)

A washing, wiping and inspection protocol for taro and tarua leaves for export is discussed in section 4.2.5. The biology of *A. fabae* indicates it would be susceptible to this kind of management option. Specific points to consider include:

- it can occur on both sides of the leaf
- it is black and therefore should be visible, although small numbers of juveniles may be harder to detect

- it may move when disturbed, also making it easier to see
- it may be dislodged from leaves
- because apterous forms can walk small distances and alate forms can fly, it is capable of recontamination, either from water used for washing, or by flying onto leaves after washing and wiping

The available information is not enough to precisely measure the efficacy of the existing taro and tarua protocol, or the likely protocol for island cabbage leaves. However there have been substantial numbers of detections of live organisms (including aphids and similar small, cryptic, mobile organisms) on taro or tarua leaves that have been through the washing, wiping and inspection protocol. Potential modifications to this protocol discussed in section 4.2.5 are likely to improve the efficacy.

Overall, the biology of *A. fabae* indicates that it is likely to be susceptible to a management system involving washing, wiping and visually inspecting leaves. However, although the level of risk is at the lower end of the scale, without modifications to the existing protocol this management option on its own is not likely to be in proportion to the risk.

Modifications to the protocol can improve the efficacy, and with modifications this management option is likely to be in proportion to the risk. However until the protocol is in place and can be tested, significant uncertainty remains.

5.2.3.2 Visual inspection at the border option (*A. fabae*)

Small, cryptic mobile organisms such as aphids, mites and whitefly are frequently intercepted at the border on a range of pathways, including fresh leaves. *Aphis fabae* is black and likely to move when disturbed. It is therefore visually detectable, although small numbers of juveniles may be harder to detect.

The biology of *A. fabae* indicates it would be susceptible to this kind of management option. An inspection sampling regime will need to be developed that gives the level of efficacy required in proportion to the risk.

5.2.3.3 Combination of options

Combining the two management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded, visual inspection will also provide information which will reduce the uncertainty about the efficacy provided by the washing, wiping and inspection protocol.

5.3 *Haritalodes derogata* – cotton leaf-roller

Scientific name: *Haritalodes derogata* (Fabricius, 1775) (Lepidoptera: Crambidae)
Other relevant scientific names: *Sylepta derogata* (Fab., 1775)**;** *Syllepte derogata* (Fab., 1775)
Common name: cotton leaf-roller

5.3.1 Hazard identification

5.3.1.1 Description

Haritalodes derogata is a small moth with small leaf-roller larvae (1-30mm) that feed on leaves.

5.3.1.2 Exporting country/s status

H. derogata is present in Fiji and Samoa (Robinson *et al.* 1994).

5.3.1.3 New Zealand status

H. derogata is not known to be present in New Zealand. Not recorded in: Dugdale (1988); MacFarlane *et al*. (2010); PPIN (2010)

5.3.1.4 General geographic distribution

H. derogata is reported from Asia, Africa (Silvie 1990), Australia (Queensland, NSW) (ANIC 2010), PNG (Preston 1998), Solomon Is, Caroline Is, (Robinson *et al.* 1994).

5.3.1.5 Commodity association

H. derogata appears to be primarily associated with plants in the Malvaceae. It is known to be a pest of island cabbage (Preston 1998- as *Sylepta*),

5.3.1.6 Plant associations

H. derogata is mostly a pest of various species in the Malvaceae, such as *Abelmoschus esculentus* (okra) (Anioke 1989), *Gossypium* spp. (cotton) (Arora *et al.* 2009), *Hibiscus cannabinus* (kenaf), *Hibiscus rosa-sinensis* (hibiscus) and *Manihot esculenta* (cassava), (Silvie 1990). It is also reported from *Ceiba pentandra* (kapok) (Bombaceae) *Corchorus* spp. (jute) (Tiliaceae) and to a lesser extent from families Amaranthaceae, Sterculiaceae, Chenopodiaceae, Cucurbitaceae, Poaceae and Rubiaceae (Silvie 1990).

CPC (2007) lists *Solanum lycopersicum* (tomato) and *Solanum melongena* (eggplant) as major hosts. However, apart from CPC (2007) there is no obvious record for eggplant and only one record for tomato (Odebiyi 1982-cited in Silvie 1990).

5.3.1.7 Plant part affected

Larvae feed on the leaf epidermis; the margins are cut perpendicular to the vein and rolled under towards the midrib reducing surface area and therefore photosynthesis. The leaf remains green and open at the apex. Severe infestations defoliate plants (Vennila *et al.* 2007).

5.3.1.8 Potential for establishment and impact

H. derogata has been reported from parts of India and Pakistan that are ecoclimatically similar to New Zealand so it is assumed that this moth could establish here. *H. derogata* is a pest of many plants and is therefore likely to have unwanted impacts in New Zealand.

5.3.1.9 Hazard identification conclusion

Given that *Haritalodes derogata*:

- is associated with the leaves of island cabbage;
- is not present in New Zealand;
- is present in Fiji and Samoa;
- has the potential to establish and have unwanted impacts;

H. derogata is considered a hazard on island cabbage leaves in this risk analysis.

5.3.2 Risk assessment

5.3.2.1 Biology

Description

Adults are 11-13 mm long with a wing span of 23-28mm. Wings are white to cream with brown markings, with the head and thorax spotted black (Silvie 1990-as *Syllepte*; Anioke 1989- as *Sylepta*). Larvae are 1 mm up to 30 mm long, and are transparent to light yellow at hatch, becoming green (Anioke 1989; Silvie 1990; Vennila *et al.* 2007- as *Sylepta*). Eggs are about 0.5mm diameter with a yellow-green hue.

Life cycle (as reported from India and Africa)

A female can lay 200-300 eggs singly or less often in batches usually on the undersides of leaves, sometimes on the upper surface (Silvie 1990; Arora *et al.* 2009- as *Sylepta*). Eggs hatch in 2-6 days. The young larvae feed gregariously (Anioke 1989) on the underside of the leaves under a loose web of threads strung between leaf hairs (Silvie 1990). At about 4 days old they roll the leaf margin under, fixing it with silk, and feed within the protection of the rolled leaf (Silvie 1990; Vennila *et al.* 2007; Arora *et al.* 2009). There are 5 and sometimes 6 larval instars (Anioke 1989; Ahsan & Khalequssaman 1982- as *Sylepta*). Larvae about to pupate can become pinkish in colour. Pupation usually occurs within the leaf roll, or sometimes on shed leaves or leaf litter on the ground (Vennila *et al.* 2007). In Africa and India the lifecycle is completed in 22-53 days and there are 5-6 generations per year (Anioke 1989; Arora *et al.* 2009; Vennila *et al.* 2007). Diapause is reported from India but not known to occur in Africa (Silvie1990).

5.3.2.2 Entry assessment

Island cabbage is likely to be arriving as bundles of leaves. Eggs and young larvae are usually found on the undersides of leaves. They would not be readily detected unless each leaf was inspected. Aggregations are more likely to be found than single eggs or larva, however eggs are more commonly laid singly. Eggs take 2-6 days to hatch after being laid and would be well protected within a bundle of leaves. Larvae do not tend to cut and roll the leaf margin before they are 4 days old (Silvie 1990).

Adults rest on the undersides of leaves during the day, but it is expected they will be disturbed during harvest, sorting and packing. Mature larvae and pupae are found within a distinctive leaf-margin roll. It is expected that leaves with noticeably rolled margins would be discarded at harvest.

Given that:

- eggs and young larvae are small and inconspicuously coloured;
- leaves will be in bundles and unlikely to have 100% inspection;

The likelihood of entry of eggs and young larvae is considered to be moderate. The likelihood of entry of mature larvae and pupae is considered to be very low, and therefore non negligible. The likelihood of entry of adults is considered to be negligible.

5.3.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

Silvie (1990) notes that if the leaf is unrolled the disturbed larvae will move with agility to fall to the ground then move to a new leaf and make another roll. It is therefore assumed they can travel a short distance, which in some circumstances may be sufficient to enable them to find a new host.

The larvae feed primarily on Malvaceae. If island cabbage leaves were to be discarded in domestic compost or within a garden there would need to be plants such as *Althaea*, *Hibiscus*, *Abutilon*, *Hoheria*, *Lavatera, Pavonia* or *Plagianthus* very nearby. *Hibiscus* species are widely cultivated in the Auckland region. *Hoheria,* or lacebark, species are also popular garden and landscape plants, and are grown either as variegated cultivars, hybrids, or pure specimens throughout most of the country (Scheele and Sweetapple 2010).

Given that:

- there is no evidence to suggest larvae will move long distances, but it appears they can move short distances if necessary;
- a number of known hosts grow in New Zealand;

The likelihood of exposure is considered to be low.

5.3.2.4 Assessment of establishment and spread

H. derogata is found in regions of Africa, India, Bangladesh and Pakistan, often as a pest of cotton or okra. Although referred to as having a sub-tropical to tropical distribution, it does occur in regions where temperatures can range from -1˚C to 45˚C, *e.g.* Uttar Pradesh.

In Australia *H. derogata* is found in Queensland and New South Wales (NSW). It occurs throughout coastal Queensland from the tip of Cape York (Bamaga) to the NSW border (Mt Tamborine) and inland only as far as Toowoomba. It is found at places where rainforest and monsoon forest occur. In NSW it is found at Rous (near Lismore), Wooloolga (near Coffs Harbour) and Mt Keira (near Wollongong); these are all locations where rainforest is present. At the southern end of its range it is found nearly to the limit of subtropical rainforest but does not venture into cool temperate rainforest (pers. comm. E.D. Edwards, Australian National Insect Collection, CSIRO, 16 June 2010).

The distribution in NSW includes areas with a high degree of similarity to parts of New Zealand (Fagan *et al*. 2008). There are a number of known and potential host plants, exotic and native, present in the Auckland and Northland regions and throughout New Zealand, including the widely distributed *Hoheria* and *Plagianthus* species. Based on these factors it is considered that *H. derogata* can survive and establish in the Auckland and Northland regions of New Zealand.

Given that:

- *H. derogata* has been collected from parts of NSW that are climatically similar to the northern North Island of New Zealand;
- there are known and potential host plants present in suitable areas;

The likelihood of establishment is considered to be moderate.

Spread

This moth is most likely to be spread by movement of host plants by individuals or through the nursery/garden centre trade. Natural spread is likely to be slow and would be limited by climate and availability/accessibility of hosts.

The likelihood of H. derogata distribution within New Zealand spreading through ecoclimatically suitable areas of New Zealand is considered to be low.

5.3.2.5 Consequence assessment

Economic consequences

H. derogata is a known pest of cotton and okra, which are not grown in New Zealand as crops. Alternative hosts in the Malvaceae such as *Hibiscus* species are commonly grown as ornamentals in New Zealand. *H. derogata* is likely to cause cosmetic damage to the appearance of such plants and severe infestations would make the plants unsaleable. For instance, on cotton, rolled leaves can reduce seed production by 20-60% (Silvie 1990), cotton bolls may ripen prematurely and bud formation may be impaired. *Hibiscus* may be similarly affected. This is likely to have a small, localised impact on growers and sellers of these plants.

Although Odebiyi (1982, in Silvie 1990) has reported tomato to be a host there is insufficient information to assess the potential impact of *H. derogata* on tomatoes and tomato growers.

The potential economic consequences are likely to be restricted in distribution and are considered to be low.

Environmental consequences
Hoheria and *Plagianthus* species are native to New Zealand and widespread as forest, amenity and garden trees. They are not proven hosts for *H. derogata* but it is possible they would be palatable to *H. derogata* as this species feeds on several different genera in the Malvaceae and a few plants from other families such as Amaranthaceae and Tiliaceae[9] (Silvie 1990). It seems unlikely that *H. derogata* would reach levels of infestation that would cause significant damage as climate and quality of diet may be limiting factors.

The potential environmental consequences are considered to be low.

Human health consequences
None are known.

Socio-cultural consequences
Home gardens in areas where this moth can establish are likely to be affected, as various species in the Malvaceae like *Hibiscus*, *Althaea* and *Abutilon* are grown as ornamentals.

The socio-cultural consequences are considered to be low

5.3.2.6 Risk estimation

In this risk analysis, the likelihood of entry is moderate for eggs and young larvae, exposure is low, establishment is moderate, and potential economic and environmental consequences are low.

As a result the risk estimate for Haritalodes derogata is non-negligible and it is classified as a hazard in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

5.3.3 Risk management options

Given the risk estimate for *H. derogata* associated with island cabbage is non-negligible, options for phytosanitary measures are considered and factors relating to efficacy are discussed.

5.3.3.1 Post harvest cleaning and visual inspection option (*H. derogata*)

A washing, wiping and inspection for taro and tarua leaves for export is discussed in section 4.2.5. The biology of *H. derogata* indicates it would be susceptible to this kind of management option. Specific points to consider include:

- Eggs and larvae are most commonly on the undersides of leaves
- Newly hatched larvae are usually gregarious and although very small should be visible in numbers, but less visible if solitary
- Rolled leaf margins will protect larvae but will also draw attention to their presence
- Disturbed larvae move quickly, drop from leaves, and may have silk threads attached to them enabling them to float on water, so can potentially recontaminate leaves

9. *Entelea arborescens* (Whau) is endemic to New Zealand and found from Northland through to Bay of Plenty

The available information is not enough to precisely measure the efficacy of the existing taro and tarua protocol, or the likely protocol for island cabbage leaves. However there have been significant numbers of detections of live Lepidoptera on leaves that have been through the washing, wiping and inspection protocol. Potential modifications to this protocol discussed in section 4.2.5 are likely to improve the efficacy.

Overall, the biology of *H. derogata* indicates that it is likely to be susceptible to a management system involving washing, wiping and visually inspecting leaves. However, although the level of risk is at the lower end of the scale, without modifications to the existing protocol this management option on its own is not likely to be in proportion to the risk.

Modifications to the protocol can improve efficacy, and with modifications this management option is likely to be in proportion to the risk. However, until the protocol is in place and can be tested significant uncertainty remains.

5.3.3.2 Visual inspection at the border option (*H. derogata*)

All life stages of several moth species are frequently intercepted at the border. *H. derogata* larvae are transparent to light green so may not be readily detectable as solitary individuals unless they have rolled the leaf margin.

The biology of *H. derogata* indicates it would be susceptible to this kind of management option. An inspection sampling regime will need to be developed that gives the level of efficacy required in proportion to the risk.

5.3.3.3 Combination of options

Combining the two management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded visual inspection will also provide information which will reduce the uncertainty about the efficacy provided by the washing, wiping and inspection protocol.

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6 Risk assessment of potential hazard organisms group B: sessile arthropods that are cryptic and/or small

6.1 Group hazard identification

The biosecurity risk from this group of hazards is assessed using three examples: all life stages of the whitefly *Aleurodicus dispersus*, the pseudococcid mealybug *Maconellicoccus hirsutus* and the diaspid scale *Pseudaulacaspis pentagona*. It is assumed that because they are fixed onto the commodity and will have similar detectability, any risk management for these example species will also manage the risk from other organisms in this hazard group, including any that have yet to be identified.

The organisms classed as hazards identified in Appendix 1 that appear to have life stages meeting the criteria for this group are listed in the following table. The organisms in **bold** have been assessed in this chapter; the organisms not in bold have not been assessed. Not all identified hazards are necessarily risks on this pathway.

Table 5. Sessile hazard organisms which are likely to be cryptic or small

Taxonomy	Type of organism	Included hazards	Sessile cryptic or small life stage
Acarina	mites	*Tetranychus* species	eggs
Coleoptera	beetle	*Harmonia arcuata*	Eggs
Coleoptera	weevils	*Apirocalus cornutus, Elytrurus griseus, Sphaerorhinus aberrans*	eggs
Hemiptera	bugs	*Amblypelta cocophaga, Brachylybas variegatus, Lampromicra* sp., *Micraspis lineola, Nysius* sp., *Tectocoris diophthalmus, Phaenacantha sp.,*	Eggs
Hemiptera	scale insects and mealybugs	*Coccus capparidis,* ***Maconellicoccus hirsutus****, Planococcus minor,* ***Pseudaulacaspis pentagona****, Unaspis citri*	Sessile nymphs and female adults, eggs
Hemiptera	'planthoppers'	*Colgar tricolour, Empoasca quadripunctata, Euricania disciguttata,*	Eggs
Hemiptera	whitefly	***Aleurodicus dispersus****, Bemisia tabaci*	Eggs
Lepidoptera	moth larvae/ caterpillars	*Anomis lyona, Earias vittella, Haritalodes derogata, Tiracola plagiata, Xanthodes transversa*	Eggs
Orthoptera	grasshoppers	*Phaneroptera brevis, Valanga* sp.	Eggs
Thysanoptera	thrips	*Thrips sp*	Eggs

6.2 *Aleurodicus dispersus*- spiralling whitefly

Scientific name:	*Aleurodicus dispersus* Russell, 1965 (Hemiptera: Aleyrodidae)
Common name:	spiralling whitefly

6.2.1 Hazard identification

6.2.1.1 Description

Aleurodicus dispersus is a very small (2mm) phloem sap-sucking insect with a moth-like appearance that feeds on leaves.

6.2.1.2 Exporting country/s status

Aleurodicus dispersus is reported from Cook Islands, Fiji, Samoa and Tonga (Waterhouse 1997).

6.2.1.3 New Zealand status

Aleurodicus dispersus is not known to be present in New Zealand - not listed in Macfarlane *et al*. (2010). Recorded as 'not present' by PPIN (2011).

6.2.1.4 General geographic distribution

A. dispersus is native to Central America and the Caribbean. It has been reported from parts of: South America, southern USA, the Pacific, Africa, Queensland (Australia), the Philippines, India, Sri Lanka and the Maldives (Kessing and Mau 1993; Martin 1990 in FAO datasheet).

6.2.1.5 Commodity association

A. dispersus is reported on *Abelmoschus manihot* (island cabbage) (Preston 1998). On most plants it is usually found on the undersides of leaves, but "in heavy infestation may also be found on the upper leaf surface, fruit and non plant material" (Botha *et al*. 2000). Lambkin (2006) reported that eggs are laid on foliage and fruit, and CPC (2010, unreferenced) reported that eggs may be transported on leaves and also on fruit. The only records of interceptions of *A. dispersus* on fresh produce at the New Zealand border are on leaves (Quancargo database, accessed November 2009).

6.2.1.6 Plant associations

A. dispersus is highly polyphagous, being common on a wide range of different plant families. In the original description of this species from Florida, Russell (1965) recorded it from 38 genera in 27 plant families. CPC (2010) reports *Prunus* species as main hosts. Other main hosts are *Ageratum conyzoides* (billy goat weed), *Cajanus cajan* (pigeon pea), *Persea americana* (avocado), *Hibiscus rosa-sinensis* (China rose), *Manihot esculenta* (cassava) and *Solanum nigrum* (black nightshade). Other hosts include *Acacia* (wattles), beans, blackberries, *Bougainvillea*, *Capsicum*, *Chrysanthemum*, citrus, coconut, *Euphorbia hirta* (garden spurge), guava, *Ipomoea batatas* (sweet potato), lettuce, lima bean, plantain, soybean, raspberries and roses (CPC 2010).

6.2.1.7 Vector

A. dispersus has been reported as a vector of the cassava brown streak virus (CBSV), Potyviridae, in *Manihot esculenta* (cassava) in Kenya, although it has not proven to be an efficient vector (Mware *et al*. 2009). This virus is recorded from East Africa and does not appear to be in the Pacific (ICTVdb 2006). Susceptible host species are found in the Families Euphorbiaceae and Solanaceae (ICTVdb 2006).
As CBSV has not been recorded from the Pacific (Davis and Ruabete 2010; Pearson and Grisoni 2002; ICTVdb 2006) *A. dispersus* will not be considered as a potential vector in this risk analysis.

6.2.1.8 Potential for establishment and impact

There are areas in northern New Zealand that are considered suitable for *A. dispersus* establishment. This would be much broader if *A. dispersus* established in glasshouses. It is likely to impact on horticultural and nursery sectors and the natural environment.

6.2.1.9 Hazard identification conclusion

Given that *Aleurodicus dispersus*

- Is associated with island cabbage;
- Is present in the Cook Islands, Fiji, Samoa and Tonga;
- Is not recorded from New Zealand;
- Is potentially able to establish and have unwanted impacts;

A. dispersus is considered a hazard on island cabbage in this risk analysis.

6.2.2 Risk assessment

6.2.2.1 Biology

Eggs are a translucent yellow colour aging to tan, elliptical and about 0.3mm long (Aiswariaya et al 2007). Each egg has a short stalk (pedicel) which is inserted into the stomata (pores) on the underside of the leaf during oviposition (Paulson and Beardsley 1985). Waxy secretions are deposited along with the eggs which are usually laid at right angles to leaf veins in irregular lines forming a loose spiral pattern (Wijesekera 1990). In India the eggs hatch within 5-8 days (Geetha 2000 In: Mani 2010).

There are four nymphal instars which last a total of 14-25 days (Geetha 2000 In: Mani 2010). The first instar or “crawler” has functional legs and can walk a few millimetres from its hatch site before settling to feed. The second and third instars have atrophied legs, appear scale-insect-like and tend to be sedentary. The fourth instar is the final feeding stage. When it is fully grown it pupates in the larval skin which is then termed the puparium. The puparium soon becomes covered in a cottony white material, and produces long glass-like wax filaments.

When the adults emerge they are about 2mm in length with clear wings that become white and coated in a waxy powder within a few hours (Kessing and Mau 1993; Aiswariaya et al 2007). Adults are able to fly short distances and could be carried farther by wind. They are active at temperatures between about 12-32˚C (Wijesekera 1990).

In India, egg to adult takes about 22-29 days and adults live for 13-22 days (Geetha 2000 in Mani 2010), with females producing eggs daily. A female can produce up to 64 eggs in her lifetime (Mallapanavar 2000 in: Mani 2010). Mated females will produce both sexes whereas unmated females will produce only male progeny (Kessing and Mau 1993).

Cherry (1979) noted that temperatures below 10˚C cause mortality in eggs and adults, but the nymphs could cope with slightly lower exposure to cold. Heavy sporadic rains and cool temperatures may result in a temporary reduction in *A. dispersus* populations, which will increase again in warmer, drier weather (Cherry 1979).

6.2.2.2 Entry assessment

In general whitefly adults tend to disperse quite quickly when disturbed, so it is assumed that *A. dispersus* would fly off the plant as leaves are being harvested[10]. Eggs and the sedentary immature stages will remain firmly attached to leaves and are not likely to be easily dislodged by rain or washing. It is expected that if leaves are individually checked on both sides the waxy deposits and spiral pattern of the eggs should be visible and the leaf discarded. It is possible that on occasion there may be very few eggs laid, or crawlers may move from their hatch leaf to an overlapping leaf to settle and feed, or rinsing may remove some of the waxy deposit; these scenarios would reduce detectability. First instars are less than 1mm in length, are a transparent green colour with two puffs of wax at the anal end so will be less obvious than the later instars, especially if there are only a few on the underside of a leaf. CPC (2011, unreferenced) states “these early insect stages are often cryptic”.

Given that:

- Eggs are very small and laid into stomata on the undersides of leaves;
- First instars are very small, sedentary and may blend in colour with the leaf;
- There are likely to be occasions when there are only a few eggs or juveniles on a leaf and are therefore not obvious; but:
- It is expected leaves will be inspected at harvest and that most whitefly would be detected;

The likelihood of entry for A. dispersus is considered to be low[11].

6.2.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in

10. Note that live adult whitefly have been intercepted on leaves previously, and that the previous chapter addresses that life stage.
11. The likelihood of entry for *Bemisia* species is considered to be moderate as they are less conspicuous than *A. dispersus.*

landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

The life-stages that are most likely to come in on leaves are eggs, nymphs and pupae. Only the adult will actively disperse beyond the leaf upon which the egg was laid (Kessing and Mau 1993). Island cabbage leaves will wilt quickly, especially in warm temperatures. Sedentary life-stages rely on the leaf they are hatched on for nutrition. Therefore, the life-stage most likely to achieve adulthood and become sufficiently mobile will be the fourth instar, particularly if it has passed into the non-feeding puparium. The summer months in the Auckland region are usually warm enough to allow an adult to emerge and look for a suitable host.

A. dispersus is a polyphagous whitefly with host plants such as *Citrus* species, *Solanum* species and *Hibiscus* all plentiful in the Auckland region.

Given that:

- Adults are the most actively mobile life-stage;
- The average time from egg to adult is 22-29 days;
- Island cabbage will perish within a few days;
- The most likely stage to reach adulthood before the leaf has deteriorated is the non-feeding puparium, but;
- Host plants suitable for *A. dispersus* are widely available in the Auckland region;

The likelihood of exposure, depending on life stage, is considered to be low to moderate.

6.2.2.4 Assessment of establishment and spread

The Auckland and Northland regions have summer climates suitable for *A. dispersus*. Winter will be less suitable but will not necessarily prevent establishment, particularly if arrivals reach protected environments such as greenhouses and glasshouses. In Taiwan the estimated temperature thresholds for development of *Aleurodicus dispersus* varied from nearly 5˚C for eggs to nearly 10˚C for 3^{rd} and 4^{th} instars; adult survival was reduced at temperatures below 5˚C (Wen *et al.* 1994).

It is likely there will be more than one whitefly per leaf, and likely both sexes will be present and thus able to locate each other. Arrival of whitefly on leaves would need to occur in the summer months to allow for the opportunity to develop to adulthood, mate and establish a population. It is likely that the winter season or adverse environmental conditions would reduce the numbers of whitefly severely, but leaving enough survivors to found a summer population. In an experimental study, Waterhouse and Norris (1989) reported 20 pairs of whitefly produced 1549 progeny in 37 days under laboratory conditions.

There are other areas of New Zealand that may have both suitable summer conditions and hosts for *A. dispersus*; however, unless exposed to a heated glasshouse it is unlikely to survive the cold, wet winters in these areas. Seasonal introductions to these areas are likely to be by prevailing winds and movement of plant material each summer.

Given that:

- The Auckland and Northland climate is suitable for permanent populations;
- It is very likely there will be several whitefly of both sexes present on a leaf;
- locating a mate is not unlikely;

- known hosts are plentiful;
- apart from in protected environments, the winter season or adverse environmental conditions will limit population increase and limit spread in New Zealand;

The likelihood of establishment and spread is considered low.

6.2.2.5 Consequence assessment

Economic consequences

Direct damage results from the piercing and sucking of sap from the leaf phloem. Mostly immature stages and adults feed on sap which can weaken plants, cause premature leaf drop and reduce yields. The honeydew that is produced by the whitefly provides a substrate for sooty moulds to grow on the leaf surface, which in turn decreases the photosynthetic ability of the plant thereby reducing yields. Sooty mould, honeydew and the white flocculence all reduce the market value of plants and crops.

In New Zealand the crops/plants likely to be affected include *Citrus*, avocado, macadamia, stone-fruit, lettuce, peppers, tomatoes, beans and sweet potato; cut-flowers such as roses and chrysanthemums; and ornamentals such as azaleas, dahlias, canna lilies, poinsettia and hibiscus. The impacts are likely to be on the horticultural and nursery sectors.

The potential economic consequences are considered to be moderate in the areas affected.

Environmental consequences

Aleurodicus dispersus infests hosts from 38 genera in 27 plant families, potentially affecting many amenity and native species in urban, suburban and rural areas. Based on known attacks on native plants by exotic species present in New Zealand, Beever *et al.* (2007) suggested that, in terms of risk to native flora, sap-sucking hemipterans, particularly polyphagous species, are a high risk group. In New Zealand there are seven exotic and nine endemic whitefly species. Four exotic whiteflies have been recorded on native hosts.

- *Orchamoplatus citri* (Takahashi 1940) was known only from citrus (Rutaceae) until recorded on *Alectryon excelsus* (native, Sapindaceae), *Melicope ternata* (native, Rutaceae), *Metrosideros excelsa* (native, Myrtaceae) and *Choisya ternata* (exotic, Rutaceae) in New Zealand (Beever *et al.* 2007).
- *Aleyrodes proletella* Linn. 1758 was reported from the NZ endemic *Euphorbia glauca* G.Forst., (Euphorbiaceae)
- *Siphonius phillyreae* (Halliday 1835) was reported from the NZ endemic *Nestegis cunninghamii* (Hook.f.) L.A.S.Johnson, (Oleaceae)
- *Trialeurodes vaporariorum* (Westwood 1856) was reported from the NZ endemic *Pittosporum eugenioides* A. Cunn., (Pittosporaceae) and *Geniostoma rupestre* Forster et Forster f. var. *ligustrifolium* (A.Cunn.) B.J.Conn, (Loganiaceae)

It is likely that *A. dispersus* would find hosts in the native flora.

As distribution is likely to be restricted because of climate suitability the potential environmental consequences are considered to be low.

Human health consequences

Waterhouse and Norris (1989) comment that the flocculence or the whiteflies themselves may have contributed to allergies and dermatitis reported during the height of an infestation in Hawaii. In New Zealand it is unlikely *A. dispersus* would reach levels of infestation that would have any significant impact on human health

The potential human health consequences are considered to be very low.

Socio-cultural consequences

It is likely domestic gardeners would feel some impact through loss of yield, cost and difficulty in controlling the insect and the sooty mould. These impacts will be restricted to the areas where *A. dispersus* is likely to establish.

The potential socio-cultural consequences within New Zealand are considered to be very low.

6.2.2.6 Risk estimation

In this risk analysis, the likelihood of entry is low for eggs and nymphs, exposure is low, establishment is low, and the potential consequences are also low.

As a result the risk estimate for Aleurodicus dispersus is non- negligible and it is classified as a risk in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

6.2.3 Risk management options

Given the risk estimation for *A. dispersus* is non-negligible options for phytosanitary measures are considered and factors relating to efficacy are discussed.

6.2.3.1 Post harvest cleaning and visual inspection option (*A. dispersus*)

A protocol for the washing, wiping and inspection of taro and tarua leaves for export is discussed in section 4.2.5. The biology of *A. dispersus* indicates it would be susceptible to this kind of management option. Specific points to consider include:

- Eggs are embedded into the underside of the leaf
- Nymphs are firmly attached to underside of leaf
- Waxy secretions should increase detectability
- Recontamination by eggs or nymphs is unlikely

The available information is not enough to precisely measure the efficacy of the existing taro and tarua protocol, or the likely island cabbage protocol. However there have been numerous occasions in the last three years where live small, sessile arthropod life stages (such as moth and whitefly eggs and pupae, mite eggs) have been intercepted on taro or tarua leaves that have been through the washing, wiping and inspection protocol. Potential modifications to this protocol discussed in section 4.2.5 are likely to improve the efficacy.

Overall the biology of *A. dispersus* indicates it is less likely to be susceptible to washing and wiping than to inspection. Although the level of risk is at the lower end of the scale, without modifications, this management option on its own is not likely to be in proportion to the risk.

Modifications to the protocol can improve the efficacy, and with modifications this management option is likely to be in proportion to the risk. However, until the protocol is in place and can be tested, significant uncertainty remains.

6.2.3.2 Visual inspection at the border option (*A. dispersus*)

Small, cryptic, sessile organisms such as whitefly eggs, pupae, moth and/or mite eggs are frequently detected at the border on a range of pathways including fresh leaves. *A. dispersus* is light coloured with a white-ish, waxy coating. It is visually detectable, although small numbers of eggs and nymphs may be harder to detect.

The biology of *A. dispersus* indicates it would be susceptible to this kind of management option. Efficacy will depend on the sampling regime, therefore, an inspection sampling regime will need to be developed that gives the level of efficacy required in proportion to the risk.

6.2.3.3 Combination of options

Combining the two management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded then visual inspection will also provide information which will reduce the uncertainty about the efficacy provided by the washing, wiping and inspection

6.3 *Maconellicoccus hirsutus* – pink hibiscus mealybug

Scientific name: *Maconellicoccus hirsutus* (Green, 1908) (Hemiptera: Pseudococcidae)

Other relevant scientific names: *Phenacoccus hirsutus; Phenacoccus quaternus; Pseudococcus hibisci; Phenacoccus glomeratus; Pseudococcus crotolariae; Spilococcus perforatus; Paracoccus pasaniae; Maconellicoccus perforatus; Maconellicoccus pasaniae*

Common names: pink hibiscus mealybug, hibiscus mealybug, pink mealybug, hirsutus mealybug, grape mealybug, mulberry mealybug, cochenille de l'Hibiscus

6.3.1 Hazard identification

6.3.1.1 Description

Maconellicoccus hirsutus is a sap-sucking mealybug that secretes honeydew and prefers tender young plant tissues.

6.3.1.2 Exporting country/s status

Maconellicoccus hirsutus is reported from Tonga, Samoa and Vanuatu (Williams and Watson 1988, CAB/EPPO 2004).

6.3.1.3 New Zealand status

M. hirsutus is not known to be present in New Zealand. Not recorded in: Cox (1987), Ben-Dov (1994), Macfarlane et al. (2010), PPIN (2011).

6.3.1.4 Geographic distribution

M. hirsutus occurs in tropical and subtropical regions and extends into some temperate areas. It is generally accepted that it originated in southern Asia and it has been recorded from much of this region. It probably reached Egypt as early as 1908, and has now spread through much of Africa. In the Middle East it is known from as far north as Lebanon. In Australia it is known from South Australia, Western Australia, Northern Territories and Queensland (ANIC 2011) where the earliest records only date from 1959. *M. hirsutus* was introduced to Hawaii in the 1980s (Williams, 1996). It was first confirmed present in the Caribbean in 1994, in Grenada, and has quickly spread to other islands. Almost all the serious damage by *M. hirsutus* is in areas between 7^{o} and 30^{o}N, where there are reports of seasonal differences in the incidence of the pest (Williams, 1996). However, Williams (1996) suggests that because *M. hirsutus* is known as far north as Lebanon in the Middle East, outbreaks of this species in the West Indies pose a threat to the more temperate areas of the USA where cotton and grapes could be susceptible; these crop plants are prone to attack in India and Egypt (Mani, 1989; Amin and Emam, 1996). Williams (1996) goes on to say: "*Phenacoccus madeirensis* (Green), a polyphagous and normally tropical mealybug found throughout Central and Southern America and in Africa is known from many parts of Mexico and USA. This species was first reported from Sicily by Longo and Russo (1990) and later infesting many plants there (Mazzeo *et al*, 1994). There seems to be no reason why *M. hirsutus* could not similarly survive in southern

Europe and southern USA." *M. hirsutus* has been detected since in California and Florida in the US (Hoy *et al*, 2006; Kairo *et al*, 2002).

It is now found in the Americas including California, Florida, Mexico, Belize in Central America, and Guyana and Venezuela in South America (Hoy *et al*, 2006; Goolsby *et al*, 2002; Kairo *et al*, 2002; Williams, 1996). It is found in China and Tibet (Ben-Dov, 1994; Williams, 1996; CPC, 2007; ScaleNet, 2010). In the Pacific it is also found in Irian Jaya, the Fed. States of Micronesia, Guam, Palau, Papua New Guinea, Tuvalu, and the Solomon Islands (Williams and Watson 1988, CAB/EPPO 2004).

6.3.1.5 Commodity association

M. hirsutus is reported from island cabbage leaves (as *Hibiscus manihot*) (Williams and Watson 1988).

6.3.1.6 Plant associations

M. hirsutus is highly polyphagous; Ben-Dov (1994) records 98 host genera/species in 36 families while Meyerdirk and others (2001) record over 200 genera of plants in 70 different families. It is a well-known pest of cotton, hibiscus and many ornamentals (Ben-Dov, 1994). When it established in Grenada, it rapidly became a pest of food plants, ornamentals, weeds, fruit and forest trees (Persad and Khan 2002). Some hosts enable the insect to complete its entire life cycle while others are only suitable for feeding.

Hosts include:
Grapes (Amin et al 1996), *Asparagus officinalis*, *Capsicum annum*, *Citrus* sp., *Colocasia esculenta* (taro), cucurbits, *Daucus carota* (carrots), *Cyperus* sp. (sedges), *Euphorbia* sp., *Ficus* sp., *Ipomoea batatas* (sweet potato), *Jasminum* sp., *Latuca sativa* (lettuce), *Persea americana* (avocado), *Prunus* sp., *Pyrus communis* (pear), *Rosa* sp., *Zea mays* (maize) (after Chang & Miller 1996; cited in Anon. 2002); *Hibiscus sabdariffa* (roselle leaves)(Hill 2008).

6.3.1.7 Plant parts affected

M. hirsutus infests the leaves, shoots, fruit (Meyerdirk *et al*, 2001; CPC, 2007) of host plants.

6.3.1.8 Potential for establishment and impact

M. hirsutus is reported from South Australia which indicates it is potentially able to establish in parts of New Zealand. It is likely to cause unwanted impacts within horticultural industries.

6.3.1.9 Hazard identification conclusion

Given that *Maconellicoccus hirsutus*:
- is not present in New Zealand;
- is present in Vanuatu, Samoa and Tonga;
- is found on island cabbage (*Abelmoschus manihot*);
- is associated with leaves;
- is potentially able to establish and have unwanted impacts;

Maconellicoccus hirsutus is considered to be a hazard in this risk analysis.

6.3.2 Risk assessment

6.3.2.1 Biology

M. hirsutus is a sap-sucker that secretes honeydew. It forms colonies on the host plant that grow into large masses of waxy white coverings if left undisturbed. Eggs are laid in a loose cottony ovisac that is attached to the plant surface, usually on twigs, branches and bark of the host plant, and also on the leaves and terminal ends. Females lay eggs on the terminal areas of the host, but as the weather gets colder females search for shelter in which to oviposit such as crevices in bark (Meyerdirk et al. 2001). First instar nymphs, or crawlers, are mobile. They settle in densely packed colonies in cracks and crevices of the host plant, with a preference for soft tender young tissues, and start to feed and develop. New plant growth becomes severely stunted and distorted as a result of their feeding.

Male and female nymphs can be distinguished by the end of the second instar. The male has four nymphal instars while the female has three. At the end of the second instar, males produce cocoons (puparia). Male adults are winged and capable of flight whereas the female is wingless. The lifecycle can be completed in about five weeks under favourable conditions and there may be up to ten generations per year in the subtropics. *M. hirsutus* can overwinter at all life stages and this can occur in protected parts of the host such as bark crevices. Both sexual and parthenogenetic reproduction has been reported, but it has been assumed that, overall, reproduction is restricted to the sexual form with the sex ratio approximately 1:1. Females can lay 150–600 eggs over the period of a week. Infestations of *M. hirsutus* can be associated with attendant ants, which collect the honeydew they secrete (CPC, 2007; Meyerdirk *et al*, 2002; Mani, 1989).

M. hirsutus forms colonies on the host plant. It prefers apical and tender regions of the plant, but the older plant parts may also harbour large populations. As it feeds, *M. hirsutus* injects toxic saliva into the plant. Both this and direct feeding can cause various symptoms on the host, including malformed leaf and shoot growth, stunting, bushy shoot tips, and occasional death. Sooty mould may develop on leaves and stems due to heavy honeydew secretions. If undisturbed, colonies will grow into masses of waxy whitish coverings over most plant structures or even entire plants. Dieback of young shoots and limbs may occur and whole trees may eventually die (Meyerdirk *et al*, 2001).

6.3.2.2 Entry assessment

The prevalence of *M. hirsutus* in particular parts of Tonga, Vanuatu and Samoa is not known. However, it is assumed that it will be found in the areas that grow island cabbage.

CPC (2010) states that adults, nymphs, eggs and pupa are found on leaves, so all of these life stages could be found on leaves of *A. manihot* that are being imported into New Zealand. *M. hirsutus* usually forms dense colonies (CPC 2010), and these would probably be detected during harvest or packaging of island cabbage leaves, although occasionally solitary individuals could be missed. The eggs are laid in ovisacs (Meyerdirk et al. 2001), which would be visible to the naked eye, and it is very unlikely that single eggs would be found on leaves. Male puparia (3^{rd} instar) are 1.1 to 1.5 mm long, and 0.35 to 0.45mm wide (Meyerdirk et al. 2001). Individuals may avoid detection and enter New Zealand on island cabbage leaves. Adult males and females are approximately 2-3mm long (Meyerdirk et al. 2001). The white waxy covering of females and nymphs and the white waxy filaments in the egg mass allow for easy detection (Meyerdirk et al. 2001) but it is still possible that some individual adults or nymphs could be missed.

The time from harvest in Tonga, Vanuatu and Samoa, to sale at New Zealand markets is likely to be less than 48 hours. The flight to New Zealand is usually about 4 hours. It is likely that most *M.*

hirsutus individuals would survive transit as they will be protected between leaves that are bundled together.

M. hirsutus has not been intercepted at the New Zealand border, although present in Australia. However Pseudococcidae have been intercepted on taro leaves, with at least two interceptions of live juveniles (*e.g.* Consignment no. C2009/278387, C2010/215234) (MAFBNZ Quancargo Database), indicating that leaf imports can be a potential pathway for Pseudococcidae.

Given that:

- life stages of *M. hirsutus* are found on leaves ;
- it is expected that colonies of *M. hirsutus* would be detected during harvest and processing but occasionally individuals could be missed;
- *M. hirsutus* is likely to survive the transit time to New Zealand;

The likelihood of entry is considered to be low.

6.3.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

Because nymphs and adults feed on leaves, there is potential for some continued development and survival after harvest, although leaves are likely to wilt within a day or two. If leaves are thrown in compost heaps, then adults, crawlers and nymphs have some opportunity to reach suitable hosts. The potential for dispersal depends on the life stage and sex: adult males are the only winged forms, but they are short-lived and some data suggests they are not important in dispersal (Lo *et al*, 2006). Female mealybug nymphs and adults have some limited mobility (Bartlett, 1978). The primary dispersal stage for mealybugs is the mobile crawler which can move short distances actively or long distances passively (Bartlett, 1978; James, 1937).

Field experiments showed that another mealybug species (*Pseudococcus maritimus*) actively moved a maximum of between 47 and 90 cm away from the original point of infestation. Overall, mealybugs showed little tendency to disperse away from the point of release (Grasswitz and James, 2008). These results indicate that movement of *M. hirsutus* by walking is likely to be extremely slow. First instars of other species in the same family can be passively dispersed via wind currents. Some were shown to disperse as far as eight metres, but overall there was a rapid drop-off in dispersal with increasing distance from the source plants after three metres (Grasswitz and James, 2008). Moreover, the passive nature of dispersal by wind currents means that the crawlers do not have the capacity to actively choose to land upon a suitable host plant. Some mealybugs may be carried to new host plants by ants (Beardsley *et al*, 1982), and *M. hirsutus* is known to be attended by ants (Meyerdirk *et al*, 2001).

Crawlers are susceptible to extremes of temperature, desiccation, rain, predation and a lack of suitable settling sites, therefore mortality can be high for this life stage (APHIS, 2007).

M. hirsutus is extremely polyphagous, and suitable host species are widely distributed throughout New Zealand, and likely to be available to dispersing crawlers.

Given that:

- crawlers can move short distances actively or long distances passively;
- crawlers can be vulnerable to extremes of temperature and humidity, predation and other factors that result in mortality;
- crawlers that are wind dispersed are unable to actively choose to land on a suitable host plant;
- adults can move at least short distances to find egg laying sites;
- *M. hirsutus* is extremely polyphagous, and suitable host species are widely distributed;

The likelihood of exposure is considered to be low to moderate.

6.3.2.4 Assessment of establishment and spread

Both parthenogenesis and sexual reproduction have been noted to occur in this species, although researchers have observed regional differences. Which of these reproductive strategies (or both) would be likely to occur in populations from the Pacific Islands is unknown. If sexual reproduction is necessary then the possibility of males and females encountering each other would be facilitated by females releasing a sex pheromone that can attract the male from up to several hundred metres away (Meyerdirk *et al*, 2001). Solely parthenogenic populations have been reported (for example in Bihar, India) (cited in Williams, 1996) and this would greatly increase the likelihood of establishment if the progeny were female.

Females can lay hundreds of eggs. Crawlers, ovisacs and males may migrate by means of air currents; females (which are non-flying) and crawlers are mobile and can walk from host to host in the infested area (Meyerdirk *et al*, 2001). This species is polyphagous on a huge variety of plants including plants of commercial interest, garden plants and weeds in New Zealand, therefore suitable hosts are highly likely to be readily found.

M. hirsutus is found predominantly in tropical and subtropical zones. An assessment of climate suitability (Anonymous, 2002) found that *M. hirsutus* is unlikely to survive in New Zealand in most years because temperatures are not warm enough to supply sufficient day degrees for a single generation to develop. However, in the absence of specific information, this was calculated by assuming a similar temperature threshold to the related tropical mealybug *P. manihoti*, and it is suggested that the ability of *M. hirsutus* to develop may be slightly underestimated. Nevertheless, it would appear that a generation could be completed in a very warm year in the Hawkes Bay region, suggesting that short-term establishment could be a possibility in this area. A population may not persist through a cool year. The report (Anonymous, 2002) does not appear to have assessed any site in New Zealand north of Auckland in terms of temperature but it does mention that a negative correlation with relative humidity was observed and that the North Island conditions are unlikely to be conducive to significant population development.

Populations could establish under glass, particularly if the source population exhibits parthenogenic reproduction which would allow a single individual to found a reproducing population. The likelihood for exposure to plants in commercial greenhouses in New Zealand is negligible because of protocols and practices that would be undertaken to protect commercial crops. However, domestic greenhouses and glasshouses are likely to be a suitable environment for *M. hirsutus*. As crawlers can be carried on clothing as well as plant material the risk is non-negligible

Given that:

- *M. hirsutus* populations reproduce either sexually or asexually, or a combination of the two strategies;
- mate-finding in sexually reproducing populations is assisted by female production of pheromones;
- *M. hirsutus* would be likely to have a very limited distribution due to climatic factors;
- domestic glasshouses are likely to be a suitable environment for *M. hirsutus*;

The likelihood of establishment is considered to be moderate in regions where climate is suitable.

Once established in New Zealand, *M. hirsutus* could be spread by human movement of host plants. Crawlers, ovisacs and males can also spread via air currents, and females, and crawlers are mobile and can walk short distances from host to host (Meyerdirk *et al.* 2001). However for most of New Zealand the climate would not be suitable for establishment, which would limit the spread of *M. hirsutus*.

Given that:

- *M. hirsutus* could spread by human movement of hosts, by wind currents or by limited movement of females, crawlers from host to host;
- much of New Zealand would have an unsuitable climate for *M. hirsutus* establishment, limiting spread;

The likelihood of the organism spreading from where it establishes in New Zealand is considered to be moderate.

6.3.2.5 Consequence assessment

Economic consequences

If *M. hirsutus* were to establish in New Zealand its extreme polyphagy indicates the potential in some areas for significant damage to plants of economic interest, including fruit (for example grapes, passionfruit, *Citrus* spp., guava), vegetables (for example asparagus, beetroot, sweet pepper, cucurbits, carrots, kumara, avocado) and others. When fruits are infested, they can be covered with the white waxy coating and sooty mould. Infestation can lead to fruit drop, or fruit may remain on the host in dried and shrivelled condition. If flower blossom is attacked, the fruit sets poorly. Thus fruit production and marketability is reduced. The impacts will be limited by the lack of ability for *M. hirsutus* to establish through much of New Zealand. Establishment could result in the disruption of current management practices, which could affect the cost of production. It could result in the need for expensive eradication programmes, or increased compliance costs for exports to countries without *M. hirsutus*. There may be adverse effects on market access; for example- if industry has to change from current low chemical production regimes to high chemical usage.

Given that:

- damage by *M. hirsutus* would decrease productivity of a number of commercial crops if not controlled;
- controlling *M. hirsutus* could increase treatment costs for a number of commercial crops in New Zealand;
- establishment of *M. hirsutus* in New Zealand could cause disruption of access to some markets, but;
- *M. hirsutus* would be likely to have a very limited distribution due to climatic factors;

The potential economic consequences are considered to be low.

Environmental consequences

M. hirsutus is extremely polyphagous, and some native species are in the same genera as known hosts for *M. hirsutus* (for example *Passiflora tetrandra*). Based on known attacks on native plants by exotic species in New Zealand, sap-sucking hemipterans such as mealybugs, particularly polyphagous species, could be a high risk group for native flora (Beever *et al*, 2007). The displacement of native mealybug species is another possible consequence of establishment. Although *M. hirsutus* could find many suitable native host plants if it were to establish in New Zealand, its environmental impacts would be overall limited due to its very restricted distribution in areas with suitable climate.

Given that:

- *M. hirsutus* is extremely polyphagous and is likely to find suitable native host plants as well as attacking many garden and amenity plants that are grown in New Zealand;
- *M. hirsutus* could displace native mealybug species, but;
- *M. hirsutus* would be likely to have a very limited distribution due to climatic factors;

The potential environmental consequences are considered to be low.

Human health consequences

There are no known human health consequences.

Socio-cultural consequences

Mealybugs can be a problem to home and amenity gardeners by feeding on and weakening plants, transmitting viruses, secreting honeydew and attracting ants.

As M. hirsutus is likely to have a very limited distribution due to climatic factors the potential socio-cultural consequences for New Zealand are considered to be low.

6.3.2.6 Risk estimation

The likelihood of entry is considered to be low, the likelihood of exposure is considered to be moderate, the likelihood of establishment is considered to be low, and the likelihood of spread is considered to be moderate. The potential economic, environmental and socio-cultural consequences are considered to be low, and no impact on human health has been detected.

As a result the risk estimate for M. hirsutus is non-negligible and it is classified as a hazard in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

6.3.3 Risk management options

Given the risk estimate for *M. hirsutus* is non-negligible, options for phytosanitary measures are considered and factors relating to efficacy are discussed.

6.3.3.1 Post harvest cleaning and visual inspection option (*M. hirsutus*)

A washing, wiping and inspection protocol for taro and tarua leaves for export is discussed in section 4.2.5. The biology of *M. hirsutus* indicates it would be partially susceptible to this kind of management option. Specific points to consider include:

- All life stages are likely to be visible, although individuals can be missed during inspections
- Eggs are in ovisacs attached to leaves and shoots
- Other sessile life stages are attached by their mouthparts to leaves and shoots
- Washing is unlikely to dislodge *M. hirsutus*
- Sessile life stages are unlikely to recontaminate the commodity

The available information is not enough to precisely measure the efficacy of the existing taro and tarua protocol, or the likely protocol for island cabbage leaves. However there have been substantial numbers of detections of live organisms (including mealybugs, scale and similar small, cryptic, sessile organisms) on taro or tarua leaves that have been through the washing, wiping and inspection protocol. Potential modifications to this protocol discussed in section 4.2.5 are likely to improve the efficacy.

Overall, the biology of *M. hirsutus* indicates that it is less likely to be susceptible to a management system involving washing, wiping than to visual inspection of leaves. Although the level of risk is at the lower end of the scale, without modifications, this management option on its own is not likely to be in proportion to the risk.

Modifications to the protocol can improve the efficacy, and with modifications this management option is likely to be in proportion to the risk. However until the protocol is in place and can be tested, significant uncertainty remains.

6.3.3.2 Visual inspection at the border option (*M. hirsutus*)

Small, cryptic, sessile organisms such as mealybugs and scale are frequently intercepted at the border on various pathways including leaves. *M. hirsutus* is an orange-pink colour with a white, mealy wax coating. It is visually detectable although small numbers of individuals may be harder to detect.

The biology of *M. hirsutus* indicates it would be susceptible to this kind of management option. An inspection sampling regime would need to be developed that gives the level of efficacy required in proportion to the risk.

6.3.3.3 Combination of options

Combining the two management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded visual inspection will also provide information which will reduce the uncertainty about the efficacy of the washing, wiping and inspection protocol.

6.4 *Pseudaulacaspis pentagona* – white peach scale

Scientific name:	*Pseudaulacaspis pentagona* (Targioni-Tozzetti, 1886) (Hemiptera: Diaspididae)
Other relevant scientific names:	*Aspidiotus lanatus*, *Aspidiotus vitiensis*, *Aspidiotus pentagona*, *Diaspis amygdali*, *Diaspis geranii*, *Diaspis lanata*, *Diaspis lanatus*, *Diaspis patelliformis*, *Diaspis pentagona*, *Epidiaspis vitiensis*, *Sasakiaspis pentagona*
Common name:	white peach scale

6.4.1 Hazard identification

6.4.1.1 Description

P. pentagona is a small scale insect, which feeds on sap. It is found predominantly on trunks and branches but is also found occasionally on leaves, roots and fruit.

6.4.1.2 Exporting country/s status

P. pentagona is reported from Fiji, Tonga, Vanuatu and Western Samoa (Williams and Watson 1988).

6.4.1.3 New Zealand status

P. pentagona is not known to be present in New Zealand. Not recorded by: Charles and Henderson (2002), Macfarlane *et al*. (2010). ScaleNet (2010) states that there are erroneous records of *P. pentagona* being present in New Zealand. PPIN (2010) states that *P. pentagona* is not established in New Zealand.

6.4.1.4 General geographic distribution

Pseudaulacaspis pentagona is a cosmopolitan species. In addition to the countries mentioned above, it has been recorded in New Caledonia, Norfolk Island, Papua New Guinea, Solomon Islands, Irian Jaya, Wallis Island (Williams and Watson 1988), Australia (New South Wales and Queensland), Belau, Federated States of Micronesia (Caroline Islands), Guam, the Northern Mariana Islands, and Wallis & Futuna (CPC 2010). It has also been recorded in Asia, Africa, Europe, and the Americas (Scalenet 2010).

6.4.1.5 Commodity association

It is recorded on 'aibika cabbage' (island cabbage – *Abelmoschus manihot*) in the Solomon Islands (Williams & Watson 1988). *P. pentagona* is recorded as an important insect pest of *A. manihot* (Preston 1998, citing Dori 1998, Sutherland 1984, Hinkley 1963).

It is not entirely clear which plant parts of island cabbage are infested. Williams and Watson (1988) record it from a number of hosts including *A. manihot* and state that it occurs on "bark, leaves and fruit". They do not specify plant parts for particular hosts. However Preston (1998) says *Pseudaulacaspis pentagona* are found attached to lower branches and stems of aibika (*A. manihot*).

Jepson and Knowles (1919, 1920) record *Diaspis pentagona* [*Pseudaulacaspis pentagona*] severely damaging the related species *Hibiscus esculentus* [*Abelmoschus esculentus*] by destroying the stems.

6.4.1.6 Plant associations

P. pentagona is a broadly polyphagous species. ScaleNet (2010) lists over 300 hosts in 78 plant families. The host plant range could be much wider than is listed (CPCI 2010). However, *P. pentagona* cannot complete development on some of the hosts listed, which indicates that some may not be true host plants.

6.4.1.7 Plant parts affected

P. pentagona is often found as thick crusts heavily infesting tree trunks and older branches in temperate regions, and rarely on roots, while the leaves and fruit are not usually infested (CPC 2010). However Hill (1987) records the scale insects as encrusting twigs, with some on leaves; Hely *et al.* (1982) state that "scale attacks wood, leaves and fruit" and Watson (2005) states that they are found "rarely on leaves and roots". Williams and Watson (1988) state that they occur "on bark, leaves and fruit".

6.4.1.8 Potential for establishment and impact

P. pentagona is reported from New South Wales in Australia, and the Northwest of America so is potentially able to establish in New Zealand. It is a pest of plants economically important to New Zealand .

6.4.1.9 Hazard identification conclusion

Given that *Pseudaulacaspis pentagona*:

- is not known to be present in New Zealand;
- is recorded on *A. manihot*, and may be found on leaves of *A. manihot*;
- is recorded in Fiji, Tonga, Vanuatu and Samoa;
- is recorded as causing damage to plants species of economic, environmental and/or socio-cultural importance to New Zealand and can potentially establish here;

It is considered to be a hazard in this risk analysis.

6.4.2 Risk assessment

6.4.2.1 Biology

P. pentagona is an armoured scale insect. Members of this family produce fibrous, wax-like coverings, into which they incorporate their moult skins as they grow. The covering or test of adult females is pale, and around 1.5-3 mm in diameter. Reproduction is sexual. Eggs hatch into first instar nymphs (crawlers), which disperse actively or passively. Once the crawlers settle, they begin feeding by inserting their piercing-sucking mouthparts into the host plant. After female crawlers moult to second instar they cannot move from that site. After feeding, the second instar female moults to the adult stage, also sessile. The only other mobile stage apart from the crawler is the adult male, which is winged, but short-lived and non-feeding. Unlike soft scale insects and mealybugs, armoured scale insects do not produce honeydew (Beardsley & Gonzalez 1975), and are consequently not attended by ants.

(After Watson 2005, unless otherwise stated): *P. pentagona* overwinters as mated females in cold climates, and eggs may also overwinter in warmer climates; there are one to four generations per year. At 11–15˚C a minimum of 110 days is taken to complete a generation, but at 26˚C, generation time is 40 days and females begin to oviposit around 16 days after maturing (Ball 1980). Takeda (2006) found that temperature was the most important factor in diapause termination, and that even when females were collected in mid-winter, exposure to temperatures of 25˚C caused some to start egg-laying. Overwintering females continued feeding in the laboratory (Takeda 2006). Adult females lay about 100 eggs, which hatch within 3 to 14 days (depending on temperature).

6.4.2.2 Entry assessment

P. pentagona is usually found on trunks and branches, and less often on leaves. Scale insects often have an aggregated distribution (Borges et al. 2006). Aggregations are more likely to be found than single adults or crawlers. However it is assumed that *P. pentagona* do not always form aggregations and single adults and crawlers may be found on leaves occasionally. Small aggregations or single individuals could be missed on inspection of the leaves during harvesting of leaves.

Crawlers and male adults are likely to be removed during harvesting and processing. Adult males only live a day so are unlikely to be associated with island cabbage leaves unless they emerge from pupation during transit. Females and their eggs are protected by a scale and difficult to remove therefore are likely to remain on leaves during harvesting and processing. Armoured scales are small and may be difficult to detect, particularly in low numbers.

According to CPC (2010), *P. pentagona* is probably intercepted in most countries, but the interceptions go largely unreported. In New Zealand this species is very frequently intercepted at the border on sea-freighted, cold treated kiwifruit from Italy, including live specimens (for example Consignments C2002/60377, C2005/328760) (MAFBNZ Quancargo Database). It has not been recorded as intercepted on other commodities.
P. pentagona is a long-lived species (at 11–15˚C a minimum of 110 days is taken to complete a generation). It is known to survive other transit conditions including cold storage, and thus it is very likely to survive air transit on island cabbage leaves from the Pacific. All life stages on Island cabbage leaves would survive the transit time to New Zealand.

Given that:

- *P. pentagona* is usually found on trunks and branches and less commonly on leaves;
- Females and eggs are protected by a scale so may survive harvest and packaging;
- Armoured scales are small and may be difficult to detect;
- *P. pentagona* could survive the short air transit time from the Pacific Islands to New Zealand;

The likelihood of entry is considered to be very low.

6.4.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

The potential for dispersal from the pathway depends on the life stage and sex. Adult males are the only winged forms, but they are short-lived (Hanks & Denno 1994) and some data suggests that for mealybugs (*q.v.*) they are not important in dispersal (Lo et al. 2006). The mobile crawler is the primary dispersal stage. Later instar nymphs and adult females are immobile and would be unable to disperse to a new host, and would die once the leaves they were attached to had decomposed to the point where they were no longer a suitable host. However a mated female (or a dead female with viable eggs), could remain at a leaf disposal location and produce mobile crawlers. Crawlers from one adult female could start a new population.

Adult females and eggs are also the stages most likely to survive packing and transit. Eggs may hatch in transit or on arrival. Adult females of *P. pentagona* would probably be able to continue development if ambient temperatures exceed 10.5˚C, based on temperature thresholds calculated by Takeda (2004). This condition could be met from October in the northern parts of New Zealand (NIWA 2010).

The following factors will influence the likelihood of exposure of crawlers:

(i) Longevity of the host leaves

Armoured scale insects produce 1 to 10 eggs daily and females usually produce offspring continuously over several weeks until their death (Kotega 1990, cited in Morse et al. 2009). Therefore it is likely that crawlers will be produced for as long as the host leaves remain in good condition. Some leaves will not be consumed but thrown away, possibly on to compost heaps. Survey information from the UK indicates that a significant proportion (19%) of vegetables purchased was thrown away uneaten (Ventour 2008).

(ii) Different vegetable disposal methods

Some methods of disposal are higher risk than others. Crawlers from infested leaves disposed into domestic compost would have the highest likelihood of exposure. Indeed, some armoured scale insects grow well on the tubers and particularly on the sprouts of potatoes (Berry 1983), and would be capable of establishing on such hosts in domestic compost. However there is very little information available regarding domestic and particularly industry pathways and practices such as the disposal of culled and unsold vegetables by wholesalers and retailers.

(iii) Dispersal ability of crawlers

Crawlers can disperse by walking, by wind or by vectors such as animals. Recent research on the significance of walking as a dispersal mechanism in mealybug crawlers has produced slightly different conclusions, though it is clear that the distance covered by walking is small. Lo et al. (2006) suggested that mealybug crawlers moved from plant to plant by walking, using vine trunks, strainer wires and posts. Grasswitz and James (2008) found a maximum active movement of 90 cm from the origin point, leading them to suggest that crawlers only very rarely reach adjacent plants by this means. Branscome (2007) showed sexual differences in armoured scale crawlers: females moved about on plants for up to 12 hours before settling to feed, but males remained near their mother. It is assumed that behaviour of mealybug crawlers is similar to that of armoured scale insect crawler.

Armoured scale insect crawlers are known to be wind and vector-distributed; they can be moved over several kilometres by wind, flying insects, birds and other animals including humans and some are known to deliberately move to high points of their host plants in order to disperse (Brown 1958, Beardsley & Gonzalez 1975, Greathead 1990, Lo *et al.* 2006). Lo *et al*. (2006) found mealybug crawlers on aerial traps placed 5m to 15m from source vines. Grasswitz and James (2008) showed that some *P. maritimus* crawlers dispersed as far as eight metres, but overall there was a rapid drop-off in dispersal with increasing distance from the source plants after three metres. Moreover, the passive nature of wind dispersal means crawlers cannot actively choose to land upon a suitable host plant.

(iv) Mortality at the crawler stage

Mortality in *P. pentagona* crawlers in the field was assessed at around 90%, compared to that of 30% for subsequent life stages (Oda 1963). Crawlers are susceptible to extremes of temperature, desiccation, rain, predation and a lack of suitable settling sites. However Barrass *et al*. (1994) found that 75% of mealybug crawlers (three species of *Pseudococcus*) survived low humidity (32% RH) for 48 hours. Although this work was laboratory-based, it suggests that mealybug crawlers are more likely to survive wind-dispersal in the field than previous literature has suggested.

There would be no shortage of suitable host species throughout New Zealand for *P. pentagona*, which is extremely polyphagous. Additionally, this scale insect is able to exploit most plant parts including bark, leaves and fruit (Branscome 2007) so it is not dependent on coming into contact with a specific part of a host plant. The available evidence does however suggest that the source of infestation must be more or less contiguous with, or very close to, the new host. Situations of exposure that might fit into this scenario could include infestation of sprouting potatoes in domestic compost, or infestation of hosts very close to infested leaves disposed of by wholesalers or retailers. Island cabbage leaves are expected to perish within a few days of harvest, and therefore will be unlikely to support any of the scale life stages past that point. The proportion of leaves that are both infested with scale, especially life stages that are mobile, and are subject to potential exposure is likely to be very small.

Given the perishability of island cabbage leaves the likelihood of exposure is considered to be very low.

6.4.2.4 Assessment of establishment and spread

A mated female or immatures of both sexes would be necessary to establish a reproductive population, as there are no reports of parthenogenesis in this species. Since exposure probably depends on successful crawler dispersal, for establishment to take place crawlers of both sexes need to find a suitable host, develop to adults, successfully locate each other, mate and produce viable offspring. This likelihood is considered to be higher for scale insects than for solitary insects, due to their tendency to have an aggregated or clumped spatial distribution. Yamamura and Katsumata (1999) referred to this type of pest as gregarious, and considered it to have a higher probability of introduction into new areas via trade, due to the heightened likelihood of their locating a mate in the new environment.

P. pentagona are multivoltine at higher temperatures and females each lay around 100 eggs, so the potential for rapid population increase in suitable conditions is high.
P. pentagona is widely considered to be tropical/subtropical species and if that is the case it may be limited to glasshouses in colder parts of the country. However, this species is frequently intercepted at the border on sea-freighted, cold treated kiwifruit from Italy (including live specimens), and the neotype of *P. pentagona* is recorded from Como, north-western Italy (Davidson *et al*. 1983), near Milan. *P. pentagona* is also recorded from the Washington D.C. area and from Indiana by Davidson *et al*. (1983), who state only that it "tends" to be a tropical or subtropical species.

The likelihood of establishment from the island cabbage pathway is considered to be low.

The main dispersal stage of *P. pentagona* is the mobile first instar, which has legs. Crawlers can walk up to perhaps 1 m, but can be distributed across much greater distances by wind, flying insects and birds (Watson 2005). There is nothing restricting its spread by these methods in New Zealand. Additionally, it is readily carried on consignments of plant material and fruit (Watson 2005) so it is likely to be moved around within New Zealand on these commodities.

The likelihood of the P. pentagona spreading within New Zealand is high.

6.4.2.5 Consequence assessment

Economic consequences

P. pentagona was described as a very destructive pest by Kosztarab (1996), especially on flowering cherry, mulberry, peach and other deciduous fruit trees. Williams and Watson (1988) and Danzig and Pellizzari (1998) also describe it as a destructive species, and it is also known to attack currant, grape, kiwifruit and walnut, as well as some woody ornamental plants (Watson 2005). It is unclear whether commercial pip fruit crops are reproductive hosts of this species, although CSL (2007) lists ornamental apple species as major hosts. Severe infestations can form heavy crusts, causing branches or trees to die (CPCI 2010), and feeding activities can result in early leaf drop. Armoured scale insects are difficult to manage because of the protection afforded by their waxy caps. Establishment in New Zealand could cause disruption of access to some markets, including Western Australia.

The potential economic consequences of establishment are considered to be moderate.

Environmental consequences

P. pentagona is a polyphagous species, with over 300 recorded hosts in 78 plant species (ScaleNet 2010). Damage to amenity plants and the increased use of pesticides for control in modified habitats are possible consequences of establishment of both species. Additionally, damage to native plants is possible. Beever et al. (2007) suggested that, in terms of risk to native flora, sap-sucking hemipterans such as armoured scale insects are a high risk group (particularly polyphagous species). Charles and Henderson (2002) recorded a number of exotic armoured scale insect species on native plant hosts, and noted that some polyphagous exotic species are now occasionally found on native plants in isolated patches of native bush. Competitive displacement of native armoured scale insect species is also a possibility.

The potential environmental consequences of establishment are considered to be low to moderate.

Human health consequences
There are no known human health consequences.

Socio-cultural consequences
Scale can weaken plants and decrease yields. They are also difficult to control. Home gardens and amenity plantings may be affected by this scale.

The potential socio-cultural consequences are considered to be low.

6.4.2.6 Risk estimation
P. pentagona is considered to have very low likelihoods of entry and exposure; a low likelihood of establishment, and high likelihood of spread in New Zealand. The economic impacts are likely to be moderate and the environmental impacts are likely to be low to moderate.

P. pentagona is less likely to be found on leaves than on stems, branches and trunks. The proportion of leaves that are likely to be infested with *P. pentagona* and then subject to successful exposure and result in successful establishment is considered to be very small**.** When the likelihoods are considered in combination the risk is considered **negligible**.

Therefore risk management measures are not justified.

Note that although the risk posed by *P. pentagona* has been assessed as negligible on this pathway, it remains a "regulated pest". The very low likelihood of entry suggests that it is unlikely to be detected on island cabbage leaves at the border. If it is intercepted on any imported lots at the border this may imply that the likelihood of entry is higher than originally assessed. The infested lot will be treated to ensure the pests are effectively controlled prior to release. Alternatively, the consignment shall be reshipped or destroyed at the importers option and expense.

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7 Risk assessment of potential hazard organisms group C: arthropods that feed internally

7.1 Group hazard identification

The biosecurity risk from this group of hazards is assessed using all life stages of the nematode *Aphelenchoides besseyi* and the moth *Earias vittella* as examples. It is assumed that any risk management for the identified risk from *A. besseyi* and *E. vittella* will also manage the risk from other organisms in this hazard group, including any that have yet to be identified.

The organisms classed as hazards identified in Appendix 1 that appear to have life stages meeting the criteria for this group, are listed in the following table. The organisms in **bold** have been assessed in this chapter; the organisms not in bold have not been assessed. Not all identified hazards are necessarily risks on this pathway.

Table 6. Hazard organisms which are likely to be living and/or feeding internally

Taxonomy	Type of organism	Included hazards	internal life stage
Lepidoptera	Moth	*Acrocercops sp.*, ***Earias vittella***	early instar larvae
Nematoda	foliar nematodes	***Aphelenchoides besseyi,*** *Aphelenchoides sp.*	all life stages

7.2 *Aphelenchoides besseyi* – rice leaf nematode

Scientific name: *Aphelenchoides besseyi* Christie, 1942 (Nematoda: Aphelenchoididae)

Other relevant scientific names: *Aphelenchoides oryzae* Yokoo, 1948
Asteroaphelenchoides besseyi (Christie 1942) Drozdovski, 1967

Common name/s: rice white-tip nematode, rice leaf nematode, leaf and bud nematode, strawberry crimp disease nematode

7.2.1 Hazard identification

7.2.1.1 Description

Aphelenchoides besseyi is a transparent microscopic plant pathogenic foliar nematode (worm) that can live on or within its host.

7.2.1.2 Exporting country/s status

Aphelenchoides besseyi has been reported from Fiji, Cook Island and Tonga in the Pacific Islands (Bridge 1988; CABI/EPPO, 2000).

7.2.1.3 New Zealand status

Aphelenchoides besseyi is not known to be present in New Zealand. Not recorded in: Knight et al. (1997); Yeates (2010); PPIN (2011).

7.2.1.4 General geographic distribution

Aphelenchoides besseyi is a cosmopolitan parasitic worm that is widely distributed on rice (CABI/EPPO, 1997; CABI/EPPO, 1998). It has been reported in rice in many parts of Europe[12], Africa, Asia[13]; Australia (NT, QLD), Papua New Guinea; parts of North, Central and South America (Fortuner and Williams, 1975). *A. besseyi* has not been found beyond latitude 43°N on rice or beyond 40°N on strawberry (EPPO 1981).

7.2.1.5 Commodity associations

Aphelenchoides species were reported on island cabbage (*Abelmoschus manihot*) in some Pacific Islands by Orton Williams (1980) and cited in PPPIS (1996). The *Aphelenchoides* observed were not identified to species level but, given that *A. besseyi* has been reported from Fiji and Tonga on rice (Bridge 1988) and in the Cook Islands; and that it is known to infest *Hibiscus brachenridgii* which is also in the Malvaceae, it is most likely that the *Aphelenchoides* records from island cabbage in Fiji and Tonga are *A. besseyi*. It is also possible that the records are a different species of *Aphelencoides*, and if further information becomes available that it is a different species, the risk may need to be reassessed.

7.2.1.6 Plant associations

Aphelenchoides besseyi is an economically important pest of *Oryza sativa* L (rice) plant (Daughtrey et al. 1995) and on *Fragaria* × *ananassa* (strawberry) (HortFACT; CABI/EPPO 1997). Other hosts include *Hibiscus brachenridgii*, onion, garlic, sweet corn, sweet potato, soybean, yam, Chinese cabbage, sugar cane, horseradish, lettuce, millet, and many grasses (EPPO 1981; Franklin and Siddiqi, 1972). *A. besseyi* has also been reported associated with a number of orchid species, for example, *Dendrobium* sp. Lady Fay, *Cattleya* spp., *Vanda* spp. (Chitambar, 1999) and *Phalaenopsis* spp. (Zhou, 1992). Additional reported hosts (mainly ornamentals) are listed in Appendix 1

Aphelenchoides besseyi not only feeds on higher plants but can also be saprophytic and feed on many fungi such as *Fusarium solani* (Huang *et al*., 1972), *Aureobasidium pullulans* (Huang *et al*., 1979), *Alternaria tenuis* (Todd and Atkins, 1958) and *Alternaria alternata* (Rajan *et al*., 1989).

7.2.1.7 Plant parts affected

Aphelenchoides besseyi is a foliar nematode that migrates over plant surfaces through films of water. It enters plant tissue through open stomata on leaves, causing vein-delimited lesions on leaf tissue. The nematodes feed on young stems, buds and leaves and reproduce on the plant leaf mesophyll and on buds (Kohl 2011). They can be both ecto- and endo-parasites of the leaves and young tissues. For example, it is an ecto-parasite on its main hosts, rice and strawberries, but may be endo-parasitic on some of its other hosts such as *Ficus elastica* and *Polianthes tuberose*. It is uncertain how it behaves on island cabbage or *Hibiscus.*

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12 Czech Republic, Hungary, Italy and Slovenia (Fauna Europaea); Bulgaria, Southern Russia, Ukraine (CPC 2011)
13 Afghanistan, Azerbaijan, Bangladesh, Cambodia, China, India, Indonesia, Iran, Japan, Korea, Kyrgyzstan, Laos, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Tajikistan, Thailand, Turkey, Uzbekistan, Vietnam

7.2.1.8 Potential for establishment and impacts

Aphelenchoides besseyi is found in some countries that are ecoclimatically similar to New Zealand (see footnote 12) and therefore can potentially establish in New Zealand. It is a recognised plant pest and therefore has the potential for unwanted impacts.

Hazard identification

Given that:

- *A. besseyi* is present in Fiji, Cook island and Tonga;
- *A. besseyi* is not known to be present in New Zealand;
- It is most likely the records of *Aphelenchoides* species on island cabbage in Fiji and Tonga is A. besseyi
- *A. besseyi* can potentially establish and have unwanted impacts;

Aphelenchoides besseyi is therefore considered a hazard on island cabbage leaves in this risk analysis.

7.2.2 Risk assessment

7.2.2.1 Biology

The adult *A. besseyi* has a slender body (less than 1 mm long and 14-22 µm wide). Males are about as numerous as females (OEPP/EPPO, 2004) and reproduction is normally sexual although asexual (parthenogenetic) reproduction has been recorded.

Females lay eggs which develop to release larvae that look very similar to the parents but smaller and without reproductive organs (Hussey et al, 1969). Nematodes typically have four juvenile or larval stages between egg and adult. All developmental stages of *A. besseyi* can be isolated from infested plant tissues or soil (OEPP/EPPO, 2004). Early in the cycle, the nematodes feed within the buds and in tender growing points and reproduce. Juveniles and adults continue to feed on plant tissues by inserting a narrow mouth-spear or stylet into the cells and sucking the contents.

The optimum temperature for development is 21-25°C, the life cycle taking 10 days at 21°C and 8 days at 23°C, and there are several generations in a season. The life cycle of *A. besseyi* is generally short. Each female nematode can lay approximately 32 eggs, which can then hatch in 4 days. *A. besseyi* can withstand desiccation, retaining viability for 2-3 years on dry grain, but dies in 4 months on grain left in the field; the nematode is not thought to survive long periods in the soil between crops; can survive in soil over winter and that larval stages can withstand moderate desiccation in plant material (Franklin and Siddiqi, 1972). Under favourable moisture conditions, the nematodes become active again with resumption of plant growth, migrating up the stems of infected plants or to new plants in a film of water on the plant. In vitro studies suggest that the optimum temperatures for oviposition and hatching and the shortest life cycle times occur at higher temperatures, around 30^{o}C, but that nematodes remain active between 13 and 42^{o}C (Tikhnova, 1966, cited in Chitambar, 1999). Minimum temperatures for activity are variously reported as 4 ^{o}C (Qui et al 1991) and 13 ^{o}C (Tikhnova 1966) respectively, cited in Chitambar, 1999). Hoshino and Togashi (2000) and Kohl (2011) reported that the second stage juveniles may reach reproductive maturity in 6-7 days at 25 ^{o}C.

The principle dispersal of this nematode is in rice seed and accompanying chaff, also in or on any other host plant part.

Damage:
This nematode infests rice by feeding ectoparasitically on the growing points of leaves and stems causing a characteristic whitening of the top 3–5 cm of the leaf tips, which later become necrotic, and a crinkling and distortion of the flag leaf enclosing the panicle; the latter is reduced in size, as are the grains. On rice up to 14 nematodes, mostly pre-adults have been found on a single rice seed, where they remain coiled up inside the palea. *Aphelenchoides besseyi* also infests strawberries, feeding ectoparasitically on young tissue and known to be the causal agent of 'summer dwarf' or 'crimp' disease, a disease recorded from the USA, Australia and more latterly, Europe (CABI/EPPO, 2000). *A. besseyi* may also be endoparasitic, as in *Ficus elastica* and *Polianthes tuberosa*, in which it causes leaf drop and leaf lesions, respectively. The nematodes invade leaves through the stomata or epidermis on the lower surface and feed within the mesophyll tissue. In the grass *Sporobolus poirettii*, the nematode stimulates growth, resulting in increased inflorescences (Franklin and Siddiqi (1972; Luc *et al.* 1990).

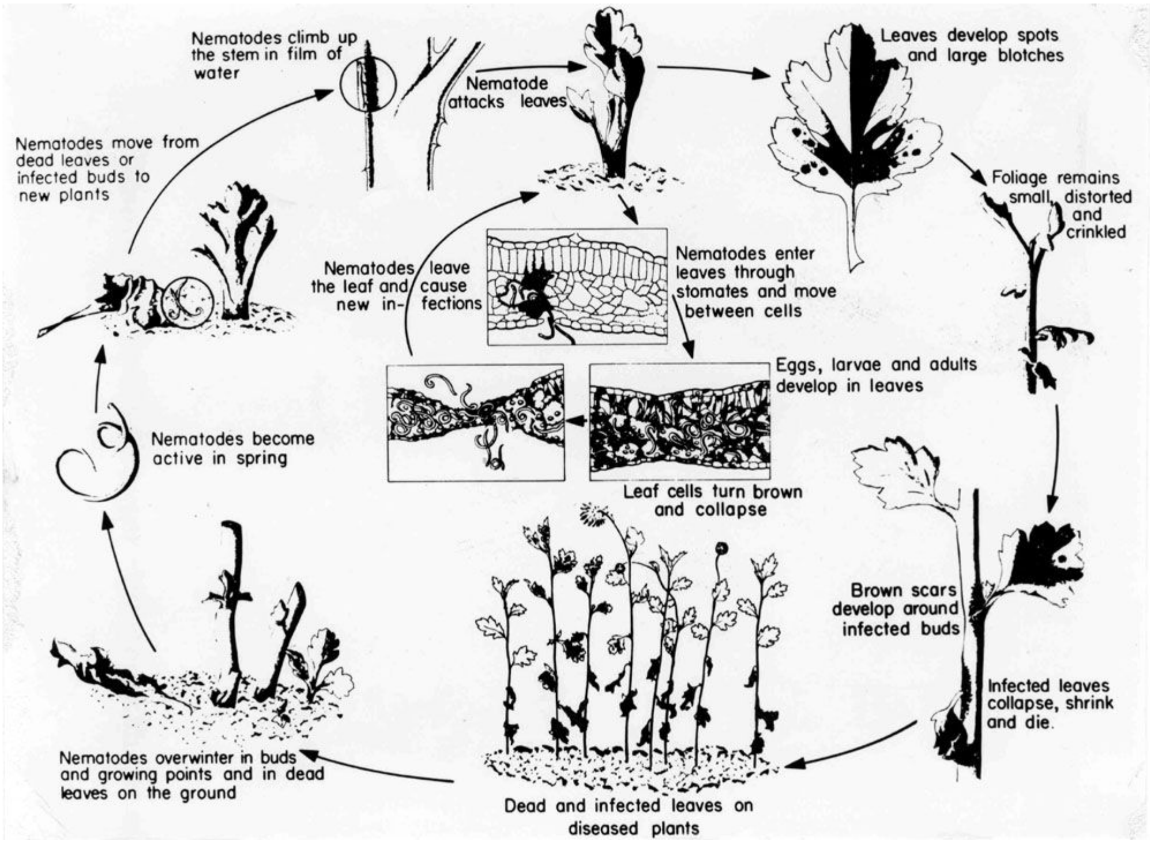

Figure 6. Disease /life cycle of foliar nematode (Aphelenchoides ritzemabosi) on chrysanthemum (courtesy Dr. G.N. Agrios, published in Plant Pathology, Academic Press, Inc., San Diego, CA).

7.2.2.2 Entry assessment

This entry assessment assumes that the unidentified *Aphelenchoides* species associated with island cabbage grown in Fiji and Tonga is *A. besseyi* although its prevalence is not known. It is also possible that the records are a different species of *Aphelenchoides*, and if further information becomes available that it is a different species, the risk may need to be reassessed.

A. besseyi is a foliar nematode and all life stages may be found associated with its host plant. *A. besseyi* is a transparent microscopic worm which can only be detected in the laboratory under light microscope or using a powerful hand lens. Although a description of symptoms on island cabbage was not given, symptoms caused by *A. besseyi* have been variously reported for other plants as discoloration, necrosis and/or distortion of buds, leaves or pods, and dwarfing of the plant. The presence of *A. besseyi* in the leaves can only be suspected /detected through symptoms.

It is expected that island cabbage is likely to be air transported to New Zealand packaged as bundles of leaves. The temperature and humidity conditions during transportation are unlikely to have any adverse effects on any *A. besseyi* populations. It is also likely that low levels of infestation may not be detected by quarantine inspectors.

Given that:

- *Aphelenchoides besseyi* may associated with island cabbage from the Pacific Islands although its prevalence is not known;
- *A. besseyi* is microscopic and transparent and cannot be detected visually;
- *A. besseyi* can be endo- or exoparasitic in the leaves without showing any symptoms at low levels of infestation;
- *A. besseyi* can survive shipment conditions without any adverse effect on its population

The likelihood of entry of Aphelenchoides besseyi is considered to be moderate.

7.2.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

Aphelenchoides besseyi are thermophilic and can withstand the heat generated in compost. Buckley and Gould (1998) observed that *A. besseyi* on plant material placed on a compost pile, survived and was reintroduced onto plants host growing nearby at a later date. *Aphelenchoides besseyi* can also tolerate desiccation and can remain viable even in dried plant material for years; and can feed and reproduce readily on various fungi such as *Fusarium verticillioides*, *F. proliferatum*, *Curvularia lunata Magnaporthe salvini, Alternaria alternata, Bipolaris oryzae* and *Pyricularia oryzae* (Jamali et al. 2008). If discarded leaves are infested with the nematode, there is the likelihood that the nematode can survive and move hosts.

It is not known to what degree host races of *A. besseyi* exist but potentially other plants such as strawberries, begonias, chrysanthemums, dahlias, zinnias, marigolds and rubber plants, would also be suitable hosts, as well as fungi. *A. besseyi* moves readily through water films over plant surfaces and can spread quickly in moist conditions to plants in direct contact with infested plants, and to other plants *via* soil or contaminated debris. Free water from irrigation, hand watering, overhead watering, rain or flooding can facilitate their dispersal to new host plants.

Given that:

- *Aphelenchoides besseyi* can survive desiccation and can feed on various fungi in the soil;
- can emerge from discarded leaves and migrate in a film of moisture onto any suitable host close by;
- a number of plants suitable for *A. besseyi* are grown in New Zealand;

The likelihood of exposure is considered to be moderate.

7.2.2.4 Assessment of establishment and spread

A. besseyi reproduces sexually although asexual reproduction (parthenogenesis) has been recorded. There is a very high likelihood that there would be more than one nematode in a leaf and, as males are as numerous as females, both sexes are likely to be present and mate to establish a viable population. *A. besseyi* has the ability to reproduce reasonably quickly.

Second stage juveniles (L2) become sexually mature in about 6 days at 25 ºC. At 30ºC, it takes about 28 hours from oviposition to hatching as an L2 juvenile, and about 70 hours from hatching to become an egg-laying, mature adult (Mochiji et al. 2008) , a condition that can be attained in composting. Rapid population growth in suitable conditions increases the likelihood of establishment.

The optimum temperature for development of *Aphelenchoides besseyi* is 28 °C and the marginal temperatures are 13 °C and 42 °C (Gergon and Misra 1992) although as low as 4°C has been reported (Qui et al (1991) cited in Chitambar, 1999). Although New Zealand is a temperate country this condition does not limit growth and development of *A. besseyi*. Temperate climate and flooded fields are also known to be adequate for *A. besseyi* survival but are not suitable for significant damage on the host plant (Gergon and Misra 1992).

Several of the known hosts (*e.g.*. strawberry is a major host), other orchid species, onions, begonias, chrysanthemums, dahlias, zinnias, marigolds and rubber plants are grown in New Zealand in either protected environments or outdoor environments such as gardens and cultivated land. Climate, therefore, is not likely to be a barrier for the establishment of *A. besseyi* in at least some parts of New Zealand such as Auckland and Northland.

Aphelenchoides besseyi is an aggressively motile nematode (Chitambar 2001). This nematode can easily spread to other plants *via* tiny films of water on the plant. It is likely that *A. besseyi* can develop and even spread further in areas where irrigation is carried out in farms and gardens. Overheard irrigation will allow this foliar nematode to be carried in water droplets to neighbouring, uninfected plants. Foliar nematodes can also spread from the direct contact of an infected leaf with uninfected plant tissue. There have been reports of foliar nematodes travelling along weed leaves to infect new plants, being carried in seeds, and within infected leaves that have senesced and fallen onto uninfected plant tissue (Lehman 1996). For example Marlatt (1970) observed an unusual mode of transmission of *Aphelenchoides besseyi*; the nematode moved from soil to plants to seed heads of a grass, *Sporobolus poiretii*, and then to *Ficus elastica* leaves touched by the grass inflorescence. However human-mediated movement of infested plants and growing media are likely to be an important mode of dispersal of the nematode between one location and another, and greenhouse conditions are likely to enable the establishment of permanent populations of *A. besseyi* throughout New Zealand.

Given that:

- *A. besseyi* do reproduce sexually but can also reproduce asexually;
- a short generation time would enable *A. besseyi* to build up populations rapidly;
- potential host plants are available;
- *A. besseyi* can disperse readily in water films, can spread from the direct contact of an infected leaf with uninfected plant tissue and to long distance by movement of plants or soil ;
- climate is not likely to be a barrier for the establishment of *A. besseyi* in at least some parts of New Zealand such as Auckland and Northland;

The likelihood of establishment and spread are considered to be high within a restricted distribution.

7.2.2.5 Consequence assessment

Economic consequences

In the Pacific Islands, Bridge (1988) reported that *A. besseyi* was a major problem in rice cultivation. Although New Zealand does not grow rice commercially, establishment of *A. besseyi* could have an impact on a number of commercial horticultural crops (*e.g.*., orchids, strawberries, onions, yam, taro, sweet potato, cut flowers) in New Zealand. The nursery industry could also be affected depending on the host range of the populations of the nematode that established. Crops grown in protected environments such as greenhouses are potentially vulnerable throughout the country. For crops grown outdoors, it is not clear how widely *A. besseyi* could establish. For example, in the northern hemisphere, *A. besseyi* is not found beyond latitude 43^{o}N on rice or beyond 40^{o}N on strawberries (EPPO, 2006) which suggests that crops in the more southern parts of New Zealand would not be at risk. Even if this assumption is correct, 40% of New Zealand's commercial strawberry crop is produced in the Auckland region (Hortfact), and orchids and other potentially vulnerable crops such as onions and sweet potato are well represented in the warmer northern regions of the country. If left uncontrolled, *A. besseyi* can downgrade the appearance and decrease the vigour of plants and therefore decrease market value. Establishment of *A. besseyi* may result in increased control costs, and compromise current pest management strategies. There may also be limitations on access to overseas markets where the nematode is absent. Whilst potentially significant for the affected sectors, in the context of the overall New Zealand economy these impacts are likely to be low to moderate.

The economic consequences are considered to be low to moderate

Environmental consequences

Although strawberry and rice are known to be the main host to *A. besseyi,* it may also parasitise a wide range of hosts. New Zealand native plant species are not proven to be hosts of *A. besseyi* but is possible they would be palatable to this nematode. New Zealand has a number of orchid species, including endemic species and genera, with varying distributions throughout the country. Some of these are endangered or threatened or of very limited known distribution, and it is not known if New

Zealand orchid species would be susceptible to *A. besseyi.* However, several genera in the Orchidaceae family including *Dendrobium* sp. are known to be hosts elsewhere Some of the other known hosts of *A. besseyi* have representatives in the same genera in New Zealand, for example *Hibiscus* and *Cyperus* (Heenan and de Lange, 2005). It is also possible that numerous native species could be attacked by this pest. A number of species in the Poaceae family are host to *A. besseyi*. The Poaceae has around 150 endemic and indigenous species in New Zealand (Landcare, 2010). It is likely some of them may also become suitable hosts if exposed to *A. besseyi*.

The potential environmental consequences are considered to be low

Human health consequences

There are no reported impacts on human health

Socio-cultural consequences

Amenity plantings and home gardens (for example, strawberries and ornamentals such as begonias, chrysanthemums, dahlias, zinnias, marigolds and rubber plants), particularly in northern regions, could be affected by *A. besseyi*.

The potential socio-cultural impacts are considered to be low

7.2.2.6 Risk estimation

The likelihood of *A. besseyi* entering New Zealand on imported island cabbage is considered moderate, and the likelihood of exposure is moderate and establishment is high. The economic consequences are considered low to moderate and the potential environmental and socio-cultural consequences are considered to be low in this risk analysis. However there is significant uncertainty in this assessment because of the limited information on which *Aphelenchoides* species are associated with island cabbage in the exporting countries.

As a result the risk estimate for A. besseyi is non-negligible and it is classified as a risk in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

7.2.3 Risk management options

Since the risk estimate for *A. besseyi* associated with island cabbage is non-negligible, options for phytosanitary measures are considered and factors relating to efficacy are discussed.

7.2.3.1 In-field control and post harvest option (*Aphelenchoides besseyi*)

Once foliar nematodes are established on leafy vegetables in the field, control can be very difficult. Although populations can be controlled with nematicides, total eradication is not possible. Nematicides applied either as foliar sprays or as soil treatments, can reduce the nematode population sufficiently to prevent symptom expression. However the nematode population is likely to build up again if nematicide application is withdrawn (EPPO 1981). A feasible management strategy, therefore, would be to exclude infested plant material from growing areas through pruning and removal of the pruned waste.

However, since it is unknown if *A. besseyi* is an endo- or ecto-parasite on island cabbage complete control is uncertain.

7.2.3.2 Post harvest cleaning and visual inspection option (*A. besseyi*)

A washing, wiping and inspection protocol for taro and tarua leaves for export is discussed in section 4.2.5. The biology of *A. besseyi* indicates it is unlikely to be susceptible to this kind of management option. Specific points to consider include:

- *A. besseyi* itself is not visually detectable as it is microscopic and transparent
- Infested leaves usually show symptoms, but in the early stages there may not be symptoms or the symptoms may not be obvious
- It can move in films of water and is aggressively motile
- It can move from one leaf to another by leaf contact
- It may be on the leaf or inside the leaf
- Because of the above mentioned points it is capable of recontaminating leaves either by water used for washing or wet leaves contacting each other

The available information is not enough to precisely measure the efficacy of the existing taro and tarua protocol, or the likely protocol for island cabbage leaves. However there have been substantial numbers of detections of live organisms on taro and tarua leaves that have been through the washing, wiping and inspection protocol. Potential modifications to this protocol, discussed in section 4.2.5, are likely to improve the efficacy.

Overall, the biology of *A. besseyi* indicates it is likely to be partially susceptible to a management system involving washing, wiping and inspection of leaves. Although the level of risk is at the lower end of the scale, without modifications this management option on its own is not likely to be in proportion to the risk.

Modification to the protocol can improve the efficacy, and manage the risks associated with leaves that are showing visible symptoms of infection. If there are leaves that are infested and not showing symptoms, these will not be detected. Until the protocol is in place and can be tested, significant uncertainty remains.

7.2.3.3 Visual inspection at border option (*A. besseyi*)

Visual inspection is only likely to detect symptomatic leaves. Asymptomatic leaf material will not be detected during inspections.

An inspection sampling regime will need to be developed that gives the level of efficacy required in proportion to the risk.

7.2.3.4 Combination of options

Combining the three options is likely to give a higher degree of efficacy than any single option.

If symptomatic leaves are detected and organisms are appropriately identified and recorded, this will provide information which will reduce the uncertainty about the efficacy of the options.

7.3 *Earias vittella* – aibika tip borer

Scientific name:	*Earias vittella* (Fab.) (Lepidoptera: Noctuidae)
Other relevant scientific names:	*Earias fabia, Earias huegeli, Aphusia speiplena, Micra partita*
Common names:	Aibika tip borer, spiny bollworm, rough bollworm, spiny cotton bollworm, shoot and fruit borer

7.3.1 Hazard identification

7.3.1.1 Description

Earias vittella is a small moth (wing span 17-25mm) with larvae that bore into shoots, pods and buds of plants.

7.3.1.2 Exporting country/s status

Tonga (CPC 2007), and in Fiji (Kamath 1979, Preston 1998), Cook Is (Stout 1982; Waterhouse 1997); Samoa (Waterhouse 1997; Stout 1982a) and Vanuatu (Waterhouse 1997).

7.3.1.3 New Zealand status

Earias vittella is not known to be present in New Zealand. Not recorded in: Dugdale 1988, Macfarlane *et al*. (2010), PPIN (2011).

7.3.1.4 General geographic distribution

Earias vittella is found in many countries in Asia, the Seychelles in Africa (CPC 2007) and has recently been recorded in the UK and Spain (Marabuto 2006). In Oceania it has been found in Australia (Queensland, Northern Territory and New South Wales) (CSIRO 2010). It has also been found in Belau, Federated States of Micronesia, Guam, Northern Mariana Islands, Papua New Guinea, and the Solomon Islands (CPC 2007).

7.3.1.5 Commodity associations

Abelmoschus manihot (island cabbage) is reported as a host (Preston 1998, Kamath 1979 (as *Hibiscus manihot*)).

7.3.1.6 Plant associations

Other hosts include okra (*Abelmoschus esculentus*), cotton (*Gossypium spp.*), hollyhock (*Alcea rosea*), safflower (*Carthamus* sp.), Indian mallow (*Abutilon* sp.), *Corchorus* sp., *Hibiscus* sp., *Malva* sp., *Malvastrum* sp., *Sida* sp., *Theobroma* sp. and *Urena* sp. (Sharma *et al.* 2010). CPC (2010) list tomato *Solanum lycopersicum* as a host, but there is no supporting reference for this and no other record has been found.

7.3.1.7 Plant parts affected

Eggs are laid on young ‘aibika’ (island cabbage) shoots and leaves. After hatching, the larvae tunnel down from the tip or near the tip. *E. vittella* attacks the main and lateral shoots at all stages of plant growth, causing dieback (Preston 1998).

On other hosts, eggs have been recorded on the undersides of leaves of cotton plants (Dhillon and Sharma 2004), and upper tender leaves of okra (Singh and Bichoo 1989). Eggs are also laid on buds and bolls of cotton (Dhillon and Sharma 2004), on okra pods (Al-Mehmmady 2000), and on cotton flower buds and petioles (Singh and Bichoo 1989). Larvae are pod borers, found in okra fruits (Singh and Bichoo 1989), and the tender portions of cotton plants – the growing shoots, buds, flowers and bolls (Anwar *et al.* 1973). First instar larvae have been recorded feeding on the upper surface of tender okra leaves (Singh and Bichoo 1989). Pupa have been recorded attached to the fruits of okra, attached to cotton plants and also recorded in shed material on the soil or in soil crevices (Singh and Bichoo 1989). Adult moths are mobile but are expected to often be found with the host plants, particularly females when ovipositing.

7.3.1.8 Potential for establishment and impact

Earias vittella reported from New South Wales in Australia which indicates it is potentially able to establish in parts of New Zealand that are ecoclimatically similar. It is a plant pest and likely to have unwanted impacts.

7.3.1.9 Hazard identification conclusion

Given that *E. vittella*

- is reported from *A. manihot*, and eggs and first instar larvae are found on the leaves of host plants;
- is recorded from Cook Islands, Fiji , Samoa, Tonga and Vanuatu;
- is not recorded from New Zealand;
- has the potential to establish in New Zealand and have unwanted impacts;

Earias vittella is therefore considered a hazard on island cabbage leaves in this risk analysis.

7.3.2 Risk assessment

7.3.2.1 Biology

Description
The adult moth is about 12-13.5mm long (Singh and Bichoo 1989) with a wing span of 17-25mm (Singh and Bichoo 1989; Kimber 2010). The body and hind wings are silvery-white, the forewings are white or peach with a central green wedge. Larvae are greyish-brown to green with a pale median line and fleshy tubercles. They are about 1 -18mm long (Singh and Bichoo 1989). Eggs are light blue-green and about 0.5mm diameter (Pearson 1958).

Life cycle
Each adult female can lay an average of about 200 eggs (Anwar et al. 1973; Singh and Bichoo 1989; Dhillon and Sharma 2004; Naresh et al. 2004, Bhat et al. 2005). On cotton plants, eggs are laid on buds, bolls, and the lower leaf surface (Dhillon and Sharma 2004). Larvae are pod borers in okra, although the first instar larvae sometimes feed on the upper surface of tender leaves (Singh and Bichoo 1989). In cotton larvae bore into tender portions of the plant, such as growing shoots, buds, flowers and bolls (Anwar et al. 1973). Pupae are sometimes attached to fruit of okra, and sometimes dry buds, leaves and bracts. Pupae have also been found in soil crevices or in shed material on soil (Singh and Bichoo 1989).

Al- Mehmmady (2000) recorded 13 generations a year in Saudi Arabia, with an average duration of the life cycle varying from about 32 to 49 days.

Earias vittella is found in countries with warm climates. Dry and cold weather extends the duration of the different life stages resulting in a prolonged duration of a generation. Humid, warm weather is considered favourable for the growth and development of this moth as it completes its development in a shorter time (Sharma et al. 1985, cited in Al-Mahmmady 2000). Prolonged exposure to 13^{o}C proves fatal, though it can survive short exposure to lower temperatures (CPC 2007).

7.3.2.2 Entry assessment

Island cabbage is likely to be arriving as bundles of leaves. Eggs have been recorded on the undersides of cotton leaves (Dhillon and Sharma 2004), and it is likely that eggs would be laid on island cabbage leaves in the same way. Eggs would not be readily detected unless each leaf was inspected. Aggregations are more likely to be found than single eggs or larva. However eggs are laid singly (Anwar *et al.* 1973) or in small groups (Al-Mehmmady 2000). Eggs are small (0.66mm x 0.53mm) (Singh and Bichoo 1989) so may be easily missed in an inspection of the leaves. Eggs take 3-4 days to hatch after being laid (Singh and Bichoo 1989) and would be well protected within a bundle of leaves.

First instar larvae have been recorded feeding on the upper surface of tender okra leaves (Singh and Bichoo 1989), and it is likely that they would also feed on island cabbage leaves in the same way. Therefore this life stage could also enter New Zealand on this pathway. Larvae are not attached to leaves the way that eggs are, and it is more likely that they would be dislodged during harvest and sorting, but it is likely that some could remain. First instar larvae are very small (1.3 to 1.4 mm (Singh and Bichoo 1989) and would avoid detection and be well protected in a bundle of leaves. Later instar larvae usually bore into other plant parts such as the pods, flowers, bolls and shoots of cotton and okra. Such boring activities are expected to be found in similar parts of island cabbage plants. Later instar larvae are not expected to be found in bunches of imported island cabbage leaves unless the leaf shoots are also harvested.

Pupae are occasionally found on leaves, but may be dislodged during harvest and sorting. They have a dirty white or pale brown cocoon which is about 14.6mm long (Singh and Bichoo 1989), and are likely to be detected during an inspection

It is expected that adults will be disturbed during harvest, sorting and packing, and will not enter New Zealand on island cabbage leaves.

Live *Earias vittella* larvae and one live pupa have been intercepted on numerous occasions at the border in consignments of okra pods, green beans and chauria leaves from Fiji over the last year (MAF Interception Database 2011).

Given that:

- Eggs are small, laid singly or in groups, and could be missed by inspection in bunches of leaves;
- first instar larvae are sometimes found feeding on leaf surfaces, but later instars are found in other plant parts where they feed, such as pods and shoots;
- pupae are occasionally found on leaves but may be dislodged during harvest and sorting;
- pupae are reasonably obvious and are more likely to be detected during inspection;

- adults are likely to be disturbed during harvest, sorting and packing;

The likelihood of entry of eggs is considered to be moderate. The likelihood of entry of first instar larvae, later instar larvae and pupae is considered to be low. The likelihood of entry of adults is considered to be negligible.

7.3.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

If eggs entered New Zealand on island cabbage leaves, larvae hatching from those eggs would have to move from the island cabbage leaves to suitable plant parts (shoots, pods, flowers) of a suitable host species. Any *E. vittella* organisms entering as first instar larvae on island cabbage leaves would similarly have to find a suitable host and suitable plant parts of that host.

A study in the UK found that 19% of vegetables purchased were thrown away uneaten (Ventour 2008) and similar proportions of vegetables are likely to be thrown away in New Zealand. However only material that is discarded into compost or the wider environment is likely to result in exposure; larvae are not likely to escape from leaves disposed of with landfill waste. If island cabbage leaves were composted it is likely that in some cases larvae could move from compost to host plants growing nearby. Hollyhock, Indian mallow, *Hibiscus* sp., and *Malva* sp. are all hosts which are common in New Zealand, and it is likely that *E. vittella* could occasionally come across these plants. Okra and some *Gossypium* species are grown in New Zealand, but only in small amounts and it would be unlikely for *E. vittella* to come across either of these plants. *Theobroma* sp. and *Urena* sp. might be present in New Zealand but if so they are not common here so are less likely to be found by *E. vittella.*

Given that:

- larvae would have to find suitable plant parts on suitable hosts;
- larvae on island cabbage leaves disposed of in compost may in some cases find suitable hosts nearby;

The likelihood of exposure is considered to be low.

7.3.2.4 Assessment of establishment and spread

Although eggs are laid singly, they are sometimes laid in small groups; several hundred are laid by each female and it is likely that some would be laid on the same leaves. It is likely that in some cases larvae hatching from these eggs could find a suitable host plant, and suitable parts on the plant for development into pupa then adults, and mate and start a new generation. If they did so, as females lay a few hundred eggs, it is likely that occasionally a population could establish from one pair of moths.

If multiple pupae entered New Zealand on a bunch of island cabbage leaves, adults may emerge and as they mate, they could similarly lay a few hundred eggs on a suitable nearby host plant and start a new population.

In most of New Zealand, the climate is not suitable for the establishment of *E. vittella*. However the north of the North Island has a high degree of similarity to parts of New South Wales (Fagan et al. 2008). This suggests that *E. vittella* could establish in the northern part of the North Island (*e.g.* from Auckland north). Greenhouses may provide a suitable environment for establishment if host plants were grown indoors.

Some of the known hosts are relatively common in New Zealand, and it is possible *E. vittella* populations could establish on these.

Given that:

- females lay a few hundred eggs and it is likely that they would lay multiple eggs on the same leaves, so it is likely that in some cases larvae could grow to become adults, find mates, and start a new population;
- The climate in the north of the North Island is likely to be suitable for their development;
- Some host plants are common in New Zealand;

The likelihood of establishment is low in limited areas of New Zealand.

Adults are mobile, although it is not known how far they could fly. They are at least able to fly short distances, so could spread to hosts near their original host plant. *E. vittella* is recorded as “not known to migrate or disperse over large distances” (Kranthi et al. 2004). However some individuals were found in the UK, possibly blown there *via* seasonal migration from countries with warmer climates (Marabuto 2006), as they are unlikely to survive winter in the UK. It is possible that instead of arriving by flight or wind they arrived with imported plant material, so it is not certain that they travelled this long distance unassisted.

It is likely that they could be spread within New Zealand by people moving host plants. The climate in most of New Zealand would be too cold for establishment of *E. vittella* and would limit its spread.

Given that:

- Adults can fly, at least short distances;
- there is a small chance of people moving infected host plant material within New Zealand;
- the climate in most parts of New Zealand will not be suitable for their reproduction and establishment, particularly in winter months;

The likelihood of the organism spreading within ecoclimatically suitable areas of New Zealand is considered to be moderate.

7.3.2.5 Consequence assessment

Economic consequences

Earias vittella is a pest of cotton and okra, but neither of these are major crops here. It is possible that it would have a limited impact on the nursery industry, as it also attacks hollyhock, hibiscus, and *Abutilon* which are sold in plant nurseries.

This moth is unlikely to have an impact on commercial fruit or vegetable growers as there do not appear to be fruit or vegetable hosts.

As the moth is likely to have a very limited distribution the potential economic consequences are considered to very low.

Environmental consequences

None of the recorded hosts are native New Zealand species. There are some endemic species related to the recorded hosts. For example *Solanum aviculare* var. *latifolium* is endemic (Landcare New Zealand Flora 2010), and there are some native *Solanum* species which are also found overseas. Apart from these, Solanaceae are generally not endemic. In the Malvaceae family (as many of the hosts are) there are *Hibiscus, Hoheria* and *Plagianthus* species, which are endemic (Landcare New Zealand Flora 2010). There are no endemic Sterculiaceae. There are some endemic Asteraceae. Some of these plants may be suitable as hosts for *E. vittella* but it is unlikely that *E. vittella* would have major impacts on these plants.

The potential environmental consequences are considered to be low.

Human health consequences

There are no known human health consequences.

Socio-cultural consequences

The plants mentioned above (in the economic consequences section) sold by plant nurseries are grown by home gardeners, so *E. vittella* may become a minor pest for home gardeners in affected areas.

The potential socio-cultural consequences are considered to be very low.

7.3.2.6 Risk estimation

The likelihood of entry of eggs is moderate, with larvae and pupae low. The likelihood of exposure is low. The likelihood of establishment is low in limited areas of New Zealand, the likelihood of spread is moderate. The potential economic impact within New Zealand is very low, environment and socio-cultural impacts are low.

As a result the risk estimate for E. vittella is non-negligible and it is classified as a hazard in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

7.3.3 Risk management options

Given the risk estimate for *Earias vittella* is non-negligible options for phytosanitary measures are considered and factors relating to efficacy are discussed.

7.3.3.1 Post harvest cleaning and visual inspection option (*E. vittella*)

A washing, wiping and inspection protocol for taro and tarua leaves for export is discussed in section 4.2.5. The biology of *E. vittella* indicates it will be partially susceptible to this kind of management option. Specific points to consider include:

- Eggs are usually on the underside of leaves, first instar larvae on the leaf upper surface, later instars within the leaf and pupae sometimes on leaves
- External life stages should be visible
- Damage from larvae on the leaf or in the leaf should be detectable
- Those on leaf surfaces should be easily dislodged
- Recontamination is not very likely

The available information is not enough to precisely measure the efficacy of the existing taro and tarua protocol, or the likely protocol for island cabbage leaves. However there have been significant numbers of detections of live Lepidoptera on leaves that have been through the washing, wiping and inspection protocol. Potential modifications to this protocol discussed in section 4.2.5 are likely to improve the efficacy.

Overall, the biology of *E. vittella* indicates that it is likely to be susceptible to a management system involving washing, wiping and visually inspecting leaves. Although the level of risk is at the lower end of the scale, without modifications, this management option on its own is not likely to be in proportion to the risk.

Modifications to the protocol can improve efficacy, and with modifications this management option is likely to be in proportion to the risk. However, until the protocol is in place and can be tested significant uncertainty remains.

7.3.3.2 Visual inspection at the border option (*E. vittella*)

Moth larvae and pupae have previously been detected at the border. It is expected that damage to leaves would be detected. However, very small amounts of damage or very few damaged leaves within a consignment could easily be missed during an inspection.

All life stages of several moth species are frequently intercepted at the border. *E. vittella* eggs are less likely to be detectable as their colour may enable them to blend with the leaf. Individual larvae may be less detectable in the early stages as they are very small. Older larvae should be detectable because of the damage to leaves from the mines.

The biology of *E. vittella* indicates it would be susceptible to this kind of management option. An inspection sampling regime will need to be developed that gives the level of efficacy required in proportion to the risk.

7.3.3.3 Combination of options

Combining the two management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded visual inspection will also provide information which will reduce the uncertainty about the efficacy provided by the washing, wiping and inspection protocol.

7.3.3.4 No measures option (*E. vittella*)

Taking into account the non-negligible, but very low impacts of establishment of this species, and the lack of a fully effective risk management option, the option of no risk management is included.

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8 Risk assessment of potential hazard organisms group D: arthropods that are obvious and/or large

8.1 Group hazard identification

The biosecurity risk from this group of hazards is assessed using all life stages of the beetle *Adoretus versutus*, the snail *Achatina fulica* and the bug *Amblypelta cocophaga cocophaga* as examples. It is assumed that any risk management for the identified risk from these example species will also manage the risk from other organisms in this hazard group, including any that have yet to be identified.

The organisms classed as hazards identified in Appendix 1 that appear to have life stages meeting the criteria for this group, are listed in the following table. The organism in bold have been assessed in this chapter; the organisms not in bold have not been assessed. Not all identified hazards are necessarily risks on this pathway.

Table 7. Hazard organisms which are likely to be obvious or large

Taxonomy	Type of organism	Included hazards	Mobile, large and/or obvious life stage
Coleoptera	beetle	***Adoretus versutus***, *Harmonia arcuata*	adults
Coleoptera	weevils	*Apirocalus cornutus, Elytrurus griseus, Sphaerorhinus aberrans*	adults
Gastropoda	snail	***Achatina fulica***	Hatchlings, young juveniles
Hemiptera	plant bugs	***Amblypelta cocophaga cocophaga***, *Brachylybas variegates, Lampromicra sp., Micraspis lineola, Nysius sp., Tectocoris diophthalmus, Phaenacantha sp.,*	adults
Lepidoptera	moths	*Anomis lyona, Haritalodes derogata, Tiracola plagiata, Xanthodes transversa*	adults, possibly late instar and pupae
Orthoptera	grasshoppers	*Phaneroptera brevis, Valanga sp.*	nymphs and adults

8.2 *Adoretus versutus* – Rose beetle

Scientific name: *Adoretus versutus* Harold (Coleoptera: Scarabaeidae)
Common name: Rose beetle

8.2.1 Hazard identification

8.2.1.1 Description

Adoretus versutus are medium sized beetles (females 9-12mm in length) which are nocturnal and feed on foliage. Eggs, larvae and pupae are found in soil where larvae feed on roots.

8.2.1.2 Exporting country/s status

Adoretus versutus is recorded from the Cook Islands, Fiji, Tonga, Vanuatu (Waterhouse 1997) and Samoa (Stout 1982).

8.2.1.3 New Zealand status

A. versutus are not known to be present in New Zealand. Not recorded in: Leschen *et al*. (2003), Macfarlane *et al*. (2010), PPIN (2011).

8.2.1.4 General geographic distribution

A. versutus is native to India and Sri Lanka. It is found in Pakistan, parts of Africa, Indonesia and Malaysia. It has spread to a number of countries in the Pacific region, including American Samoa and Wallis and Futuna (CPC 2010; Walker 2007). It was first reported in Fiji in 1906, although it was likely to have been introduced in the late 19th century (CPC 2010). It was subsequently reported in Samoa in 1914 and Vanuatu in 1982 (Jackson and Klein 2006), and was discovered in New Caledonia in 2004 (Aberlenc *et al*. 2004).

8.2.1.5 Commodity association

The adult beetles feed on the leaves of *Abelmoschus manihot* and other plants (Stout 1982; Watt 1986). Larvae feed on roots of other plants (Waterhouse and Norris 1987) and live in soil therefore larvae will not be associated with island cabbage leaves.

8.2.1.6 Plant associations

A. versutus are polyphagous. Larvae feed on roots of sugarcane and other grasses, and adult beetles feed on leaves of many plants including cocoa, coffee, cowpea, citrus, eggplant, fig, ginger, grape, guava, *Hibiscus* spp., pear, plum, sugarcane, and ornamentals such as rose (Waterhouse and Norris 1987; CPC 2011).

8.2.1.7 Potential for establishment and impact

It is assumed that *A. versutus* has some degree of tolerance for cold as it occurs in Pakistan and Uttar Pradesh and also feeds on temperate climate crops such as *Prunus* species. It is assumed it could establish in the north of the North Island. Its polyphagous habit means it would impact upon the horticultural and nursery sectors. Given the larvae feed on the roots of various grasses it is likely pasture could be affected.

8.2.1.8 Hazard identification conclusion

Given that *A. versutus*

- is not known to be present in New Zealand;
- is found in Fiji, Vanuatu, Samoa, the Cook Islands, and Tonga;
- is found on leaves of island cabbage;
- is likely to establish in New Zealand and have an adverse impact

Adoretus versutus is therefore considered a hazard on island cabbage leaves in this risk analysis.

8.2.2 Risk assessment

8.2.2.1 Biology

A. versutus is a beetle in the family Scarabaeidae. It has four life stages: egg, larva, pupa and adult beetle. The eggs are laid individually in the soil, with the female burrowing 7–10 cm down to deposit them. Hatching occurs in 12 to 14 days, but can be as few as seven days under hot conditions (Waterhouse and Norris 1987).

The larvae are fleshy white grubs with a sclerotised rusty-orange head capsule. There are three larval instar stages that last 12–14, 12–14 and 28–33 days respectively (52–61 days in total) in Samoa. However, in Fiji these larval stages are reported to take up to 120 days in total (Waterhouse and Norris 1987). Development is affected by temperature and the organic matter content of the soil. The larvae feed on roots and other organic material in the soil. They may be found close to the surface when the soil is wet, and second and third instar larvae may crawl on the soil surface at night (Waterhouse and Norris 1987).

Pupation occurs in an earthen cell 10–15 cm deep in the soil, with the adults emerging 16–18 days later (Waterhouse and Norris 1987). Adult females are generally larger than the males, measuring 9–12 mm in length and 5–6 mm wide (Kumar *et al*. 2009). They are reddish chestnut in colour, and covered with sparse grey decumbent hairs (Kumar *et al*. 2009).

During the day, adult beetles remain in the soil or shelter under fallen leaves, stones and logs. They are nocturnal feeders, emerging in the evening to fly to food plants such as *Hibiscus* spp., cocoa and rose, feeding on the leaves and returning to the soil or other shelter before sunrise. Adult beetles can do considerable damage to the leaves, perforating them with sieve-like holes or skeletonising them and can reach substantial population densities. A population numbering more than 7000 has been reported feeding on a single tree in Samoa (Waterhouse and Norris 1987).

Their longevity in the field is unknown, but they have been reported living from 29–30 days in laboratory tests (Waterhouse and Norris 1987). Fecundity is also unknown, but it has been estimated that the females produce about 40 eggs (Waterhouse and Norris 1987). *Adoretus versutus* breeds all year round in Samoa. In Fiji adult beetles are more common from November to May (Waterhouse and Norris 1987). Fiji experiences cooler temperatures from May to September, unlike Samoa where the temperatures remain relatively constant all year.

8.2.2.2 Entry assessment

Adoretus versutus is common in Fiji, Tonga and Samoa (Watt 1986) and is present in a number of other Pacific countries where island cabbage is grown. The eggs, larvae and pupae are only found in the soil, and are not associated with the leaves. However, the adult beetles feed on the leaves of island cabbage (Stout 1982; Watt 1986).

Adoretus versutus has a history of accidental introductions to new environments. In the cases of introductions to Vanuatu and Futuna Island, it is likely that the beetles were inadvertently transported by boats, attracted by the lights of port facilities at night (Aberlenc et al. 2004). This does not suggest a specific pathway associated with trade in foliar commodities such as island cabbage. Additionally, imports of island cabbage to New Zealand are most likely to be air freighted.

Adult beetles are nocturnal feeders, only feeding during daylight if released after a period of starvation (Waterhouse and Norris 1987). During the day they shelter in the soil or under leaf litter, stones and twigs. Therefore are unlikely to be present on the leaves during harvest, and have a low likelihood of being packed amongst the leaves for export.

Adult beetles drop to the ground if disturbed (Waterhouse and Norris 1987) so are unlikely to remain on the leaves during harvest or handling.

Given that:

- Only adult beetles are likely to be associated with the leaves;
- Adults feed nocturnally on leaves and drop to the ground if disturbed;
- Adults usually shelter in the soil or under leaf litter on the ground during the daytime when island cabbage leaf harvest would occur;
- Adults are large and mobile (females are 9-12mm long and 5-6mm wide) and should be detected prior to export;

The likelihood of entry on island cabbage leaves is considered to be negligible.

8.2.2.3 Risk estimation

The likelihood of entry of *Adoretus versutus* on island cabbage leaves from the Pacific Islands is considered to be negligible.

As a result the risk estimate for Adoretus versutus is negligible and it is not classified as a risk in the commodity. Therefore risk management measures are not justified.

Note that although *A. versutus* is not assessed as a risk on this pathway and therefore risk management measures over and above standard commercial practice are not justified, it remains a ‘regulated pest’. Therefore, if it is intercepted on any imported lots at the border the infested lot will be treated to ensure the pests are effectively controlled prior to release. Alternatively, the consignment shall be reshipped or destroyed at the importers option and expense.

8.3 *Achatina fulica* –giant African snail

Scientific name: *Achatina fulica* Authority (Pulmonata: Achatinidae)
Synonyms: *Lissachatina fulica*
Common name: Giant African snail

8.3.1 Hazard identification

8.3.1.1 Description

Achatina fulica is a large herbivorous and detritivorous snail.

8.3.1.2 Exporting country/s status

Achatina fulica is reported from Vanuatu, Samoa, Tonga and many other Pacific Island countries[14] (Lambert 1974 cited in Venette and Larson 2004, Hoddle 2004, Raut and Barker 2002). It appears to have been eradicated from Fiji (Raut and Barker 2002, Thiengo *et al*. 2007).

8.3.1.3 New Zealand status

A. fulica is not known to be present in New Zealand. Not recorded in Barker (1999), not recorded as present in PPIN (2010).

8.3.1.4 General geographic distribution

Originally from eastern coastal Africa, *A. fulica* has been spread by people, accidentally and deliberately (mostly for food and medicinal purposes) (Raut and Barker 2002). It is found in Asia[15], Hawaii, and Central and South America[16] (CPC 2010, Dundee 1974).

8.3.1.5 Commodity association

A. fulica feed on leaves (*e.g.* Thakur 2004) and other plant parts (*e.g.* Lobao et al. 2000). Preston (1998) is not specific about how *A. fulica* is a problem in island cabbage crops but he states "...serious pests of aibika include slugs and the Giant African Snail (*Achatina fulica* Bowd)." It is not unlikely that juvenile *A. fulica* will either feed or seek shelter on the leaves of island cabbage.

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14 American Samoa, French Polynesia, Guam, Marshall Is, Fed States Micronesia, New Caledonia, Nthn Mariana Is, Palau, Papua New Guinea, Solomon Is, Wallis and Futuna Is. (CPC 2010)
15 Bangladesh, Brunei Darussalam, Cambodia, China, India, Indonesia, Japan (Ryukyu Is), Malaysia, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, Vietnam (CPC 2010)
16 Brazil, Venezuela (CPC 2010)

8.3.1.6 Plant associations

A. fulica are polyphagous, with up to 500 hosts recorded (Smith 2005). Hosts which are crops in New Zealand include beans and peas, brassicas, carrots, citrus, pumpkin, cucumber, lettuce, onion, potato, spinach, sweet potato and tomato. Eucalyptus and many ornamental plants are hosts (Raut and Barker 2002). *A. fulica* are generally considered herbivores feeding on living and decaying vascular plant material and have also been reported to eat unicellular algae. They have been described as opportunistic omnivores or scavengers (Olsen 1973 cited in Raut and Barker 2002).

8.3.1.7 Potential for establishment and impact

Parts of New Zealand have been assessed as potentially suitable for the establishment of *A. fulica* (Cooling 2005). New Zealand has many suitable host plants for *A. fulica.* This snail is an internationally recognised quarantine pest (USDA, ISSG 2011) and is likely to have a significant impact on crops and native plants.

8.3.1.8 Hazard identification conclusion

Given that *Achatina fulica*

- is not found in New Zealand;
- is present in Vanuatu, Samoa and Tonga;
- is associated with island cabbage (*Abelmoschus manihot*);
- is potentially able to establish and have an adverse impact;

it is considered to be a hazard in this risk analysis.

8.3.2 Risk assessment

8.3.2.1 Biology

At hatch *A. fulica* are 4-5mm long and by 133 days old are approximately 42 to 45mm (Thakur 1998). *A. fulica* may exceed 200mm in shell length but generally average around 50-100mm (Cooling 2005). The shell is generally reddish-brown with weak yellowish vertical markings, but colouration varies with environmental conditions and diet. The shell is more translucent in the juvenile stage (Cooling 2005). Individuals have been recorded living up to nine years; however the average lifespan is closer to 5 years (Cooling 2005).

They are hermaphrodites, and attain sexual maturity at around 5-8 months after egg hatch or later. Egg production can occur up to 380 days after mating. They lay eggs in clutches of ten to 400, and have two to six clutches a year. They lay eggs in a shallow depression in the soil (Raut and Barker 2002).

Newly hatched snails stay with the eggs for up to seven days, and then begin travelling to nearby food plants. Juveniles disperse widely, and have been recorded dispersing as far as 500m in six months. Reproductively mature adults are least active (Tomiyama and Nakane 1993), with adults generally returning to the same home sites at the end of each night (Raut and Barker 2002). *A. fulica* are described as nocturnal (Raut and Barker 2002) but have been recorded as active in the daytime after rain (Tomiyama and Nakane 1993). They are dependent on the availability of moisture, so are active under high humidity conditions. They usually spend daytime hours under protective cover to avoid light and desiccation.

They aestivate in dry weather, with aestivation lasting 2 to 10 months depending on the climatic zone (Raut and Barker 2002). They can survive periods of cold by hibernating (Cooling 2005).

8.3.2.2 Entry assessment

At the New Zealand border *A. fulica* has been intercepted from Samoa and other countries, usually on containers, with two interceptions with passengers (Quancargo 2010). No interceptions of *A. fulica* with plant commodities have been recorded (Quancargo 2010), however a large number of interceptions on leafy crops are identified as Gastropoda or Stylommatophora and some of these could be *A. fulica*. Stylommatophora have been intercepted on leafy imports arriving in New Zealand from Fiji, Samoa, Niue, Norfolk Island, French Polynesia, and Tonga (MAFBNZ 2010). Even if these interceptions are not *A. fulica*, they show that other Stylommatophora are present on leafy crops entering New Zealand, which suggests *A. fulica* could also be present as they have similar biology.

In the Pacific Islands, island cabbage will be harvested all year round. It is likely that snails will occasionally be active when leaves are harvested, particularly in summer which is the rainy season. *A. fulica* feeds on leaves during the night, and it is likely that sometimes juveniles will shelter during the day under leaves or in bunches of shoots. Island cabbage is harvested during the day, and it is possible that *A. fulica* would be on harvested leaves.

It is expected that *A. fulica* would be detectable, particularly adults. However, as there have been interceptions of snails it is apparent that sometimes they will not be detected prior to export. Therefore it is assumed that very young juveniles may sometimes miss being detected given they are the smallest active life stage and may have sheltered in a depression between leaf veins.

Given that:

- It is expected that snails would usually be detected at harvest or packaging, but;
- Juvenile *A. fulica* may rest on the underside of leaves during the day when leaves are harvested, or could be harvested while feeding on leaves after rain;
- Stylommatophora have been detected at the border on leafy crops entering New Zealand from the Pacific Islands;

The likelihood of entry is considered to be low.

8.3.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

Tomiyama and Nakane (1993) tracked individual *A. fulica* juveniles and found that they moved a mean of 5.5 to 9.2 metres per night (SD 2.9-5.6m), so they could easily move to nearby host plants. If they are discarded into compost heaps or rubbish dumps, *A. fulica* are polyphagous so are likely to find a suitable host nearby, and as they are also detritivores it is not unlikely they would be able to live initially on the rubbish or compost surrounding them.

Given that:

- Uneaten island cabbage leaves are likely to end up in rubbish dumps or compost heaps, but only leaves discarded in compost are likely to result in snails escaping;
- *A. fulica* are detritivores and polyphagous herbivores;
- *A. fulica* juveniles have been recorded moving a mean of 5.5 to 9.2m per night so are able to move to nearby edible detritis or host plants;

The likelihood of exposure is considered to be moderate.

8.3.2.4 Assessment of establishment and spread

Environmental suitability of New Zealand
A. fulica feeds on decayed vegetation and animal matter, with the juveniles feeding primarily on plants. It has been recorded feeding on up to 500 different kinds of plants from a wide range of families including eucalyptus and most species of vegetables as well as feeding on the bark of relatively large trees such as citrus (Venette and Larson 2004). Many of these hosts are found in New Zealand. It is therefore likely to be able to find appropriate food sources in New Zealand.

A. fulica is most closely associated with tropical and subtropical moist and dry broadleaf forests, although over much of its introduced range it has a predilection for modified environments such as plantations and gardens (Raut and Barker 2002). High humidity, a lack of frost and cover from direct exposure to sun appear to be environmental requirements. Eight to 21 days at a minimum temperature of 15^{o}C are required for eggs to hatch. Adults remain active at temperatures ranging from 9^{o}C to 29^{o}C and survive temperatures of 2^{o}C by hibernation and 30^{o}C by aestivation (Mead 1961, Raut and Barker 2002). Activity is largely restricted to areas with at least 80% relative humidity.

Overlay mapping of mean annual temperature, mean minimum temperature, vapour pressure deficits (a measure of humidity), relative soil calcium levels and land cover has shown that although optimal conditions for establishment of *A. fulica* do not occur in New Zealand (Cooling 2005), much of the North Island, the west coast of the South Island and Stewart Island has been assessed as potentially suitable (Cooling 2005). *A. fulica* occurs in a large number of countries around the world. According to Venette and Larson (2004) all of the countries in which it is established have tropical climates with warm, mild year-round temperatures and high humidity. However, Raut and Barker (2002) say

A fulica is highly adaptable and tolerant of a wide range of conditions. It can survive in a range of habitat types and appears to be adapting to temperate climates expanding from its original niche as a tropical snail. *A. fulica* is likely to be able to establish in parts of the North Island.

Likelihood of establishment from island cabbage leaves:
A. fulica can produce eggs up to 380 days after they have mated, and they can lay up to 400 eggs in a clutch, so it is possible that a mature individual entering a new area could found a population. However, sexually mature *A. fulica* would be too large to avoid detection during picking of island cabbage leaves and it is assumed that only small juveniles would enter New Zealand on this pathway.

A. fulica can self fertilise, but virgin animals provide clutches comprising fewer than ten eggs, most of which are sterile and progeny arising from these eggs rarely survive through sexual maturity (Olson 1973 cited in Raut and Barker 2002). Therefore two juveniles would have to enter New Zealand, grow to maturity, find each other and mate in order to found a population. It is possible that this could occur, as explained below:

A. fulica will lay clutches of 10 to 400 eggs (Raut and Barker 2002, Thakur 1998). Newly emerged juveniles do not disperse widely, but stay near the site of hatching, feeding on decaying plant matter and preferred host plants (Raut and Barker 2002). It is possible that two or more juveniles from a nearby clutch are found on the same leaf or leaves close growing island cabbage leaves at harvest, and end up in the same bunch of leaves which are exported to New Zealand. Then the two or more juveniles could end up in the same compost heap or rubbish dump.

Slightly older juvenile *A. fulica* disperse quite widely, they have been recorded moving 500m in six months (Tomiyama and Nakane 1993). They are likely to be vulnerable to some level of predation. It is expected that any juveniles arriving on the same bunch of island cabbage leaves would eventually disperse and be separated by some distance by the time they reached sexual maturity. It is not known what methods these snails use to locate one another when they wish to mate, but it is assumed they could detect other snails of the same species by slime trails. The likelihood of this is low with few juveniles in the environment.

Given that:
- environmental conditions are likely to be suitable for *A. fulica* in many parts of the North Island;
- *A. fulica* are polyphagous and likely to find suitable hosts within New Zealand;
- Fertilised individuals are very unlikely to enter New Zealand on island cabbage leaves as they would be too large to avoid detection at the border;
- Young juveniles feed near where their eggs were laid, so it is not unlikely that more than one juvenile could end up in a bunch of island cabbage leaves exported to New Zealand;
- Although juveniles disperse widely it is assumed that they would find each other by detecting slime trails, but;
- It is considered few juveniles would enter and survive to maturity, and
- the likelihood of finding each other decreases with lower numbers of dispersed individuals

The likelihood of establishment in New Zealand, of young juveniles arriving on island cabbage leaves is low but non-negligible.

The rate at which *A. fulica* would spread in New Zealand is uncertain. It is likely to spread within New Zealand as a hitchhiker on vehicles and machinery, and juveniles on plants which are moved around the country. *A. fulica* often crawls into crevices and has been intercepted twice on used vehicles at the New Zealand border (MAFBNZ 2010). *A. fulica* are often intercepted on containers, and have been intercepted with timber, scrap metal and cartons, and on ship decks and holds (MAFBNZ 2010) indicating they are likely to be moved with goods being transported around the country. Individuals spreading to areas in the north of the North Island could establish.

Given that:

- *A. fulica* often crawls into crevices;
- *A. fulica* have been intercepted on cars, containers, timber, cartons, scrap metal and ship holds and decks;
- Juveniles are likely to be moved with plants;

The likelihood of the organism spreading within the climatically suitable areas of the North Island is high.

8.3.2.5 Consequence assessment

Economic consequences

Economic impacts associated with damage to crops from *A. fulica* and associated control attempts are likely to be locally significant. The estimated annual losses in Florida based on a 2002 dollar value, if *A. fulica* had become established, are some US$ 54 million (Venette and Larson 2004). The extent of possible damage in New Zealand would not be of this order and would depend on the extent of spread, the crops affected and the population size of the snails. It is however likely to be significant. In 2007 324 ha of citrus, 35 ha of brassicas (broccoli, cabbage and cauliflowers), 3 ha of carrots, 13 ha of lettuce and 31 ha of potatoes were grown in Northland.

In Brazil, although *A. fulica* has not been considered a potentially serious large-scale agricultural pest, it is a concern in small scale agriculture (Thiengo *et al*. 2007). In farms of less than 10 planted hectares, losses of up to 30% have been recorded (Thiengo *et al*. 2007).

After a period of rapid population growth, *A. fulica* populations usually decline markedly, probably because of disease (Raut and Barker 2002).

Plant diseases such as black pod disease caused by *Phytophthora palmivora* are spread in the faeces of *A. fulica* (Raut and Barker 2002). *Phytophthora palmivora* is a widespread pathogen causing many different diseases on a wide range of plants. The pathogen is believed to have originated in Southeast Asia but is now pantropical. It causes significant losses to farmers of tropical fruit and vegetable crops (Anon 2008). *Phytophthora palmivora* is reported from Fiji, Samoa, Tonga and Vanuatu (CPC 2010) and has been assessed as a risk in a previous risk analysis (MAFBNZ 2008).

As the snail (and the fungus) is likely to be ecoclimatically limited in where they establish, the potential economic consequences are considered to be low, although significant impacts are expected in climatically suitable areas.

Environmental consequences

A. fulica is sometimes found invading primary or secondary forest but is usually found in disturbed low to mid elevation sites (Raut and Barker 2010). In Brazil *A. fulica* is found in forest regions, particularly forest edges (up to 500m in from the edge) and regenerating forest (Thiengo *et al*. 2007). There are few reports of damage to native plants but this probably reflects the interests of investigators rather than the lack of damage (Raut and Barker 2002).

Raut and Barker (2002) listed the possible negative environmental effects of a heavy infestation of *A. fulica* as: (i) herbivory on native plants; (ii) altered nutrient cycling as large amounts of material pass through the animal's gut; (iii) adverse effects on indigenous gastropods from competition with *A. fulica*; (iv) adverse effects on indigenous gastropods from the introduction of biological control agents to control *A. fulica*; and (iv) adverse effects on indigenous gastropods from the use of chemical controls on *A. fulica.* While some introduced biological control agents have wiped out native gastropod species overseas, biocontrol agents would not be introduced here without extensive host range testing, so (iv) is unlikely to be a problem in New Zealand.

There are more than 1000 species of native snails in New Zealand. The large flax snails and kauri snails are some of the more well known snails found in the northland area (RD&I Wellington, 2006) which may be negatively impacted by the arrival of the giant African snail.

Cooling (200) suggests *A. fulica* is more likely to increase its diet of fresh plants and other material when introduced to new environments.

As the snail (and the fungus) is likely to be ecoclimatically limited in where they establish, the potential environmental consequences are considered to be low, although significant impacts are expected in climatically suitable areas.

Human health consequences

Achatina fulica is a vector of the rat lungworm, *Angiostrongylus cantonensis*, which causes eosinophylic meningoencephalitis in humans, which can be fatal (Thiengo *et al*. 2007). *A. cantonensis* does not seem to be recorded from New Zealand (*e.g.* Alicata and McCarthy 1964), but is presumed to be in Samoa (Reid and Wallis 1984) and is found in Vanuatu (Bowden 1981). The parasite is passed to humans through eating raw or improperly cooked snails, or transferral to the human mucus membranes such as eyes and nose and possibly skin lacerations after handling snails (Anon. no date, Cooling 2005). It is believed that foods such as salad greens or fruit contaminated by snail slime or faeces can also be a means of human infection (Cooling 2005). The majority of giant African snails carry the parasite so the likelihood of it arriving with the snails is high (Cooling 2005). However snails over a year old are more likely to be carrying the parasite than younger individuals (Cooling 2005), so if only young snails can enter on this pathway there is less likelihood of them carrying this parasite.

A related species, *Angiostrongylus costaricensis* may also be carried by *A. fulica* (Cooling 2005). This nematode causes abdominal symptoms rather than neurological ones (Cooling 2005).

The bacterium *Aeromonas hydrophila* is also associated with *A. fulica* (Cooling 2005). This bacterium causes wound infections, and is present in New Zealand.

The overall potential human health consequences are considered to be moderate.

Socio-cultural consequences

One of the major impacts of this snail is as a nuisance pest. In humid, tropical places populations can get so large that it is difficult to walk on footpaths without treading on snails, snails rest all over houses and cars can skid on dead snails on roads. Large numbers of decaying snails can smell and attract flies and cockroaches (Cooling 2005). In New Zealand it is likely to be considered a nuisance although it is unlikely to reach the proportions it can in hotter climates.

Domestic gardens will be impacted by the presence of this snail.

The potential for socio-cultural consequences are considered to be moderate.

8.3.2.6 Risk estimation

The likelihood of entry is low, and the likelihood of exposure is moderate. In the North Island, the likelihood of establishment is low, and likelihood of spread high. In the north of the North Island, the potential economic consequences are low, and potential environmental, human health and socio-cultural consequences are moderate.

As a result the risk estimate for Achatina fulica is non-negligible and it is classified as a hazard in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

8.3.3 Risk management options

As the risk estimate for *A. fulica* is non-negligible, options for phytosanitary measures are considered and factors relating to efficacy are discussed.

8.3.3.1 Post harvest cleaning and visual inspection option (*A. fulica*)

A protocol for the washing, wiping and inspection of taro and tarua leaves for export is discussed in section 4.2.5. The biology of *A. fulica* indicates it is likely to be susceptible to this kind of management option. Specific points to consider include:

- Juvenile snails are likely to be on the underside of leaves
- The colour and size of the juvenile snails means they should be visible
- They should be readily dislodged
- Recontamination is not as likely from washing as it would be for faster-moving organisms

The available information is not enough to precisely measure the efficacy of the existing taro and tarua protocol, or the likely protocol for island cabbage leaves. However, there have been substantial numbers of detections of live organisms (including snails, beetles, bugs, moths, and other large, mobile, obvious organisms) on taro and tarua leaves that have been through the washing, wiping and inspection protocol. Potential modifications to the protocol, discussed in section 4.2.5, are likely to improve the efficacy.

Overall the biology of *A. fulica* indicates it is likely to be susceptible to a management system involving washing, wiping and visually inspecting leaves. Although the level of risk is at the lower end of the scale, without modifications this management option on its own is not likely to be in proportion to the risk.

Modifications to the protocol can improve the efficacy, and with modifications this management option is likely to be in proportion to the risk. However, until the protocol is in place and can be tested, significant uncertainty remains.

8.3.3.2 Visual inspection at the border option (*A. fulica*)

Large, mobile organisms such as snails, beetles and bugs are intercepted frequently at the border on a range of pathways, including fresh leaves. *A. fulica* juveniles have reddish-brown shells becoming less translucent as they age. Therefore they are visually detectable although very young juveniles may be more difficult to detect.

The biology of *A. fulica* indicates it would be susceptible to this kind of management option. An inspection sampling regime will need to be developed that gives the level of efficacy required in proportion to the risk.

8.3.3.3 Combination of options

Combining the two management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded, visual inspection will also provide information which will reduce the uncertainty about the efficacy provided by the washing, wiping and inspection protocol.

8.4 *Amblypelta cocophaga cocophaga* – coconut bug

Scientific name: *Amblypelta cocophaga cocophaga* China (Hemiptera: Coreidae)
Common name: coconut bug

8.4.1 Hazard identification

8.4.1.1 Description

Amblypelta cocophaga cocophaga is 14-15mm long bug which feeds on fruit and growing stages of plants.

8.4.1.2 Taxonomy

Amblypelta cocophaga has been split into *Amblypelta cocophaga cocophaga* and *Amblypelta cocophaga malaitensis* (Brown 1958). This risk analysis refers to *A. cocophaga cocophaga* as *A. cocophaga malaitensis* is found only in Malaita in the Solomon Islands (Brown 1958) and not found in the exporting countries of interest. Most literature refers to *A. cocophaga* without distinguishing the subspecies.

8.4.1.3 Exporting country/s status

A. cocophaga cocophaga is found in Fiji (Evenhuis & Polhemus 2008) and Vanuatu (Brown 1958),

8.4.1.4 New Zealand status

Amblypelta cocophaga cocophaga is not known to be present in New Zealand. It is not recorded in: Larivière & Larochelle (2004), Gordon (2010), PPIN (2011).

8.4.1.5 General geographic distribution

Other than Fiji and Vanuatu the distribution of *A. cocophaga cocophaga* appears to be restricted to Papua New Guinea (FPI 2010), the Solomon Islands (Hill 2009) and Singapore (CPC 2008).

8.4.1.6 Commodity association

Amblypelta cocophaga cocophaga is reported from *Abelmoschus manihot* (FPI 2010).

8.4.1.7 Plant associations

A. cocophaga cocophaga is polyphagous, with a recorded host range of 43 species in 30 plant families (CPC 2010). It is found on various plantation undergrowth shrubs and on plants in the bush (forest) (Phillips 1940 cited in Levin Mitchell 2000) up to an altitude of about 900m in the Solomon Is. (Brown 1958). Hosts include members of the families Arecaceae, Euphorbiaceae, Passifloraceae, Polypodiaceae, Rosaceae, Fabaceae, Convolvulaceae and Cucurbitaceae (Huwer 1996, Landcare Research 2010).

It is a pest of coconut and cacao, and it has been recorded damaging shoots of papaya, kapok, cassava and *Eucalyptus* (Levin Mitchell 2000, Bigger 1985). In its native range *A. cocophaga*

cocophaga has caused significant problems with plantation trees growing near bush-land. CPC (2010) states the following: "Most fruit crops are at risk and *Eucalyptus* [*deglupta*] suffered around 40% losses in a study conducted by Bigger (1985)."

Mangifera indica (mango), *Capsicum* sp. (chilli), *Cucumis melo* (melon), *Ficus carica* (fig), *Citrus sinensis* (late Valencia orange) and *Vitis vinifera* (grape) are recorded hosts of *A. cocophaga cocophaga* (Huwer 1996).

8.4.1.8 Plant part affected

Eggs are laid on the lower surface of leaves of palm (Levin Mitchell 2000), sometimes on flowers and fruit (Brown 1959), and are assumed to be laid on the leaves of *A. manihot.* Nymphs feed on flowers of the spadix of palms, and small nuts (Phillips 1940 cited in Levin Mitchell 2000). Adults and nymphs feed on young shoots of *Eucalyptus* (Levin Mitchell 2000). *A. cocophaga cocophaga* feeds on petioles and stems of cassava (Brown 1958b cited in Levin Michell 2000), and has been recorded feeding on cacao pods and terminal shoots (Levin Mitchell 2000).

8.4.1.9 Potential for establishment and impact

A. cocophaga cocophaga is potentially able to establish and have unwanted impacts.
Although the distribution of *A. cocophaga cocophaga* is currently restricted to tropical areas, it has been reported from altitudes of up to 900m indicating that it may have the ability to establish in cooler climates. It has been reported as a pest of various crops.

8.4.1.10 Hazard identification conclusion

Given that *A. cocophaga cocophaga*

- is not known to be present in New Zealand;
- is found on *A. manihot,* and eggs are laid on leaves of host plants;
- is found in Fiji and Vanuatu
- is potentially able to establish and have unwanted impacts

Amblypelta cocophaga cocophaga is therefore considered a hazard on island cabbage leaves in this risk analysis.

8.4.2 Risk assessment

8.4.2.1 Biology

Description
Eggs are 2mm long, sub-oval and golden green when first laid, turning to a darker opalescent green and finally wine-red as they mature (CPC 2008).
There are five nymphal instars. The first instar is 3.5-4.0 mm in length. As development proceeds through the various instars, the distribution of the colours changes with combinations of shades of red, green and yellow, white and brown. Body size increases to a length of 12-13 mm in the fifth instar (CPC 2008).

Adult bugs are 14-15 mm long and green-yellowish-brown in colour. The female is stouter than the male (CPC 2008).

Life cycle
The time from oviposition to adult emergence from pupa is 36 to 41 days, and the preoviposition period is 15 to 19 days (Levin Mitchell 2000). Instars 1-5 have been recorded occupying 4, 7, 6, 7 and 9 days respectively, and the entire life cycle takes about 42 days (Lever 1933 cited in CPC 2008). Female lifetime fecundity is over 100 eggs (Levin Mitchell 2000).

8.4.2.2 Entry assessment

Island cabbage is likely to be arriving as bundles of leaves. Eggs have been recorded on palm leaves (Levin Mitchell 2000). *Abelmoschus manihot* is known to be a host of *Amblypelta cocophaga cocophaga,* and it is assumed that eggs would also be laid on *A. manihot* leaves. Eggs would not be readily detected unless each leaf was inspected. Aggregations of eggs or nymphs are more likely to be detected than individuals. Eggs are 2mm long, and change from golden green, to darker opalescent green then wine-red (CPC 2008). The green stages of the egg are likely to be missed on inspection on green leaves, whereas the wine red stage may be more obvious. Eggs would be well protected within a bundle of leaves.

It appears that nymphs and adults prefer fruits and shoots to leaves, so there is a lower likelihood of these life stages being found on island cabbage leaves. Additionally, adults fly readily (Brown 1958) and are unlikely to remain on island cabbage leaves during harvest and packing.

Given that:

- Eggs have been recorded on the leaves of host plants;
- It is assumed that eggs are laid on island cabbage leaves;
- Nymphs and adults feed primarily on other plant parts and are less likely to be found on island cabbage leaves;
- adults fly readily and would be unlikely to remain on leaves at harvest and packaging;

The likelihood of entry of eggs is considered to be low, the likelihood of entry of nymphs is considered to be very low, the likelihood of entry of adults is considered to be negligible.

8.4.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

Uneaten leaves may be thrown away; survey information from the UK indicates that a significant proportion (19%) of vegetables purchased was thrown away uneaten (Ventour 2008). Compost heaps in home gardens are often open topped. Island cabbage leaves may be discarded onto a compost pile; leaves discarded with landfill waste are unlikely to result in exposure. Nymphs would then have a few days to move to a new host plant before the leaves are no longer able to support them or are covered by a new layer of waste. It is not known how far nymphs can move.

Many of the host species are tropical and are not common in New Zealand, however, *Eucalyptus*, *Capsicum* spp., citrus, cucurbits and figs are grown in home gardens (Huwer 1996, NZPND 2010). CPC (2010) states "*A. cocophaga* has become a pest of plantation *Eucalyptus deglupta, E. tereticornis* and *E. urophylla* in the Solomon Islands. If provided with the opportunity through availability of a similar range of plants to that attacked by *A. lutescens, A. cocophaga* might well be able to utilize just as broad a host range". It is assumed that there may be some palatable species within an achievable distance.

Given that:

- island cabbage leaves may be discarded into the environment or open compost piles, leaves discarded with landfill waste are unlikely to result in exposure and;
- Some recorded host plants are found in New Zealand gardens, but;
- Most known hosts are tropical species not grown in New Zealand gardens

The likelihood of exposure is considered to be very low.

8.4.2.4 Assessment of establishment and spread

A. cocophaga cocophaga has been reported from an elevation of about 900m in the Solomon Islands. It is not certain how this would translate to suitable climatic conditions in New Zealand but indicates that it may have the ability to establish in warmer areas such as the north of the North Island.

Known hosts are likely to be limited, apart from *Eucalyptus tereticornis* which is fully naturalised in New Zealand (NZPND 2010), and oranges, melons and grapes which grow throughout the north of the North Island. However, potential hosts are widespread.

The likelihood of establishment and spread is considered to be very low in climatically suitable areas.

8.4.2.5 Consequence assessment

Economic consequences

In its native range *A. cocophaga cocophaga* has caused significant problems with plantation tees growing near bush-land. CPC (2010) states the following: "Most fruit crops are at risk and *Eucalyptus* [*deglupta*] suffered around 40% losses in a study conducted by Bigger (1985)." However, most of the fruits referred to are likely to be tropical fruits that are not grown in New Zealand, such as mango. It is possible there would be some damage to the host species (citrus, grape and melon) that are grown here but this would have a very limited distribution.

The potential consequences are considered to be very low.

Environmental consequences

Hosts include members of the family Arecaceae. The endemic New Zealand species *Rhopalostylis sapida* (Nikau Palm) is in this family and could potentially be a host.

There are hosts in the families Euphorbiaceae, Passifloraceae, Polypodiaceae, Rosaceae and Fabaceae. These families include endemic New Zealand species, and endemic genera in the family Fabaceae include Kowhai (*Sophora*) and kakabeaks (*Clianthus* sp.) (Huwer 1996, NZPND 2010,). However, the distribution of *A. cocophaga cocophaga* is likely to be climatically limited.

The potential environmental consequences are considered to be very low

Human health consequences

There are no reported human health impacts.

Socio-cultural consequences

A. cocophaga cocophaga may have limited and localised effects on home gardens.

The socio-cultural consequences are considered to be very low

8.4.2.6 Risk estimation

The likelihood of entry of A. *cocophaga cocophaga* eggs and nymphs are considered to be low and very low respectively. The likelihood of exposure is considered to be very low, and the likelihood of establishment and spread very low. The economic, environmental and sociocultural impacts of establishment of this species are likely to be very low and there are unlikely to be any impacts on human health.

The proportion of island cabbage leaves that are infested with *A. cocophaga cocophaga* eggs and nymphs, subject to successful exposure and which result in successful establishment is considered to be very small. When the likelihoods are considered in combination, and taking into account the very low potential consequences, the risk is considered to be negligible.

Therefore risk management measures are not justified.

Note that although the risk posed by *A. cocophaga cocophaga* has been assessed as negligible on this pathway, it remains a "regulated pest". The very low likelihood of entry suggests that it is unlikely to be detected on island cabbage leaves at the border. If it is intercepted on any imported lots at the border this may imply that the likelihood of entry is higher than originally assessed. The infested lot will be treated to ensure the pests are effectively controlled prior to release. Alternatively, the consignment shall be reshipped or destroyed at the importers option and expense.

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9 Risk analysis of potential hazard organisms group E: Hitchhikers

9.1 Group hazard identification

A hitchhiker is an organism that has an opportunistic association with a commodity or item with which it has no biological host relationship.

The biosecurity risk from this group of hazards is assessed using all life stages of the ant *Solenopsis geminata* as an example. It is assumed that any risk management for the identified risk from *Solenopsis geminata* will also manage the risk from other organisms in this hazard group, including any that have yet to be identified.

The organisms classed as hazards identified in Appendix 1 that appear to have life stages meeting the criteria for this group, are listed in the following table. The organisms in **bold** have been assessed in this chapter; the organisms not in bold have not been assessed. Not all identified hazards are necessarily risks on this pathway.

The following ants have been intercepted on fresh leaves from the Pacific Islands (MAF 2011) and are species known not to be present in New Zealand (Don 2007):

Table 8. Hazard organisms which are likely to be living and/or feeding internally

Taxonomy	Type of organism	Included hazards	Mobile life stage
Hymenoptera	ants	*Anoplolepis gracilipes*, *Cardiocondyla nuda*, *Cardiocondyla wroughtonii*, *Crematogaster* sp., *Monomorium destructor, Monomorium floricola*** *Monomorium minutum, Monomorium monomorium, Monomorium* sp., *Nylanderia bourbonica (was Paratrechina)**, *Paratrechina longicornis, Paraparatrechina minutula (was Paratrechina), Nylanderia* sp*** (was Paratrechina), Nylanderia vaga** (was Paratrechina), Pheidole fervens, Pheidole oceanica, Pheidole* sp. *Pheidole umbonata, Ponera loi, Ponera* sp., ***Solenopsis geminata*****, *Tapinoma melanocephalum**, Tapinoma* sp., *Tetramorium bicarinatum, Tetramorium simillimum, Triglyphothrix obesa* ssp. *Striatidens.*	All castes (workers, soldiers etc.) including queens

***NOTE:** There has been a taxonomic change to the genus *Paratrechina.* However *Paratrechina longicornis* remains in this genus (LaPolla et al 2010).
** species that had queens intercepted at the New Zealand border.

9.2 *Solenopsis geminata* – tropical fire ant

Scientific name: *Solenopsis geminata* Fabricius (Hymenoptera: Formicidae)
Other relevant scientific names: *Solenopsis geminata rufa* Jerd.; *Atta geminata*
Common name[/s]: tropical fire ant; red ant

9.2.1 Hazard identification

9.2.1.1 Description

Solenopsis geminata is a ‘hitchhiking’, polymorphic, reddish-brown ant, 3-8mm long, with a square brown head. It belongs to the fire ant family, tends honeydew excreting homopterans and has a severe sting.

9.2.1.2 Exporting country status

Solenopsis geminata is reported from Cook Is., Fiji and Tonga (Yates and Wetterer 2006)

9.2.1.3 New Zealand status

Solenopsis geminata is not known to be present in New Zealand. Not recorded in: Don (2007); not recorded in MacFarlane *et al*., (2010), recorded as present in NZ by PPIN however this was a post-border incursion record in a Bay of Plenty container yard and it is not known to have established.

9.2.1.4 General geographic distribution

Other Pacific countries *S. geminata* is reported from include Australia, American Samoa, French Polynesia, Guam, Kiribati, New Caledonia, Northern Marian Is., Papua New Guinea and Solomon Is. It is reported from Africa (including Sth Africa), Central and South America[17], Mexico, USA and parts of Asia.[18] (Yates and Wetterer 2006)

9.2.1.5 Commodity association

Solenopsis geminata is a hitchhiker species which means there is no direct association with island cabbage leaves. However, *S. geminata* has been intercepted on fresh leaves from the Pacific in the past. This species may tend honeydew excreting homopterans that live on island cabbage leaves and by this way be associated. Alternatively *S. geminata* may find its way into a consignment of island cabbage leaves at any point along the import pathway.

9.2.1.6 Plant associations

Solenopsis geminata is commonly found in association with crop and weed species such as:

Brassica oleracea var. capitata (cabbage), *Capsella bursa-pastoris* (shepherd's purse), *Cenchrus ciliaris* (buffelgrass), *Citrus*, *Coffea* (coffee), *Cynodon dactylon* (Bermuda grass), *Festuca arundinacea* (reed fescue), *Fragaria ananassa* (strawberry), *Glycine max* (soyabean), *Leptochloa dubia* (green strangletop (USA)), *Lycopersicon esculentum* (tomato), *Malachra*, *Paspalum conjugatum* (sour paspalum), *Paspalum distichum* (knotgrass), *pastures*, *Pennisetum clandestinum* (kikuyu grass), *Solanum spp.*, *Sorghum bicolor* (sorghum)

and less commonly with:
Abelmoschus esculentus (okra), *Ananas comosus* (pineapple), *Carica papaya* (papaw), *Coffea arabica* (arabica coffee), *Cordia myxa* (sebesten), *Croton bonplandianus*, *Cucumis sativus* (cucumber), *Eleusine coracana* (finger millet), *Gossypium hirsutum* (Bourbon cotton), *Grewia*

17 Argentina, Brazil, Colombia, Ecuador, Venezuela
18 China, India, Indonesia, Japan, Myanmar, Philippines, Sri Lanka, Taiwan,Vietnam

asiatica (phalsa), *Ipomoea batatas* (sweet potato), *Mangifera indica* (mango), *Musa* (banana), *Nicotiana tabacum* (tobacco), *Oryza sativa* (rice), *Passiflora* (passionflower), *Persea americana* (avocado), *Saccharum officinarum* (sugarcane), *Solanum melongena* (aubergine), *Theobroma cacao* (cocoa), *Trichosanthes dioica* (pointed gourd), *Zea mays* (maize) (CPC 2011)

9.2.1.7 Potential for establishment and impact

Solenopsis geminata has established in places where the climatic conditions are not favourable to its survival (*e.g.*.: Winnipeg, Canada- Ayre 1977). Various authors have commented that it is able to nest in buildings-(Yates and Wetterer 2006). It is likely to establish in parts of New Zealand which are ecoclimatically suitable and has the potential to establish in buildings. It is likely to have economic, environmental and socio-cultural/health impacts.

9.2.1.8 Hazard identification conclusion

Given that *Solenopsis geminata*

- is a hitchhiking ant that has been intercepted numerous times in imported leaves from the Pacific;
- is likely to be associated with island cabbage by tending honey-dew excreting insects on the leaves;
- is present in the Cook Islands, Fiji and Tonga;
- is not recorded from New Zealand;
- is potentially able to establish in New Zealand and have unwanted impacts;

Solenopsis geminata is therefore considered a hazard on island cabbage in this risk analysis.

9.2.2 Risk assessment

9.2.2.1 Biology

Solenopsis geminata is a hitchhiker species commonly found as a pest in urban and disturbed areas such as crop fields and orchards. It is known to nest under *Citrus* trees, eat the seeds and seedlings, and girdle the tree trunks introducing, disease (Essig 1926; Wolcott 1933; Suarez-Sotolongo 1990; French 2004).

Solenopsis geminata belongs to the group of 18-20 species of fire ants in the *Solenopsis* genus (~200spp). This species is polymorphic (with major and minor castes), 3 to 8 mm in length. The body is reddish-brown, the almost square head is brown.

Winged reproductive females and males leave mature colonies on mating flights about dusk on warm, moist evenings. At a suitable site a few kilometres from the parent colony the mated queen will shed her wings and tunnel into the ground to start a new colony. The queen will lay 10-15 eggs/day for about 10 days then stop laying until the workers mature, which can take 2-4 weeks (Yates & Wetterer, 2006). Queens can lay up to 1123 eggs per day (Travis, 1941). Eggs hatch in 14-17 days, the larval stage lasts 24 days to 6 weeks and pupation lasts up to 19 days (Veeresh, 1990a). Egg to adult development can take between 3-4 weeks and up to 2 months (Vargo, 1993). Colony maturity is reached in 1-2 years (Wilson & Taylor, 1967).

Monogyne (single queen) and polygyne (multiple queens) colonies occur (McKay *et al.* 1990). The number of queens per polygyne colony can vary greatly, *e.g.* between 3-90 were recorded by Vargas *et al* (1993). Numbers of workers per nest vary, from around 4000 to hundreds of thousands (Taber 2000; Way *et al.* 1998). The nest is usually a short, wide mound with multiple entrances at certain times of year and a network of underground foraging tunnels, up to 100ft long. The whole system can extend 1.5m underground. Nest densities differ considerably from 4-20/ha (McInnes & Tschinkel, 1995) to 6000/ha (Vareesh 1990 cited in Taber 2000). A full description of colony characteristics can be found in Harris (2005).

S. geminata is able to colonise most types of soil and media, particularly disturbed habitats of varying types. It may also nest in well drained woodlands and sandy areas (Taber 2000). Nests can occur at the base of established trees, rocks, concrete and near water sources. Colonies were found in the grounds of a tourist complex in the Kakadu region (Northern Territory, Australia) but were absent from the surrounding undisturbed savannah (Hoffman & O'Connor, 2004). It prefers mild winter temperatures and high humidity, low to mid level elevations, below 1,500ft although it has been recorded at 3,000 ft. (CPC, 2007). It has established in climatically unsuitable places for its survival by nesting and foraging indoors.

Optimal foraging temperatures are reported to be 25-33˚C (Rani & Narenden 1987 in: Veeresh 1990) and workers with brood seem to prefer temperatures from 22-32˚C depending on the relative humidity (Cokendolfer & Francke, 1985, in Harris 2005).

S. geminata typically forage within 15m of the nest (Levins et al 1973; Perfecto and Vandermeer 1996) and most often on the ground (Carroll & Risch 1983).This species is omnivorous, with seeds comprising the larger part of the diet. Foragers also feed on arthropods (often pest species of crops), tend honeydew producing homopterans, and will take meats, sweets and fats. (Harris 2005). *S. geminata* is seldom a direct pest of crops but does girdle plants, bite branches, shoots, buds, flowers, fruits and imbibe sap (Hill 1975). Lakshmikantha et al (1996) recorded significant damage to potato tubers and tomatoes. This species can also gnaw through the bark of *Citrus* trees (French, 2004).

9.2.2.2 Entry assessment

Ants may be associated with leaves by tending honey-dew excreting homopterans. However many ants are hitchhikers. As a hitchhiker species *S. geminata* can be associated with any part of the fresh produce import pathway. Although commonly found in disturbed areas such as crop fields and orchards, it is an urban pest also, so may be found nesting in or near buildings. Ants could be incidentally exported with island cabbage leaves.

S. geminata queens have been intercepted on fresh leaves from the Pacific (MAF Interception database 2011). This ant species has been intercepted at the New Zealand border at least 55 discrete times from 1964 to 2002 and frequently on fresh produce from the Pacific (Harris 2005). Nests, queens and workers have been intercepted associated with fresh produce (taro, taro leaves, tarua leaves), stored products and miscellaneous items (Harris 2005; MAF Interception database 2011).

Although it would be very unlikely whole nests could be moved with fresh island cabbage leaves, it is possible individual ants or small groups could find their way into the cartons prior to export, from within or around the packing house or storage areas or from air containers that have not been cleaned.

Established colonies of a congener *S. invicta,* (red imported fire ant), showed that they could survive 42 days at 30˚C without food and water (Porter, 1989). Experiments by Kaspari and Vargo (1995) found small (founder size) and large colonies (approximating a 9 month old colony) survived 28 days without food and water, but solitary queens only survived less than 6 days. It is assumed that *S. geminata* will have a similar tolerance for food and water deprivation. This exceeds the flight time from the Pacific to New Zealand.

S. geminata has previously survived the flight time from Fiji and Tonga (about 3 hours) to Auckland, and the shipping time of 6-8 days in the past (Harris 2005).

Given that *Solenopsis geminata*:

- has been intercepted previously on fresh leaves from the Pacific;
- as a hitchhiker can be associated with any point of the import pathway;
- is known to survive the transit period;

The likelihood of entry of Solenopsis geminata is considered to be moderate.

9.2.2.3 Exposure assessment

Initially any ants arriving in produce are likely to move from the point where the boxes are opened because of the disturbance. They are generalist feeders and likely to move to areas where they can find shelter and food. Their mobility increases the likelihood of exposure.

Dispersal by human mediated movement is also likely. Most consignments are coming into Auckland during the summer months. Temperatures will be suitable for *S. geminata* to forage.

The likelihood of exposure for Solenopsis geminata is considered to be high.

9.2.2.4 Assessment of establishment and spread

Workers on their own cannot begin a colony as they are sterile.

S. geminata has successfully spread and established outside of its native range and is well established in the Pacific. A single mated queen is sufficient to start a population if she arrives with enough fat reserves to locate a nest site and rear the first workers. The time of year is important as establishment is less likely in winter although a suitable microclimate (inside a building or glasshouse) could allow this. For instance *S. geminata* has been reported from some environments where the conditions are unfavourable for this species to survive outdoors *e.g.*., Winnipeg, Canada (Ayre, 1977). However it may survive in climate-controlled buildings, greenhouses or other human dwellings and infrastructure. In such cases, although its capacity for local spread is restricted its continued presence facilitates long distance dispersal to locations more suitable for establishment (McGlynn 1999; Holway *et al*. 2002).

Colony size can increase rapidly in a matter of weeks (Risch and Carroll 1982a, b).Dispersal occurs with winged reproductives (alatae) leaving the nest to mate and found new colonies, usually a few kilometres from the source colony (Holway et al 2002). This form of dispersal usually results in scattered colonies and may make eradication or control difficult (Roque-Albelo and Causton 1999). Human facilitated dispersal will likely increase spread over short and long distances. Whole nests can be inadvertently moved in nursery stock or hay bales as has happened in Hawaii (Harris, 2005).

Climate matching showed New Zealand has a high degree of similarity with sites where *S. geminata* has established, but the mean annual temperature is lower throughout New Zealand than any known site where *S. geminata* has established outside of tropical glasshouses. A nest was found in a ditch next to a container storage yard at Mt Maunganui, June 2003 (Harris, 2005) and was subsequently eradicated (S. O'Connor pers. comm. 2007). The nest did not have brood in it. It is likely, given the site microclimate, this nest was 'maintaining' and by summer could have gone into production and even produced alatae (S. O'Connor, pers.comm. 22/5/2007). The north of the North Island is more suitable for the establishment of this species than other regions, but microclimate will be a key factor.

Given that

- The north of the North Island is climatically suitable;
- *S. geminata* has previously established a nest in Tauranga which was eradicated;
- *S. geminata* has the ability to nest indoors so this makes other areas of New Zealand potentially suitable;
- *S. geminata* is highly mobile and polyphagous;
- New colonies are founded by winged, mated queens which facilitates spread; but:
- Queens have been less frequently intercepted than workers and establishment depends upon mated queens arriving if whole nests do not;

The likelihood of establishment and spread for S. geminata is considered to be low to moderate.

9.2.2.5 Consequence assessment

Economic consequences

Potential impacts are broad including damage to crops from chewing and girdling plant of stems (*e.g.*.: *Citrus*, tomatoes, avocados, potato and cucumber), disease spread, seed predation, and chewing of polyethylene irrigation tubing should *S. geminata* establish in large numbers. Large incursions would mean movement controls on a range of freight including produce, flowers and nursery stock until eradication was successful. Increased measures or restrictions on exports to countries free of *S. geminata* are also likely (Harris 2005). Surveillance and response programmes are very costly.

The potential economic consequences within affected areas of New Zealand are considered to be moderate.

Environmental consequences

Outside of urban areas, *S. geminata* is most likely to prefer warm coastal dunes, grassy areas, forest margins and disturbed wetlands (Harris 2005). *S. geminata* is known to alter invertebrate communities in tropical locations (Risch & Carroll 1982a) through competition and predation. In Northland there are 55 invertebrate species listed as threatened that would be at risk of predation by *S. geminata*, including *Placostylus* land snails, 4 species of endemic northern tiger beetle (*Cicindela* spp.), the nationally endangered coastal moth *Notoreas* 'northern', a suite of micro-snails, *e.g.*.: *Succinea archeyi,* and possibly the kauri snail *Paraphanta busbyi watti* (Harris, 2005).

S. geminata will sting repeatedly to immobilise invertebrate and vertebrate prey. It has been observed killing young rats (Pimental, 1955) and hatchling loggerhead sea turtles (Moulis 1996), entering pipped quail eggs and consuming the entire chick (Travis 1938), and attacking and consuming young birds in the nest or that have fallen from their nest (Pimental, 1955; Kroll, 1973). Therefore other species potentially at risk from *S. geminata* establishment in New Zealand would be hatchlings of herpetofauna, and eggs and nestlings of some birds, especially surface and burrow nesters (Harris 2005).

The potential environmental consequences within New Zealand are considered to be high.

Human health consequences

S. geminata does not necessarily have to establish to have an impact, it only needs to come into contact with people. *S. geminata* delivers a painful bite and multiple, venomous stings when disturbed. The stings result in a localised intense burning sensation, followed by the formation of a pustule. Severe, systemic allergic reactions are rare but there are occasional reports of anaphylactic shock (Travis 1941; Hoffman 1997; Yates and Wetterer 2006).

The potential human health consequences within New Zealand of entry and establishment of S. geminata are considered to be moderate.

Socio-cultural consequences

Internationally *S. geminata* colonies are common throughout urban areas. Due to their sting, chewing electrical wiring, infesting buildings and household foods, stealing seeds from seedbeds, biting holes in fabrics, they are considered a pest. Lifestyle disruption, especially to activities associated with sunny, grassy areas (picnics, barbeques, sports, playgrounds and gardening) may occur in any urban area the ant has established (Harris 2005).

The potential socio-cultural consequences within New Zealand are considered to be moderate

9.2.2.6 Risk estimation

The likelihood of entry is considered to be moderate, exposure is high, establishment low-moderate and the economic, environmental, health and socio-cultural consequences are considered to be moderate.

As a result the risk estimation for Solenopsis geminata is non-negligible and it is considered to be a risk on the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

9.2.3 Risk management options

Given the risk estimate for *S. geminata* is non-negligible options for phytosanitary measures are considered and factors relating to efficacy are discussed.

9.2.3.1 Monitoring option

Options that may be considered for monitoring include use of an insecticidal spray (such as Icon) applied weekly to the perimeter of the treatment area/packing house, which is likely to deliver a good degree of ant control. The efficacy of this can be measured by ant bait stations within packhouses.

9.2.3.2 Post harvest cleaning and visual inspection option (*S. geminata*)

A protocol for the washing, wiping and inspection of taro and tarua leaves for export is discussed in section 4.2.5. The biology of *S. geminata* indicates it will be partially susceptible to this kind of management option. Specific points to consider include:

- *S. geminata* is a small, reddish-brown, rapidly moving ant, so should be visually detectable
- Ants are more likely to be dislodged by brushing than immersion in water
- Because ants are highly mobile they are capable of recontamination, either from water used for washing or by moving to leaves after washing and wiping

The available information is not enough to precisely measure the efficacy of the existing taro and tarua protocol, or the likely protocol for island cabbage leaves. However, there have been substantial numbers of detections of live organisms (including ants) on taro and tarua leaves that have been through the washing, wiping and inspection protocol. Potential modifications to the protocol, discussed in 4.2.5 are likely to improve the efficacy.

Overall, the biology of *S. geminata* indicates it would be susceptible to a management system involving washing, wiping and visually inspecting leaves. Although the level of risk is towards the lower end of the scale, without modifications this management option on its own is not likely to be in proportion the risk.

Modifications to the protocol can improve the efficacy, and with modifications this management option is likely to be in proportion to the risk. However, until the protocol is in place and can be tested, significant uncertainty remains.

9.2.3.3 Visual inspection at the border option (*S. geminata*)

S. geminata is small but very mobile. The optimal foraging temperature is about 21-25˚C. MAF Quarantine officers reported that detection of ants on vehicles is very weather dependent (Toy and Glassey 2006). In warm temperatures ants are likely to be detected by their movement, but cool or cold weather is more likely to inhibit movement and therefore detection.

The biology of *S. geminata* indicates that it would be susceptible to this type of management option. An inspection sampling regime would need to be developed that gives the level of efficacy required in proportion to the risk

9.2.3.4 Combination of options

Combining management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded, visual inspection will also provide information which will reduce the uncertainty about the efficacy provided by the washing, wiping and visual inspection protocol.

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10 Risk assessment of potential hazard organisms group F: fungal pathogens dispersed by wind and water

In this chapter there is no group hazard identification. Each fungus that was identified as a potential hazard is assessed. This is because there are many different types of fungal pathogens known to infect plants in numerous ways and therefore the risks and management options may differ.

Table 9. Fungal pathogens that are spread by wind or rain

Taxonomy	Type of organism	Included hazards	Relevant life stage
All Fungi	All Fungi	***Choanephora cucurbitarum, Choanephora infundibulifera, Oidium abelmoschi, Pseudocercospora abelmoschi***	All stages

10.1 *Choanephora species* (Zygomycota: Mucorales: Choanephoraceae) – wet rot disease and choanephora blight

The following pathogens are included together because the biosecurity risk they present is likely to be similar: *Choanephora cucurbitarum* and *Choanephora infundibulifera*

Scientific name: *Choanephora cucurbitarum* (Berk. & Ravenel) Thaxt. 1903
Synonyms: *Rhopalomyces cucurbitarum* Berk. & Ravenel 1875
Choanephora infundibulifera f. *cucurbitarum* (Berk. & Ravenel) Schipper
Choanephora americana A. Moller 1901
Common names: Wet rot disease
Blossom end rot
Choanephora fruit rot

Scientific name: *Choanephora infundibulifera* (Curr.) Sacc. 1891
Synonyms: *Choanephora conjuncta* Couch 1925
Cunninghamia infundibulifera
Common name: Choanephora blight

10.1.1 Hazard identification

10.1.1.1 Description

The *Choanephora* species (*C. cucurbitarum* and *C. infundibulifera*) are fungi that cause fruit rots, and flower and leaf blights on a variety of plants. A typical infected leaf area may appear water-soaked with margins and leaf tips blighted.

10.1.1.2 Exporting country/s status

Choanephora cucurbitarum is reported from the Cook Islands, Fiji, Tonga, Vanuatu (NZFungi database 2011) and Samoa (Gerlach 1988).

Choanephora infundibulifera is reported from Fiji and Vanuatu (NZFungi database 2011)

10.1.1.3 New Zealand status

Neither *Choanephora cucurbitarum* nor *C. infundibulifera* are known to be present in New Zealand (NZFungi database; PPIN database, accessed March, 2011).

10.1.1.4 General geographic distribution

Choanephora cucurbitarum is widespread and has been reported from the following regions: Asia[19], Africa[20], North America, Central America, Caribbean and South America[21], Australia[22], French Polynesia, New Caledonia, Papua New Guinea, Solomon Islands. (CPC, 2011)

Choanephora infundibulifera has also been reported to be present in Burma (Thaung 2008) and India (Mitter and Tandon, 1937), Nepal and Korea (Farr and Rossman 2011) USA (Subba et al., 1990) and Nigeria (Williams, 1975; Oladiran 1980); as *C. conjuncta* from Japan, Georgia and Brunei Darussalam (Farr and Rossman 2011).

10.1.1.5 Commodity associations

Choanephora cucurbitarum and *C. infundibulifera* are reported from *Abelmoschus manihot* (island cabbage) (Pett 1995 unpublished- cited in Preston 1998).

10.1.1.6 Plant associations

Choanephora cucurbitarum has been reported as a pathogen on 48 plant species belonging to 37 genera within 17 families. The families affected are Amaranthaceae, Apocynaceae, Asteraceae, Brassicaceae, Caricaceae, Chenopodiaceae, Convolvulaceae, Cucurbitaceae, Euphorbiaceae, Fabaceae, Liliaceae, Malvaceae, Moraceae, Myrtaceae, Pedaliaceae, Poaceae and Solanaceae. The largest number of hosts affected, belong to the Fabaceae (nine genera, 12 species found) followed by Cucurbitaceae and Malvaceae with four genera each. (CPC 2011).

Hosts include:
Abelmoschus esculentus (okra); *Allium cepa* (onion); *Brassica* sp; *Capsicum* sp (sweet pepper and chilli); *Citrullus* sp. (melon); *Cucumis sativus* (cucumber); *Cucurbita maxima* (pumpkin); *Hibiscus* sp; *Ipomoea batatas* (sweet potato); *Latuca sativa* (lettuce); *Nasturtium officinalis*; *Nicotiana tabacum*; *Oryza sativa*; *Petunia* sp; *Phalaenopsis* sp; *Pinus* sp (pine tree); *Pisum sativum* (pea); *Solanum melongena* (eggplant); *Tagetes* sp (marigold); *Vicia faba* (broad bean); *Zea mays* (maize) (Farr and Rossman 2011).

Most of these host plants known to be susceptible to *Choanephora cucurbitarum* infection are grown in New Zealand and some are of economic importance to the country.

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19 Bangladesh, Brunei Darussalam, Cambodia, China, India, Indonesia, Java, Kalimantan, Iraq, Japan, Korea Republic, Malaysia, Oman, Pakistan, Singapore, Sri Lanka, Taiwan, Thailand

20 Benin, Congo, Egypt, Ghana, Guinea, Kenya, Malawi, Mauritius, Nigeria, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Zimbabwe

21 Connecticut, Delaware, Florida, Georgia, Hawaii, Iowa, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Texas, Virginia, West Virginia, Wisconsin; Cuba, Jamaica, Panama, Puerto Rico, Trinidad and Tobago, United States Virgin Islands; Brazil, Paraguay, Colombia, Peru, Venezuela

22 NSW, NT, QLD

Choanephora infundibulifera is reported from:
Abelmoschus esculentus (okra); *Dahlia variabilis*; *Glycine max* (soybean); *Gossypium hirsutum* (cotton); *Hibiscus* sp; *Jasminium* sp.; *Petunia* x *hybrida*; *Zinnia elegans*;

and from the following as *C. conjuncta*:
Abelmoschus esculentus; *Coffea arabica*; *Gossypium hirsutum*, *Hibiscus* sp; *Ipomoea purpurea*; *Petunia* sp.; *Pisum sativum* (pea) (Farr and Rossman 2011).

10.1.1.7 Plant parts affected

Both fungi species can causes disease on all plant stages: flowering, fruiting, post-harvest, pre-emergence, seedling and vegetative growing and all plant parts; pods, growing points, inflorescence, leaves, seeds, stems and whole plant. It is most aggressive under conditions of high temperature and humidity and when plants are under stress. They can also grow on dead plant material.

10.1.1.8 Potential for establishment and impacts

Choanephora cucurbitarum has been reported from New South Wales in Australia and *Choanephora infundibulifera* from Nepal and Korea. This indicates both species are potentially able to establish in parts of New Zealand. Both species can have unwanted impacts on plants of economic or environmental value to New Zealand.

10.1.1.9 Hazard identification conclusion

Given that:

- neither *Choanephora cucurbitarum* nor *C. infundibulifera* is known to be present in New Zealand;
- *Choanephora cucurbitarum* is reported from Cook Is, Fiji, Tonga and Vanuatu; and *C. infundibulifera* is reported from Fiji and Vanuatu;
- both species have been reported to be associated with island cabbage;
- both species are recorded as causing damage to plant species of economic, environmental and/or socio-cultural importance to New Zealand;

Both *Choanephora cucurbitarum* and *C. infundibulifera* are therefore considered to be hazards on island cabbage leaves in this analysis.

10.1.2 Risk assessment

10.1.2.1 Biology

Both species produces zygospores when (+) and (-) isolates are paired. Colonies characteristic of these two species grown on Potato-Carrot Agar at 25°C are very similar, however they can be distinguished from one another based on characteristics of the spores and vesicles (Kirk 1984). In *C. cucurbitarum* the sporangiospores measuring 18-27 x 9-12.6µm are light-coloured, then brown, often granular, ovoid to ellipsoid to almost triangular and have hyaline hair-like bristles 1 to 1.5 times as long as the sporangiospores. In *C. infundibulifera*, sporangiospores measuring 20-13 x 13-9µm are deep brown, ovoid, and not appendaged (Hesseltine 1953). These two species are also known to cause disease symptoms showing similar characteristics.

This section will be focussed on *Choanephora cucurbitarum* due to its polyphagous nature, worldwide distribution and because there is more information available for this species.

In *Capsicum* sp. (peppers), *Choanephora cucurbitarum* is a weak parasite; it colonises dead or dying tissue before it actively invades living tissue (Cerkaukas 2004).

Choanephora rot first attacks blossoms and then progresses into the developing fruit causing a wet rot at the blossom end. The pathogen usually sporulates profusely on the diseased part of the plant, especially on stems or fruits, appearing as spines with dark heads on the tissue surface. During infection, mycelium builds up on the affected plant tissues and enzymes are secreted to overcome the resistance of the healthy tissue, which is then invaded (Agrios, 1988). Under adverse conditions, *Choanephora cucurbitarum* produces thick-walled zygospores as the survival structures which germinate when temperatures and moisture conditions are favourable. The pathogen overwinters in the soil on dead plant tissue or as dormant spore structures (zygospores). The approximate time required for the production of mature zygospores on media was as follows: 35°C, 4 days; 30°C, 2 days; 25°C, 3 days; 20°C, 6 days; 15°C in darkness, 10 to 12 days. At 10°C no zygospores were produced (Barnett and Lilly 1956).

Abdel-Motaal et al. (2010) found that when flowers of Egyptian henbane (*Hyoscyamus muticus* L) were inoculated with *Choanephora cucurbitarum* they wilted after 3 days and necrotic symptoms begun to appear. The rotting extended to the remaining parts of the flower within 8 days and reached the stem and leaves after 10 days.

In another inoculation study on ice plant leaves (*Mesembryanthemum crystallinum*), water-soaked rot was observed on all of the inoculated leaves and stems 3–5 days after inoculation and within 7–10 days after inoculation, the inoculated plants were completely rotted (Kagiwada et al. 2010). *Choanephora cucurbitarum* has also been reported as a seed-borne pathogen on okra in Malaysia (Tai and Jamil 1975). Mehrotra and Mehrotra (1961) also reported seeing *Choanephora* species growing on a dead insect.

In Florida, Blazquez (1975) reported that sporulation on pepper and swamp hibiscus ceased soon after the ambient temperature dropped below 14.4°C and there was a rise in inoculum levels when the temperature rose above 14.4°C. The predominance of conidial heads or sporangia is governed largely by the relative humidity and its effect is magnified at temperatures above 25°C. A relative humidity approaching 100% favours the production of sporangia, while low humidity favours the formation of conidial heads (Barnett and Lilly 1955).

In India *Choanephora cucurbitarum* was found on *Solanum melongena* from August to November (12.1-33.4°C) and February to April (10.8-36.6°C). Its frequency was similar in almost all the months, when temperature was low to moderate with heavy rainfall and maximum relative humidity i.e. 87.3% (Adarsh 2010).

10.1.2.2 Entry assessment

Island cabbage is likely to be arriving as bundles of leaves. Obviously infected leaves would be expected to be detected and discarded during inspection and packaging. However the presence of the pathogen in leaves may not be detected in early infections. Infected leaves may show signs of wilting in about 3 days after infection and symptoms of soft rot may also be observed within 10 days after infection.

Given that:

- high relative humidity and rainfall favours field infection;
- most harvesting of island cabbage leaves would be done during periods of high rainfall and humidity and at temperatures above 25°C (i.e.: the summer months);
- it is possible for infection to occur just prior to harvesting and not show any visual symptoms during the transportation time;
- packaging and transportation to New Zealand may take less than 48 hours after harvest;
- the transportation period is shorter than the incubation period of the pathogen, but;
- it is expected that any leaves with obvious damage will be discarded at harvest and packaging;

The likelihood of entry of Choanephora cucurbitarum and C. infundibulifera are considered to be moderate.

10.1.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

Open markets can be subject to temperatures which are likely to go above the range of 10-14.4°C, especially during summer months. This could facilitate the rapid development of soft rot symptoms if leaves were infected prior to harvesting. Infected leaves may be disposed of on open compost or into the wider environment.

Upon disposal, the pathogen can sporulate when there is heavy rainfall, temperatures over 10-14.4°C and maximum relative humidity reaching about 87.3%, a situation which is likely in northern New Zealand. The spores released by these species are airborne and may therefore be carried over long distances to infect host species nearby. The polyphagous nature of this species increases its probability of exposure.

Given that:

- a number of known hosts of *Choanephora cucurbitarum* and *C. infundibulifera* are grown in New Zealand;
- most leaves will be cooked and eaten;
- but if leaves are infected these may be disposed of near suitable hosts which are common and widespread;
- the most susceptible region is likely to be the north of the North Island

The likelihood of exposure is considered to be moderate.

10.1.2.4 Assessment of establishment and spread

Choanephora cucurbitarum is widespread on many plant species. It can establish on any part of the plant tissue and reproduce sporangiospores for further infection within 10 days under favourable conditions. *Choanephora cucurbitarum* is known to have a wide host range and can parasitise any part of a plant that has been wounded or damaged by insects or mechanically. Wolf (1917) observed that insects carry the spores of the fungus from one flower to another. Wind, splashing water, movement of plants, physical contact with human hands and insects are known to be the major ways by which the spores are spread (Black 2001).

Since weather conditions such as temperatures above the range of 10-14.4°C, high relative humidity above 80% and consistent rainfall may take place in Auckland region over the summer months where most of the island cabbage is likely to enter, there is the likelihood of *Choanephora cucurbitarum* establishing and spreading in the northern part of the North Island.

Given that:

- the northern North Island is likely to be suitable for the establishment of *Choanephora cucurbitarum* and *C. infundibulifera*
- there are many known host plants and potential host plants available in New Zealand
- rotten leaves can produce numerous conidia and sporangiospores which are durable and mobile and can be spread by wind, insect, by water splash, by hand and by infected horticultural equipment.

The likelihood of establishment and spread in areas that are ecoclimatically suitable are considered to be high

10.1.2.5 Consequence assessment

Economic consequences

New Zealand grows a number of the food plants that have been identified as hosts to *Choanephora cucurbitarum*. Brassicas, onions, lettuce, cucurbits, capsicum and kumera are all grown in the Auckland region and north of Auckland and are likely to be affected by *Choanephora cucurbitarum*.

Engelhard (1987) reported that both pathogens caused 30% losses to cultivated hibiscus and green pepper in Florida. In southern Nigeria, Oladiran (1980) also reported that premature fruit abortion of cowpea due to *Choanephora cucurbitarum* infection was estimated at between 7% and 20%. It is assumed that losses in New Zealand are likely to be similar or less given that optimal conditions for infection will be less frequently experienced here than in tropical climates.

The economic consequences are considered to be low to moderate for the affected areas.

Environmental consequences

C. curcurbitarum is known to infect plants in a number of families (CPC, 2011). It has been recorded on genera related to *Phormium* species (flax), a common native plant (Beever *et al*. 2007). It has also been reported from genera related to native New Zealand spinach, *Tetragonia* sp. Beever *et al*. (2007) reported that as a virulent flower and leaf blight pathogen, *Choanephora cucurbitarum*, has a very wide host range and causes significant economic crop damage to related *Tetragonia* species in cultivation, indicating *T. tetragonioides* might also be susceptible if this pathogen arrived in New Zealand.

The environmental consequences are considered to be low to moderate in the affected areas.

Human health consequences
There has been no evidence found to suggest that *Choanephora cucurbitarum* or *C. infundibulifera* are likely to have any adverse effect on human health.

The consequences for human health are considered to be negligible.

Socio-cultural consequences
Domestic gardeners are likely to find their gardens will be adversely affected by the establishment of these fungi.

The socio-cultural consequences are considered to be low given the limited distribution that these fungi could achieve.

10.1.2.6 Risk estimation

In this risk analysis, the likelihood of entry is moderate for *Choanephora cucurbitarum* and/or *C. infundibulifera*, exposure is high, establishment is high, and potential economic consequences are low to moderate, potential environmental and socio-cultural consequences are low and potential consequences to human health are negligible

As a result the risk estimates for Choanephora cucurbitarum and/or C. infundibulifera are non-negligible and it is classified as a risk in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

10.1.3 Risk management options

No effective fungicide treatments are currently known for this disease. The risk estimate for *Choanephora cucurbitarum* or *C. infundibulifera* associated with island cabbage is non-negligible, therefore options for phytosanitary measures are considered and factors relating to efficacy are discussed.

10.1.3.1 Field management option (*C. cucurbitarum, C. infundibulifera*)

The following factors can influence the progression of disease and therefore may be taken in to consideration as part of a systems approach:

- Poor drainage contributes to higher humidity levels, which favours the disease
- The spacing between plants will affect the degree of air movement and drying
- Watering plants individually at the base helps to reduce leaf wetness
- Removing diseased plants as soon as possible assists in reducing field inoculum levels
- If infected leaves are removed and buried to reduce exposure to the environment. This is more effective in managing disease spread.

Any of the above may contribute to reducing the likelihood of disease, and together all would be more effective in managing disease in the absence of effective fungicides.

10.1.3.2 Post harvest washing, wiping and visual inspection option (*C. cucurbitarum, C. infundibulifera*)

A protocol for the washing, wiping and inspection of taro leaves for export is discussed in section 4.2.5. The biology of *C. cucurbitarum* and *C infundibulifera* indicates they are may be partially susceptible to this kind of management option. Specific points to consider include:

- *C. cucurbitarum* and *C. infundibulifera* are weak pathogens which rely on wounds to enable sporulation and infection
- Infection can establish in a leaf quite rapidly and may only become visible after a few days
- Unattached spores may be dislodged by water
- Spores are capable of recontaminating washed leaves

There is insufficient information to precisely measure the efficacy of the existing tarua and taro protocol or the likely island cabbage protocol. Potential modifications as discussed in 4.2.5 are likely to improve the efficacy.

Overall the biology of *C. cucurbitarum* and *C. infundibulifera* indicates that they will only be partially susceptible to a management system involving washing, wiping and visual inspection. Although the level of risk is considered to be at the low end of the scale, this management option on its own is not likely to be in proportion to the risk.

Modification to the protocol can improve the efficacy, and manage the risks associated with leaves that are showing visible symptoms of infection. If there are leaves that are infested and not showing symptoms, these will not be detected. Until the protocol is in place and can be tested, significant uncertainty remains.

10.1.3.3 Visual inspection at the border option (*C. cucurbitarum, C. infundibulifera*)

Fungi are intercepted at the border on a range of pathways including fresh leaves. Fungal lesions are not difficult to detect although few, small lesions within a consignment may be harder to detect. However, fungal infections that are in a latent, non-symptomless state will not be detected by visual inspection.

The biology of *C. cucurbitarum* and *C. infundibulifera* indicates that they will only be partially susceptible to this kind of management option.

10.1.3.4 Combination of options

Combining management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded, visual inspection will also provide information which will reduce the uncertainty about the efficacy provided by the management protocols.

10.2 *Oidium abelmoschi* – powdery mildew

Scientific name: *Oidium abelmoschi* Thum. 1878 (Erysiphales: Erysiphaceae, Anamorph, Hyphomycete)

Common name: powdery mildew

Oidium spp. have been recorded on island cabbage but not identified to species level. Therefore this risk analysis uses *Oidium abelmoschi* as a representative species of *Oidium* since it is found on closely related plant species such as Abelmoschus esculentus.

10.2.1 Hazard identification

10.2.1.1 Description

Oidium abelmoschi is a powdery mildew. Powdery mildews grow on the surface of leaves, fruit and herbaceous stems.

10.2.1.2 Exporting country/s status

Oidium abelmoschi is reported from Fiji (Landcare NZFungi 2010).

10.2.1.3 New Zealand status

Oidium abelmoschi is not known to be present in New Zealand. It is recorded as absent from the New Zealand region in Landcare NZFungi (2010). It is not recorded in PPIN (2010).

10.2.1.4 General geographic distribution

Oidium abelmoschi is reported from the Solomon Islands (Preston 1998; Landcare NZFungi 2010). It is also found in Africa, Asia, South America, Europe, and the Middle East (Farr and Rossman 2010).

10.2.1.5 Commodity association

Oidium species have been recorded on island cabbage (Preston 1998), but the species has not been reported. It is likely that it will be *O. abelmoschi*, and for the purposes of this Risk Analysis, this species will be used as an example of *Oidium* species.

10.2.1.6 Plant associations

Oidium abelmoschi has been recorded on *Abelmoschus esculentus* and *A. moschatus* (Landcare NZFungi 2010, Farr and Rossman 2010). *Hibiscus brasiliensis*, *H. cannabinus*, *H. esculentus*, *H. ficulneus*, and *H. sabdariffa* are also recorded as hosts (Farr and Rossman 2010).

10.2.1.7 Plant parts affected

Erysiphaceae (the family to which this pathogen belongs) infect green leaves, fruit and herbaceous stems (Cannon and Kirk 2007).

10.2.1.8 Potential for establishment and impact

O. abelmoschi has been reported from countries such as Finland, USSR, Yugoslavia and Romania and so it is assumed it is able to establish in New Zealand. Powdery mildews are known to damage their host plants and so *O. abelmoschi* is likely to have an unwanted impact in New Zealand.

10.2.1.9 Hazard identification conclusion

Given that *Oidium abelmoschi*:

- is not known to be present in New Zealand,
- is recorded on *A. esculentus* and *A. moschatus*, and *Oidium* spp. are recorded on *Abelmoschus manihot*;
- is in the family Erysiphaceace, which infects the leaves of host plants;
- is recorded from Fiji;
- *O. abelmoschi* is potentially able to establish and have unwanted impacts in New Zealand
-

it is considered to be a hazard in this risk analysis.

10.2.2 Risk assessment

10.2.2.1 Biology

The fungi causing powdery mildews are obligate parasites. They produce mycelium that grows on the surface of plant tissues. They obtain nutrients by sending haustoria (feeding organs) into the epidermal cells of the plant organs (Agrios 2005). The congener, *Oidium neolycopersici* does not rapidly kill the host tissues, without which it is unable to survive. The plant itself is not killed by the disease but is progressively weakened and its productivity gradually decreases (CPC 2010). *O. abelmoschi* is likely to have similar effects on its hosts.

The mycelium of powdery mildews produces short conidiophores on the plant surface. Each conidophore produces chains of conidia that are carried by air currents (Agrios 2005). Some *Oidium* species produce conidia singly (CPC 2010). Conidia of the congener *O. neolycopersici* are easily transported over long distances by air movements (CPC 2010). During unfavourable environmental conditions or lack of adequate nutrition in the host plant, powdery mildew fungi may reproduce sexually and develop a cleistothecium (an enclosed ascocarp) as the surviving structure, which may have one or a few asci inside (Agrios 2005), however for *O. abelmoschi* the teleomorph connection is unknown (Mycobank 2010).

Powdery mildew is common in cool or warm humid areas, but more common and severe in warm dry climates (Agrios 2005). High relative humidity may decrease the severity of infections caused by the congener *O. neolycopersici* (CPC 2010). Unlike many other fungal plant pathogens, *O. neolycopersici* does not require free water on plant surfaces to complete the infection process. Moreover, it was found that water may inhibit conidial germination (Mieslerova and Lebeda, 1999 in CPC 2010).

10.2.2.2 Entry assessment

The prevalence of *O. abelmoschi* on island cabbage leaves or in island cabbage growing areas is unknown.

Host plants may be infected with *Oidium* species without showing symptoms. Jacob and others (2008) found that plants sometimes showed no symptoms of disease until 15 days after inoculation with *O. neolycopersici*. Arrendo *et al.* (1996) recorded the development of disease symptoms caused by an *Oidium* sp. on tomato plants 7 days after inoculation, and the development of disease symptoms on tobacco plants 15 days after inoculation.

If this is the same for *O. abelmoschi,* infected island cabbage leaves may not show visible symptoms and the disease may avoid detection at inspection and enter New Zealand.

Given that:

- *Oidium neolycopersici* has been recorded showing no symptoms until 15 days after inoculation;
- *Oidium sp.* have been recorded showing no symptoms until 7 days or 15 days after inoculation;
- Similarly, *O. abelmoschi* is likely not to show symptoms for some time after infection, so infected leaves may not be detected, but;
- the prevalence of *O. abelmoschi* on island cabbage is not known, and;
- powdery mildews are more common and severe in warm dry areas, and;
- most island cabbage is likely to be harvested in the rainy season;

the likelihood of entry is considered to be low.

10.2.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

Conidia of powdery mildews are carried by air currents (Agrios 2005). It would be relatively easy for conidia on uneaten island cabbage leaves discarded into compost heaps to travel to new host plants growing nearby. Known hosts of *O. abelmoschi* include *Abelmoschus* and *Hibiscus* species. *Hibiscus* species are common in New Zealand, particularly in the north of the North Island above Auckland.

Given that:

- conidia are carried by air currents;
- some island cabbage leaves are likely to be discarded in compost heaps, although most are expected to be cooked or discarded with landfill waste;
- known hosts *Hibiscus* are common in New Zealand gardens north of Auckland;

the likelihood of exposure is considered to be moderate.

10.2.2.4 Assessment of establishment and spread

O. abelmoschi has been recorded in some countries with cooler climates, such as Finland (Farr and Rossman 2010) which suggests it could survive in much of New Zealand. However most countries where *O. abelmoschi* is recorded have warm or hot climates, such as Kenya, Morocco, Nigeria, and Fiji (Farr and Rossman 2010). While powdery mildews are common in cool or warm humid areas, they are more common and severe in warm dry climates (Agrios 2005). It is not known if they are common in cool dry areas.

It is most likely that *O. abelmoschi* would establish in the north of the North Island, above Auckland, as the climate is suitable. The five other *Oidium* species recorded in New Zealand in Landcare NZFungi (2010) are all recorded from the Auckland region.
Furthermore, in the north of the North Island its hosts *Hibiscus* species are common.

Its other hosts, *Abelmoschus* species, are not common in New Zealand. *Oidium* species are usually quite host specific, *O. chrysanthemi* is only recorded from *Chrysanthemum* and *Dendrathema* species by Farr and Rossman (2010). *O. hortensiae* is only recorded on *Hydrangea, Acanthus*, and *Kalanchoe* species. *O. oxalis* is only recorded from *Oxalis* species. *O. aureum* is recorded from *Fagus, Caladium* and *Tectona* spp. However *O. erysiphoides* is recorded 152 times, on 108 different genera. So it is likely that *O. abelmoschi* is quite host specific, but this is not certain.

Given that:

- the north of the North Island is suitable for *Oidium* species, with 5 species already reported from there, and;
- *Hibiscus* species are common in the north of the North Island

the likelihood of establishment in parts of New Zealand is high.

Conidia of *O. neolycopersici* are easily transported over long distances by air currents (CPC 2010) and conidia of *O. abelmoschi* are likely to be similarly transported long distances. There would be no barriers to the spread of these conidia so *O. abelmoschi* would spread freely within New Zealand. As mentioned above, conditions are likely to be most suitable for them in the north of the North Island.

Given that:

- Conidia of *O. abelmoschi* are likely to be easily transported over long distances by air currents;
- there would be no barriers to the spread of these conidia;
- conditions would be most suitable for *O. abelmoschi* in the north of the North Island;

the likelihood of O. abelmoschi spreading within parts of New Zealand is high.

10.2.2.5 Consequence assessment

Economic consequences

Powdery mildews are common, widespread and ever present among crop plants and ornamentals. The total losses, in plant growth and crop yield caused each year on all crops, probably surpasses the losses caused by any other single type of plant disease. Powdery mildews seldom kill their hosts but utilize their nutrients, reduce photosynthesis, increase respiration and transpiration, impair their growth, and reduce yields, sometimes by as much as 20-40 % (Agrios 2005).

Known hosts of *O. abelmoschi* are *Abelmoschus* and *Hibiscus* species. *Abelmoschus* spp. are not common in New Zealand. *Hibiscus* plants are sold in nurseries so there may be some limited adverse impact on this industry if *O. abelmoschi* infected nursery plants.

The potential economic consequences are considered to be very low.

Environmental consequences
New Zealand has two species of native *Hibiscus*, which are also found in the Pacific Islands. Neither *H. trionum* nor *H. diversifolia* appear to be listed as hosts for *O. abelmoschi* (NZFungi 2011; Farr and Rossman 2011). It seems unlikely this fungus will have an impact of the natural environment of New Zealand.

The potential environmental consequences are considered to be negligible.

Human health consequences
There are no known human health consequences.

Socio-cultural consequences
Hibiscus species are grown in home gardens, particularly in the far North where they are so much of a feature there that the coast is known as the Hibiscus Coast.

The potential socio-cultural consequences are considered to be very low.

10.2.2.6 Risk estimation

The likelihood of entry is low, the likelihood of exposure is moderate, and the likelihood of establishment and spread in parts of New Zealand is high. The potential impact within New Zealand is very low.

As a result the risk estimate for Oidium abelmoschi is non-negligible and it is classified as a hazard in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

10.2.3 Risk management options

As the risk estimation for *O. abelmoschi* is non-negligible options for phytosanitary measures are considered and factors relating to efficacy are discussed.

10.2.3.1 Post harvest cleaning and visual inspection option (*O. abelmoschi*)

A protocol for the washing, wiping and inspection of taro leaves for export is discussed in section 4.2.5. The biology of *O. abelmoschi* indicates it may be susceptible to this kind of management option. Specific points to consider include:

- Fungi causing powdery mildews are obligate parasites
- *Oidum* species can be symptomless for several days
- *Oidium* species are more severe in warm, dry conditions

- Water is may inhibit conidial germination

There is insufficient information available to precisely measure the efficacy of the existing taro and tarua protocol or the likely island cabbage protocol. Potential modifications as discussed in 4.2.5 are likely to improve the efficacy.

Overall the biology of *O. abelmoschi* indicates that it will be susceptible to a management system involving washing, wiping and visual inspection. Although the level of risk is considered to be at the low end of the scale, this management option on its own is not likely to be in proportion to the risk.

Modifications to the protocol can improve efficacy, and with modifications this management option is likely to manage the risks associated with leaves showing visible symptoms of infection. If there are leaves that are infested and not showing symptoms, these will not be detected. Until the protocol is in place and can be tested significant uncertainty remains.

10.2.3.2 Visual inspection at the border option (*O. abelmoschi*)

Fungal lesions are not difficult to detect although few, small lesions within a consignment may be harder to detect. However, fungal infections that are in a latent, non-symptomless state will not be detected by visual inspection.

The biology of *O. abelmoschi* indicates that it will only be partially susceptible to this kind of management option.

10.2.3.3 Combination of options

Combining the two management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded, visual inspection will also provide information which will reduce the uncertainty about the efficacy provided by the washing, wiping and inspection protocol.

10.2.3.4 No measures option

Taking into account the non-negligible but very low impacts of establishment of this species, and the lack of a fully effective risk management option, the option of no risk management is included.

10.3 *Pseudocercospora abelmoschi* – leaf spot

Scientific name: *Pseudocercospora abelmoschi* (Ellis & Everh) Deighton, 1976 (hyphomycete)
Other relevant scientific names: *Cercospora abelmoschi* Ellis & Everh. [stat. anam], (1893). *Cercospora hibisci* Tracy & Earle [stat. anam.], (1895).
Common name: leaf spot

10.3.1 Hazard identification

10.3.1.1 Description

Pseudocercospora abelmoschi is a mould that causes a leaf blotch or diffuse fungal blight.

10.3.1.2 Exporting country/s status

P. abelmoschi is recorded from: Fiji, Samoa, Tonga and Vanuatu (Preston 1998).

10.3.1.3 New Zealand status

P. abelmoschi is not known to be present in New Zealand. Not recorded in: PPIN 2010; Recorded as "absent from region" NZFungi 2010

10.3.1.4 General geographic distribution

P. abelmoschi has a mostly tropical-subtropical distribution and is recorded from the Solomon Is. (Preston 1998). It is reported from parts of Africa[23], Asia[24], South East Asia[25], Yemen, Italy, USA, West Indies[26], Venezuela, New Caledonia (Kirk 1980) and Western Australia (Biosecurity Australia 2010).

10.3.1.5 Commodity association

P. abelmoschi is reported from island cabbage (*Abelmoschus manihot*) (NZFungi 2011; Preston 1998).

10.3.1.6 Plant associations

P. abelmoschi is also reported from *Hibiscus cannabinus* L. (*H. aspera* Hook.), *H. esculentus* L. (*Abelmoschus esculentus* [L.] Moensch.), *H. sabdariffa* L., *H. syriacus* L. (Mycobank Oct 2010), *H. rosa-sinensis, H. tiliaceus* and *Dioscorea alata* (purple yam) (Farr and Rossman 2011).

10.3.1.7 Plant parts affected

P. abelmoschi causes a leaf mould on its hosts. Sooty brown conidiophores occur in dense patches. Sometimes leaves may roll, wilt and drop off the plant (Waller and Sutton 1979).

23 Gabon, Ghana, Guinea, Kenya, Malawi, Nigeria, Sierra Leone, Sudan, Tanzania, Togo, Uganda
24 Burma, India, Nepal, Pakistan
25 Brunei, Malaya, New Hebrides, Philippines, Sarawak, Taiwan
26 Antigua, Grenada, Jamaica, St. Vincent, Trinidad

10.3.1.8 Potential for establishment and impact

The distribution of *P. abelmoschi* is mostly subtropical-tropical although it is reported from countries with areas of similarity to New Zealand. *P. abelmoschi* is potentially able to establish and is likely to affect *Hibiscus* species of which there are native species in New Zealand.

10.3.1.9 Hazard identification conclusion

Given that *P. abelmoschi*

- is associated with the leaves of island cabbage;
- is not recorded from New Zealand;
- is present in Fiji, Samoa, Tonga and Vanuatu;
- is potentially able to establish and have unwanted impacts;

P. abelmoschi is therefore considered a hazard on island cabbage leaves in this risk analysis.

10.3.2 Risk assessment

10.3.2.1 Biology

Symptoms
Indistinct blotches usually occur, mostly on mature leaves (Ecoport 1999). Leaf spots can be present or absent, circular or irregular. On the upper surface of the leaf these are brown with a blackish-brown margin and on the underside the spots are pale brown to brown. Colonies are often effuse but vein-limited, hairy, brown, olive-brown or brownish-black and predominantly on the underside of the leaf (Kirk 1980). Severely affected leaves may become chlorotic, rolled, wilted and fall from the plant (Ecoport 1999).

The pathogen
Conidiophores are pale brown to brown, simple and rarely branched (Kirk 1980) and rise in a dense group from a fascicle within a pore in the leaf surface. Conidia (asexual, non-motile spores) develop at the tips of the conidiophores and are pale brown. Waller and Sutton (1979) state stromata are 20 to 30µm diameter. However Hseih and Goh (1990 cited in Mycobank 2011) state stromata lacking or small and Kirk (1980) doesn't mention them.

P. abelmoschi is assumed to be similar in its biology to *P. fuligena*, which is present both in New Zealand and in the Pacific Islands (NZFungi 2011, Farr and Rossman 2011, PPIN 2011). Conidia of *P. fuligena* germinate in free water at a high relative humidity (about 90%). Under experimental conditions with an optimal temperature of 28 ^{o}C, germination took about 48 hours. Germinated conidia penetrated pores on the tomato leaf surface within 120 hours of incubation. Lesions appeared 6 days after inoculation and mature conidiophores and conidia were present after 12 days (Wang 1996).

In the field dew, rainfall or fog may provide favourable conditions for germination, penetration, infection and sporulation of *P. fuligena* (CPC 2010), and potentially also for *P. abelmoschi.*

P. abelmoschi is reported to have survived on infected leaves for 6 weeks buried under 10cm of soil or for 16 weeks on the soil surface (cited in: Kirk 1980).

Transmission
P. abelmoschi conidia are airborne (Waller and Sutton 1979), and are the only form of inoculum (Ecoport 1999). New infections are thought to develop from conidia being blown from infected host plants and crop debris onto new hosts (Ecoport 1999).

10.3.2.2 Entry assessment

There are several records of *P. abelmoschi* on *A. manihot* leaves from Fiji, Samoa, Tonga and Vanuatu (NZFungi 2011) and so it is assumed that it is prevalent in the island cabbage growing areas. It is assumed that *P abelmoschi* will behave in a similar way to *P. fuligena*. As there can be about 6 days before leaf spot symptoms of *P. fuligena* appear (Wang 1996) it is reasonable to assume there would be leaves infected with *P. abelmoschi* harvested. Leaves are likely to be packaged as bundles, which is a protective environment and makes any initial symptoms difficult to detect. Export to New Zealand is likely to be the same day as harvest or at least within 36 hours, as island cabbage leaves are highly perishable. Flights from the Pacific to New Zealand take about 4 hours.

Given that:

- it is expected damaged leaves will be culled prior to packaging, but;
- *P. abelmoschi* may not exhibit symptoms at harvest;
- there will be minimal delay between harvest and export because of perishability;
- and leaf bundles make detection more difficult;

The likelihood of entry is considered to be moderate.

10.3.2.3 Exposure assessment

Island cabbage is destined mainly for Auckland Polynesian outdoor markets but may go to other shops and cities in New Zealand. The expected end use of island cabbage leaves is that they will be cooked and consumed domestically within 2-3 days. This is in contrast to most imported fresh fruit, which is usually consumed uncooked. Additionally, there is generally no trimmed (unavoidable) waste (*e.g.* stems, peel, seeds or cores). Correspondingly, the likelihood of exposure is likely to be less than for imported fresh fruit.

If the leaves have become less than optimal for cooking and consuming, it is unlikely that island cabbage leaves would be disposed of along roadsides, but it is more likely they will be disposed of domestically. This may be *via* rubbish bins, closed or open compost, or discarded within the garden. Unsold market surplus may be dumped into commercial rubbish bins. Rubbish may be buried in landfill, or burned, or composted. Only uncooked leaves discarded on to open compost or the wider environment are likely to result in exposure.

It is assumed that a couple of yellow or brown spots on a leaf or two will not be enough reason to discard the leaves. These are likely to be cooked and therefore remove the opportunity of exposure. However a significant number of spots are likely to mean the leaf or leaves are discarded. Those that are exposed to the environment may have the opportunity to produce conidia when the conditions are favourable. As conidia are air-borne they could be carried to a new host. *Hibiscus* species are abundant ornamental plants in the Auckland region and are hosts for *P. abelmoschi*.

Given that:

- Leaves with obvious damage will be discarded;
- A small proportion of these are likely to be exposed to the environment;

- Conidia dispersal is largely air-borne;
- Suitable hosts are found throughout the region;

The likelihood of exposure is considered to be moderate.

10.3.2.4 Assessment of establishment and spread

The distribution of *P. abelmoschi* indicates it is mostly a tropical-subtropical species, although countries such as India, Korea and Colombia have temperate upland regions. The climate of Auckland and northern New Zealand are suitable for the development of *P. abelmoschi* conidia. Germination and infection by *P. abelmoschi* is likely to require a combination of high temperatures and high humidity if it is similar to *P. fuligena* (*P. fuligena* -Wang 1996) which is not frequent but does occur occasionally. It is assumed that *P. abelmoschi* will behave similarly to other *Pseudocercospora* species, *e.g.*.: *P. fuligena* and therefore is likely to survive long enough for conditions to become favourable for its development. The narrow host range and climatic requirements indicate it would have a restricted distribution in New Zealand.

Given that:

- The climate of Auckland and northern New Zealand is suitable;
- Hosts are abundant in Auckland;
- *P. abelmoschi* can form stromata and therefore is assumed to be able to survive unfavourable periods;

The likelihood of establishment and spread is considered to be low and within a limited area.

10.3.2.5 Consequence assessment

Economic consequences

New Zealand does not grow the crops commercially (island cabbage and okra) that *P. abelmoschi* infects. *Hibiscus* species such as *H. rosa-sinensis* are ornamentals that feature commonly in the Auckland area and are grown by nurseries. *P. abelmoschi* is likely to have a very small, localised impact on growers and sellers of these plants, who may well be controlling for other similar fungal species. It has been reported from *Dioscorea alata* (purple yam) so it is possible it may affect other *Dioscorea* species (*e.g. D. communis* is grown in New Zealand).

The potential economic consequences are considered to be very low

Environmental consequences

New Zealand has two species of native *Hibiscus*, which are also found in the Pacific Islands. Neither *H. trionum* nor *H. diversifolia* appear to be listed as hosts for *P. abelmoschi* (NZFungi 2011; Farr and Rossman 2011). It seems unlikely this fungus will have an impact of the natural environment of New Zealand.

The potential environmental consequences are considered to be negligible

Human health consequences

There are no known reports of any impacts upon human health.

Socio-cultural consequences
This fungus is likely to have a very minor and localised impact on ornamental hibiscus in home gardens and amenity plantings.

The potential socio-cultural consequences within New Zealand are considered to be very low.

10.3.2.6 Risk estimation

The likelihood of entry is moderate and exposure is high, the likelihood of establishment and spread is low. The potential economic and environmental consequences are very low.

As a result the risk estimate for Pseudocercospora abelmoschi is non negligible and it is classified as a risk organism in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

10.3.3 Risk management options

As the risk estimate for *P. abelmoschi* is non-negligible options for phytosanitary measures are considered and factors relating to efficacy are discussed.

10.3.3.1 Washing, wiping and visual inspection option (*P. abelmoschi*)

A protocol for the washing, wiping and inspection of taro leaves for export is discussed in section 4.2.5. The biology of *P. abelmoschi* indicates it may be partially susceptible to this kind of management option. Specific points to consider include:

- *P. abelmoschi* infection favours warmth and high humidity
- Conidia germinate in free water and are capable of recontaminating leaves

There is insufficient information to precisely measure the efficacy of the existing tarua and taro protocol or the likely island cabbage protocol. Potential modifications as discussed in 4.2.5 are likely to improve the efficacy.

Overall the biology of *P. abelmoschi* indicates that it will only be partially susceptible to a management system involving washing, wiping and visual inspection. Although the level of risk is considered to be at the low end of the scale, this management option on its own is not likely to be in proportion to the risk.

Modifications to the protocol can improve efficacy, and with modifications this management option is likely to manage the risks associated with leaves showing visible symptoms of infection. If there are leaves that are infested and not showing symptoms, these will not be detected. Until the protocol is in place and can be tested significant uncertainty remains

10.3.3.2 Visual inspection at the border option (*P. abelmoschi*)

Fungal lesions are not difficult to detect although few, small lesions within a consignment may be harder to detect. However, fungal infections that are in a latent, non-symptomless state will not be detected by visual inspection.

The biology of *P. abelmoschi* indicates that it will only be partially susceptible to this kind of management option.

10.3.3.3 Combination of options

Combining the two management options will provide a higher degree of efficacy than either option alone. If any detected organisms are appropriately identified and recorded, visual inspection will also provide information which will reduce the uncertainty about the efficacy provided by the management protocols.

10.3.3.4 No measures option

Taking into account the non-negligible but very low impacts of establishment of this species, and the lack of a fully effective risk management option, the option of no risk management is included.

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Appendix 1 Hazard identification of organisms associated with island cabbage

This appendix is the result of the process described in section 3.1

Key to groups: A= mobile cryptic small; B= sessile cryptic small; C= internal feeders; D= mobile big obvious; E= hitchhikers; F= fungal pathogens dispersed by wind/water; G= systemic pathogens
Presence in exporting countries: NRF = No records found
Unwanted or controlled: UOR= unwanted organisms register
Risk column: Na= not assessed. Y = yes (species assessed in the risk analysis).

Invertebrates

Scientific name	Common name	Group	Presence in NZ	Association with Island cabbage-ref	Presence in exporting countries	Vector?	Unwanted or controlled?	Potential for establish-ment and impact	Hazard?	Risk?
Arthropoda: Arachnida: Trombidiformes										
Tetranychus lambi (Tetranychidae)	spider mite	AB	Y: Zhang et al 2002; Sirvid et al (2010)	Migeon & Dorkeld 2006-2010	Y for all: Migeon & Dorkeld 2006-2010			y	n	Na
Tetranychus marianae (Tetranychidae)	Mariana mite	AB	N: Zhang et al 2002; Sirvid et al (2010)	BA cite Ecoport 2000	Cook Is. NRF; Fiji BA cite CABI 2007; Samoa NRF; Tonga NRF; Vanuatu NRF			y	n	Na
Tetranychus spp.	Spider mites	AB						y	y	
Arthropoda: Insecta: Coleoptera										
Adoretus versutus (Scarabaeidae)	rose beetle	D	N: Not in Leschen et al 2003, Kuschel 1990, PPIN 2010	Stout 1982	Cook Is. Waterhouse 1997, CIBD 2010; Fiji Waterhouse 1997; Samoa Stout 1982; Waterhouse 1997; Tonga Waterhouse 1997; Vanuatu Waterhouse 1997			y	**Y**	n
Anadastus albertisi (Languriidae)	beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Apirocalus cornutus (Curculionidae)	weevil	D	N: not in Leschen et al 2003, PPIN 2010	French 2006	Cook Is. NRF; Fiji Evenhuis 2007; Samoa NRF; Tonga NRF; Vanuatu NRF			y	**Y**	Na
Apirocalus ebrius ebrius (Curculionidae)	weevil		N: not in May B 1993, Leschen et al 2003, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji as A. cornutus ebrius in Evenhuis 2007; Samoa NRF; Tonga NRF; Vanuatu NRF;				n	Na

Scientific name	Common name	Group	Presence in NZ	Association with Island cabbage-ref	Presence in exporting countries	Vector?	Unwanted or controlled?	Potential for establish-ment and impact	Hazard?	Risk?
Apirocalus terrestris terrestris (Curculionidae)	weevil		N: not in Leschen et al 2003, PPIN 2010	French 2006	NRF				n	Na
Arsipoda tenimberensis (Chrysomelidae)	leaf beetle	A	N: not in Leschen et al 2003, PPIN 2010	Stout 1982	Cook Is. NRF; Fiji NRF; Samoa Stout 1982 (Fa'anunu 2009); Tonga NRF; Vanuatu NRF			y	**Y**	Na
Aspidiomorpha adhearens (Chrysomelidae)	tortoise beetle		N: not in Leschen et al 2003, PPIN 2010	French 2006	NRF				n	Na
Aspidiomorpha australasiae (Chrysomelidae)	tortoise beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Aspidiomorpha miliaris (Chrysomelidae)	tortoise beetle		N: not in Leschen et al 2003, PPIN 2010	French 2006	NRF				n	Na
Aspidiomorpha punctum (Chrysomelidae)	tortoise beetle		N: not in Leschen et al 2003, PPIN 2010	French 2006	NRF				n	Na
Aspidiomorpha quadriradiata (Chrysomelidae)	tortoise beetle		N: not in Leschen et al 2003, PPIN 2010	French 2006	NRF				n	Na
Aspidiomorpha socia (Chrysomelidae)	tortoise beetle		N: not in Leschen et al 2003, PPIN 2010	French 2006	NRF				n	Na
Aspidiomorpha testudinaria (Chrysomelidae)	tortoise beetle		N: not in Leschen et al 2003, PPIN 2010	French 2006	NRF				n	Na
Cassena intermedia (Chrysomelidae)	shot-hole beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Cassena papuana (Galerucidae)			N: not in Leschen et al 2003, PPIN 2010	French 2006	NRF				n	Na
Cassena sp. (Chrysomelidae)	shot-hole beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Cleoporus hibisci (Chrysomelidae)			N: not in Leschen et al 2003, PPIN 2010 under either spelling	Preston 1998	NRF				n	Na
Coelophora inaequalis (Coccinellidae)	variable ladybird		Y: PPIN 2010; Flynn (unpubl)	Maddison 1993	Cook Is. Maddison 1993; Fiji Maddison 1993; Samoa Maddison 1993; Tonga Maddison 1993; Vanuatu NRF				n	Na
Elytrurus griseus (Curculionidae)	weevil	D	N: not in Leschen et al 2003, PPIN 2010	Preston 1998; Lever 1947	Cook Is. NRF; Fiji Preston 1998, Lever 1947; Samoa NRF; Tonga NRF; Vanuatu NRF			y	**Y**	Na
Epilachna signatipennis	beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF			y	n	Na

Scientific name	Common name	Group	Presence in NZ	Association with Island cabbage-ref	Presence in exporting countries	Vector?	Unwanted or controlled?	Potential for establish-ment and impact	Hazard?	Risk?
(Coccinellidae)										
Glenea aluensis (Cerambycidae)	beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Harmonia arcuata (Coccinellidae)	beetle	D	N: not in PPIN 2010; Flynn(unpubl)	Maddison 1993	Cook Is. Maddison 1993; Fiji Maddison 1993; Samoa Maddison 1993; Tonga NRF; Vanuatu NRF			y	**Y**	Na
Micraspis lineola (Coccinellidae)	beetle	D	N: not in PPIN 2010; Flynn(unpubl)	Maddison 1993	Cook Is. NRF; Fiji Maddison 1993; Samoa NRF; Tonga Maddison 1993; Vanuatu NRF			y	**Y**	Na
Monolepta sp. (Chrysomelidae)	beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji -NRF; Samoa NRF; Tonga NRF; Vanuatu NRF				n	Na
Nisotra (=*Podagrica*) *basselae* (Chrysomelidae)	Aibika flea beetle/shot hole beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Nisotra (=*Podagrica*) *obliterata* (Chrysomelidae)	Aibika flea beetle/shot hole beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Oribius cruciatus (Curculionidae)	weevil		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Oribius improvidus (Curculionidae)	weevil		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Oribius inimicus (Curculionidae)	weevil		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Oribius spp. (Curculionidae)	weevil		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Platyacus ruralis (Curculionidae)	weevil		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Rhyparidella sobrina (Chrysomelidae)	beetle		N: not in Leschen et al 2003, PPIN 2010	Preston 1998	NRF				n	Na
Sphaerorhinus aberrans (Curculionidae)	weevil	D	N: not in Leschen et al 2003, PPIN 2010	Englberger & Foliaki 1992	Cook Is. NRF; Fiji NRF; Samoa NRF; Tonga Englberger & Foliaki 1992; Vanuatu NRF			y	**Y**	Na
Arthropoda: Insecta: Hemiptera										
Aleurodicus dispersus (Aleyrodidae)	spiralling whitefly	AB	N: PPIN 2010	Preston 1998	Cook Is. Waterhouse 1997; Fiji Waterhouse 1997; Samoa Waterhouse 1997, de Barro et al 1997; Tonga Waterhouse 1997; Vanuatu NRF			y	**Y**	Y
Amblypelta cocophaga (Coreidae)	bug	BD	N: not in Lariviere & Larochelle 2004, PPIN 2010	FPI 2010	Cook Is. NRF; Fiji Evenhuis & Polhemus 2008; Samoa NRF; Tonga NRF; Vanuatu Brown 1958			y	**Y**	N
Amblypelta costalis	bug		N: not in Lariviere & Larochelle	French 2006	NRF				n	Na

Scientific name	Common name	Group	Presence in NZ	Association with Island cabbage-ref	Presence in exporting countries	Vector?	Unwanted or controlled?	Potential for establish-ment and impact	Hazard?	Risk?
szentivanyyi (Coreidae)			2004, PPIN 2010							
Amblypelta gallegonis (Coreidae)	bug		N: not in Lariviere & Larochelle 2004, PPIN 2010	French 2006	NRF				n	Na
Amblypelta lutescens papuensis (Coreidae)	Aibika tip wilt bug		N: not in Lariviere & Larochelle 2004, PPIN 2010	Preston 1998	NRF				n	Na
Amblypelta theobromae (Coreidae)	bug		N: not in Lariviere & Larochelle 2004, PPIN 2010	French 2006	NRF				n	Na
Amrasca devastans (Cicadellidae)	Aibika jassid		N: not in Lariviere 2005, PPIN 2010	Preston 1998	NRF				n	Na
Aphis craccivora (Aphididae)	cowpea aphid		Y: PPIN 2010	Preston 1998	Cook Is. Waterhouse 1997; Fiji Waterhouse 1997; Samoa Waterhouse 1997; Tonga Waterhouse 1997; Vanuatu Waterhouse 1997	y		y	**n**	**n**
Aphis fabae (Aphididae)	bean aphid	A	Y: PPIN 2010	Englberger & Foliaki 1992	Cook Is. NRF; Fiji NRF; Samoa NRF; Tonga Englberger & Foliaki 1992; Vanuatu NRF	y		y	**Y**	Y
Aphis gossypii (Aphididae)	cotton aphid		Y: PPIN 2010	Preston 1998; Sunde 1987	Cook Is. Waterhouse 1997; Fiji Waterhouse 1997; Samoa Waterhouse 1997; Tonga Waterhouse 1997; Vanuatu Waterhouse 1997	y	not officially controlled		n	n
Bemisia tabaci (Nauru biotype) (Aleyrodidae)	tobacco whitefly	AB	N: not in PPIN 2010	Englberger & Foliaki 1992 (Nauru strain in Tonga)	Cook Is. NRF; Fiji de Barro et al 1997; Samoa de Barro et al 1997; Tonga de Barro et al 1997; Vanuatu NRF	y		y	**Y**	Na
Brachylybas variegatus (Coreidae)	brown coreid bug	D	N: not in Lariviere & Larochelle 2004, PPIN 2010	Englberger & Foliaki 1992	Cook Is. NRF; Fiji Evenhuis & Polhemus 2008; Samoa NRF; Tonga Englberger & Foliaki 1992; Vanuatu NRF			y	**Y**	Na
Caridophthalmus sp. (Pentatomidae)	bug		N: not in Lariviere & Larochelle 2004, PPIN 2010	Preston 1998	NRF				n	Na
Cicadella sp. (Cicadellidae)			N: not in Lariviere 2005, PPIN 2010	Preston 1998	NRF				n	Na
Coccus capparidis (Coccidae)	tortoise scale	AB	N: Scalenet 2010	Williams & Watson 1990	Cook Is. NRF; Fiji NRF; Samoa Scalenet 2010; Tonga Scalenet 2010; Vanuatu NRF			y	**Y**	Na
Coccus hesperidium (Coccidae)	soft brown scale		Y: Hodgson & Henderson 2000.	French 2006	Cook Is. Scalenet 2010; Fiji Wilson & Evenhuis 2008; Samoa Kami & Miller 1998; Tonga Scalenet 2010; Vanuatu Scalenet 2010				n	Na
Colgar chlorospilum (Flatidae)	flatid planthopper		N: not in Lariviere 2005, PPIN 2010	Preston 1998	NRF				n	Na
Colgar missior (Flatidae)	flatid planthopper		N: not in Lariviere 2005, PPIN 2010	Preston 1998	NRF			y	n	Na

Scientific name	Common name	Group	Presence in NZ	Association with Island cabbage-ref	Presence in exporting countries	Vector?	Unwanted or controlled?	Potential for establish-ment and impact	Hazard?	Risk?
Colgar tricolor (Flatidae)	flatid planthopper	D	N: not in Lariviere 2005, PPIN 2010	Stout 1982	Cook Is. NRF; Fiji Stout 1982; Samoa NRF; Tonga Stout 1982; Vanuatu NRF			y	**Y**	Na
Dysdercus (*Paradysdercus*) *cingulatus* (Pyrrhocoridae)	red cotton bug		N: not in Lariviere 2005, PPIN 2010	FPI 2010	Cook Is. NRF; Fiji Evenhuis & Polhemus 2008; AFD 2010; Samoa NRF; Tonga NRF; Vanuatu Waterhouse 1997				n	Na
Dysdercus sp. (Pyrrhocoridae)	bug		N: not in Lariviere 2005, PPIN 2010	Preston 1998	NRF				n	Na
Empoasca quadripunctata (Cicadellidae)	Aibika jassid	AB	N: not in Lariviere 2005, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Wilson & Evenhuis 2008; Samoa NRF; Tonga NRF; Vanuatu NRF			y	**Y**	Na
Euricania disciguttata (Ricaniidae)	ricaniid planthopper	D	N: not in PPIN 2010, BUGZ 2010	Stout 1982	For all except Vanuatu- Stout 1982			y	**Y**	Na
Lampromicra sp. (Scutelleridae)	jewel bug	D	N: not in PPIN 2010, BUGZ 2010	Preston 1998	Cook Is. NRF; Fiji NRF; Samoa NRF; Tonga NRF; Vanuatu AFD 2010			y	**Y**	Na
Leptoglossus gonagra (Coreidae)	squash bug/ passionvine bug	D	N: not in Lariviere & Larochelle 2004, PPIN 2010	Preston 1998	Cook Is. Waterhouse 1997; Fiji AFD 2010, CPC 2010; Samoa Kami & Miller 1998, Waterhouse 1997; Tonga Cottrell- Dormer 1941; Vanuatu Waterhouse 1997			y	**Y**	Na
Maconellicoccus hirsutus (Pseudococcidae)	hibiscus mealybug	AB	N: not in Cox 1987, PPIN 2010	Williams & Watson 1988a	Cook Is. NRF; Fiji NRF; Samoa NRF; Tonga Williams & Watson 1988a; Vanuatu NRF			y	**Y**	Y
Myzus persicae (Aphididae)	green peach aphid		Y: PPIN 2010	Stout 1982	Cook Is. Waterhouse 1997; Fiji Stout 1982, Waterhouse 1997; Samoa Waterhouse 1997; Tonga Stout 1982; Vanuatu NRF	y		y	n	n
Nezara viridula (Pentatomidae)	bug		Y: Lariviere & Larochelle 2004	Preston 1998	Cook Is. Waterhouse 1997; Fiji Waterhouse 1997; Samoa MAFBNZ 2008 Citrus Samoa RA; Tonga Waterhouse 1997; Vanuatu Waterhouse 1997			y	n	Na
Nipaecoccus viridis (Pseudococcidae)	spherical mealybug		N: not in Cox 1987, PPIN 2010	Preston 1998	NRF				n	Na
Nysius pacificus (Lygaeidae)	bug	D	N: not in Lariviere & Larochelle 2004; not in PPIN 2010	Preston 1998 (as *Nysius* sp.)	Cook Is. NRF; Fiji AFD 2010; Samoa Kami and Miller 1998; Tonga NRF; Vanuatu AFD 2010			y	**Y**	Na
Oxycarenus (*Oxycarenus*) *luctuosus* (Lygaeidae)	cottonseed bug		N: not in Lariviere & Larochelle 2004, PPIN 2010	PestNet 2010	Cook Is. PestNet, CIBD; Fiji NRF; Samoa NRF; Tonga NRF; Vanuatu NRF				n	Na
Oxycarenus bicolor (Lygaeidae)	bug		N: not in Lariviere & Larochelle 2004, PPIN 2010	Preston 1998	NRF				n	Na
Paraputo leveri (Pseudococcidae)	mealybug		N: PPIN 2010	Fa'anunu 2009	Cook Is. NRF; Fiji Williams 2005; Samoa Williams 2005; Tonga Fa'anunu 2009; Vanuatu Williams 2005				n	Na

Scientific name	Common name	Group	Presence in NZ	Association with Island cabbage-ref	Presence in exporting countries	Vector?	Unwanted or controlled?	Potential for establish-ment and impact	Hazard?	Risk?
Parasaissetia nigra (Coccidae)	black scale		Y: Hodgson & Henderson 2000.	Preston 1998	Cook Is. Scalenet 2010; Fiji Scalenet 2010, Wilson & Evenhuis 2008; Samoa Stout 1982, Kami & Miller 1998; Tonga Englberger & Foliaki 1992; Vanuatu Scalenet 2010			y	n	Na
Peggioga sp. (Tropiduchidae)	planthopper		N: not in Lariviere 2005, PPIN 2010	Preston 1998	NRF				n	Na
Phaenacantha sp. (Colobathristidae)	linear bug	D	N: not in Lariviere & Larochelle 2004, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji *P. pacifica*- Evenhuis & Polhemus 2008; Samoa NRF; Tonga NRF; Vanuatu AFD 2010			y	**Y**	Na
Planococcus minor/pacificus (Pseudococcidae)	pacific mealybug	AB	N: PPIN 2010	French 2006; Williams & Watson 1988	Cook Is. Waterhouse 1997, Williams & Watson 1988a; Fiji Waterhouse 1997, Williams & Watson 1988a; Samoa Waterhouse 1997, Williams & Watson 1988a; Tonga Williams & Watson 1988a; Vanuatu Waterhouse 1997; Williams & Watson 1988a			y	**Y**	Na
Pseudaulacaspis pentagona (Diaspididae)	white peach scale	AB	N: Scalenet 2010; not in PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Williams & Watson 1988; Samoa Waterhouse 1997; Tonga Englberger & Foliaki 1992; Vanuatu Williams & Watson 1988			y	**Y**	N
Pulvinaria psidii (Coccidae)	white louse scale		N-Hodgson & Henderson 2000.	Preston 1998	Cook Is. Scalenet 2010, PestNet 2010; Fiji Scalenet 2010, Wilson & Evenhuis 2008; Samoa Kami & Miller 1998; Tonga Scalenet 2010; Vanuatu Scalenet 2010			y	n	Na
Saisettia coffeae (Coccidae)	scale		Y: Hodgson & Henderson 2000.	Preston 1998	Cook Is. NRF; Fiji Wilson & Evenhuis 2008; Samoa Kami & Miller 1998; Tonga Scalenet 2010; Vanuatu Scalenet 2010			y	n	Na
Seliza sp. (Flatidae)	flatid planthopper		N: not in Lariviere 2005, PPIN 2010	Preston 1998	NRF				n	Na
Sephena sp. (Flatidae)	flatid planthopper		N: not in Lariviere 2005	Preston 1998	NRF				n	Na
Tectocoris diophthalmus (Scutelleridae)	cotton/hibiscus harlequin bug	D	N: not in Lariviere & Larochelle 2004, recorded as absent in PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998, AFD 2010, Fa'anunu 2009; Samoa NRF; Tonga Englberger & Foliaki 1992, AFD 2010; Vanuatu AFD 2010			y	**Y**	Na
Thrips sp. (Thripidae)	thrips	AB	N:	Preston 1998	NRF			y	**Y**	Na
Unaspis citri (Diaspididae)	scale	AB	N: PPIN 2010	Preston 1998	Cook Is. Waterhouse 1997; Fiji Waterhouse 1997; Samoa Waterhouse 1997; Tonga Waterhouse 1997; Vanuatu Waterhouse 1997			y	**Y**	Na
Arthropoda: Insecta: Hymenoptera: Formicidae										

Scientific name	Common name	Group	Presence in NZ	Association with Island cabbage-ref	Presence in exporting countries	Vector?	Unwanted or controlled?	Potential for establish-ment and impact	Hazard?	Risk?
Anaplolepis gracilipes	Crazy ant	E	N: Landcare Research	Hitchhiker-Intercepted on leaves	Cook Is, Fiji, Samoa, Tonga, Vanuatu: GISD 2005			y	**Y**	Na
Cardiocondyla nuda	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves	Tonga-Wetterer 2002;			y	**Y**	Na
Cardiocondyla wroughtonii	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Crematogaster sp.	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Linepithema humile	ant		Y: Don 2007	Hitchhiker-Intercepted on leaves				y	**N**	Na
Monomorium destructor	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Monomorium floricola	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Monomorium minutum	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Monomorium monomorium	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Monomorium pharaonis	ant		Y: Don 2007	Hitchhiker-Intercepted on leaves				y	**N**	Na
Monomorium sp.	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Nylanderia bourbonica (was *Paratrechina)*	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Paraparatrechina minutula (was *Paratrechina)*	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Nylanderia sp. (was *Paratrechina*)	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on				y	**Y**	Na

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				leaves						
Nylanderia vaga (was *Paratrechina*)	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Paratrechina longicornis	ant	E	N:Don 2007; Landcare Research	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Pheidole fervens	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Pheidole megacephala	ant		Y: Don 2007	Hitchhiker-Intercepted on leaves				y	**N**	Na
Pheidole oceanica	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves	Tonga Wetterer 2002			y	**Y**	Na
Pheidole sp.	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Pheidole umbonata	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves	Tonga Wetterer 2002			y	**Y**	Na
Ponera loi	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Ponera sp.	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Solenopsis geminata	little fire ant	E	N: Don 2007	Hitchhiker-Intercepted on leaves	Cook Is, Fiji, Tonga- GISD 2005			y	**Y**	**Y**
Tapinoma melanocephalum	ant	E	N: Landcare Research	Hitchhiker-Intercepted on leaves	Tonga- Wetterer 2002			y	**Y**	Na
Tapinoma sp.	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Tetramorium bicarinatum	ant	E	Y: Don 2007	Hitchhiker-Intercepted on leaves	Tonga- Wetterer 2002			y	**Y**	Na
Tetramorium simillimum	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on	Tonga- Wetterer 2002			y	**Y**	Na

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				leaves						
Triglyphothrix obesa ssp. *Striatidens.*	ant	E	N:not in Don 2007	Hitchhiker-Intercepted on leaves				y	**Y**	Na
Arthropoda: Insecta: Lepidoptera										
Acrocercops cathedrae (Gracillariidae)	moth		N: not in PPIN 2010	Preston 1998	NRF			y	n	Na
Acrocercops sp (Gracillariidae)	moth	BD	Y: 13 species in NZ-Dugdale 1988	Preston 1998	Cook Is. Stout 1982; Fiji Waterhouse 1997; Samoa Stout 1982; Tonga Englberger & Foliaki 1992; Vanuatu Bradley 1962.			y	n	Na
Anomis flava (Noctuidae)	Aibika semi looper caterpillar		N: Dugdale 1988, PPIN 2010	Preston 1998	Cook Is. Stout 1982; Fiji Stout 1982, Preston 1998, Evenhuis 2008; Samoa Stout 1982, Kami & Miller 1998; Tonga Englberger & Foliaki 1992; Vanuatu NRF			y	n	Na
Anomis lyona (Noctuidae)	moth	AE	N: not in Dugdale 1988, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998; Samoa Kami & Miller 1998; Tonga NRF; Vanuatu NRF			y	**Y**	Na
Chrysodeixis eriosoma (Noctuidae)	green looper caterpillar		Y: Dugdale 1988	Stout 1982	Cook Is. Waterhouse 1997; Fiji Waterhouse 1997; Samoa Stout 1982; Kami & Miller 1998; Tonga Englberger & Foliaki 1992; Vanuatu Waterhouse 1997			y	n	Na
Crocidosema plebeiana (also spelt *plebejana*) (Tortricidae)	moth		Y: Dugdale 1988	Hopkins 1927 on Hibiscus spp. and other Malvaceae	Cook Is. NRF; Fiji Hopkins 1927; Samoa Hopkins 1927; Tonga Hopkins 1927; Vanuatu NRF			y	n	Na
Earias vittella (Noctuidae)	Aibika tip borer	D	N: not in Dugdale 1988, PPIN 2010	Preston 1998	Cook Is. Stout 1982, Waterhouse 1997; Fiji Preston 1998, Waterhouse 1997, Evenhuis 2008; Samoa Stout 1982, Waterhouse 1997; Tonga Englberger & Foliaki 1992, Waterhouse 1997; Vanuatu Waterhouse 1997		UOR	y	**Y**	Y
Euproctis sp. (Lymantridae)			N: not in Dugdale 1988, PPIN 2010	Preston 1998	NRF				n	Na
Haritalodes derogata (Crambidae)	cotton leaf roller/aikbika leaf roller	E	N: not in Dugdale 1988, PPIN 2010	Stout 1982; Preston 1998 as Sylepta derogata	Cook Is. NRF; Fiji Fa'anunu 2009 as Sylepta derogata -is this the same as Syllepteco derogata-Evenhuis 2008; Samoa Stout 1982a; Kami & Miller 1998; Tonga NRF; Vanuatu NRF			y	**Y**	Y
Spodoptera litura (Noctuidae)	cluster caterpillar		Y: Dugdale 1988	Preston 1998	Cook Is. Waterhouse 1997; Fiji Stout 1982; Samoa Stout 1982; Tonga Waterhouse 1997; Vanuatu Waterhouse 1997			y	n	Na

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Tiracola plagiata (Noctuidae)	banana fruit caterpillar	E	N: not in Dugdale 1988, PPIN 2010	Stout 1982	Cook Is. Fa'anunu 2009; Fiji Fa'anunu 2009, Evenhuis 2008; Samoa Stout 1982; Tonga Englberger & Foliaki 1992; Vanuatu NRF			y	**Y**	Na
Xanthodes transversa (Noctuidae)	Aibika hairy caterpillar	E	N: not in Dugdale 1988, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji NRF; Samoa NRF; Tonga NRF; Vanuatu Viette 1949			y	**Y**	Na
Arthropoda: Insecta: Orthoptera										
Atractomorpha crenaticeps (Pyrgomorphidae)	grasshopper		N: pers comm Peter Johns 17 Mar 2010; Kevan 1971; not in PPIN 2010	French 2006	NRF		UOR	y	n	Na
Phaneroptera brevis (Tettigoniidae)	long horned grasshopper	E	N: pers comm. Peter Johns 17 Mar 2010; not in PPIN 2010	Preston 1998;Stout 1982	NRF			y	**Y**	Na
Valanga sp. (Acrididae)	short-horned grasshoppers	E	N: pers comm Peter Johns 17 Mar 2010; not in PPIN 2010	Preston 1998	Cook Is. NRF; Fiji NRF; Samoa Kami & Miller 1998; Tonga NRF; Vanuatu NRF				**Y**	Na
MOLLUSCS										
Mollusca: Gastropoda: Caenogastropoda										
Vermicularia hibiscina			N: not in NZFungi	Farr & Rossman 2010	NRF				n	Na
Mollusca: Gastropoda: Stylommatophora										
Achatina fulica (Achatinidae)	giant African snail	E	N: PPIN 2010	Preston 1998; FPI 2010	Cook Is. ISSG; Fiji ISSG; Samoa ISSG; Tonga Venette & Larson 2004; Vanuatu ISSG	y	UOR	y	**Y**	Y
NEMATODES										
Nematoda: Adenophorea: Dorylaimida										
Xiphenema brevicolle (Longidoridae)	dagger nematode		Y: IDC new to NZ report	Orton Williams 1980	Cook Is. NRF; Fiji Bridge 1988; Samoa Bridge 1988; Tonga Orton Williams 1980; Vanuatu NRF		UOR	y	n	Na
Xiphinema ensiculiferum (Longidoridae)	dagger nematode		N: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Orton Williams 1980; Samoa Preston 1998, Orton Williams 1980; Tonga Orton Williams 1980; Vanuatu NRF		UOR	y	n	Na
Xiphinema insigne (Longidoridae)	dagger nematode		N: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. Fa'anunu 2009; Fiji Preston 1998, Orton Williams 1980; Samoa Bridge 1988; Tonga NRF; Vanuatu NRF		UOR	y	n	Na
Xiphinema krugi (Longidoridae)	dagger nematode		Y: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Orton Williams 1980; Samoa Bridge 1988; Tonga NRF; Vanuatu NRF		UOR	y	n	Na
Xiphinema rivesi (Longidoridae)	dagger nematode		N: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji NRF; Samoa Bridge 1988; Tonga Orton Williams 1980; Vanuatu		UOR	y	n	Na

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					NRF					
Nematoda: Secernentia: Aphelenchida										
Aphelenchoides besseyi (Aphelenchoididae)	foliar nematode	D	N: not in Yeates 2010, PPIN 2010	see notes	Cook Is. CABI distribution map 796, 2000; Fiji Bridge 1988; Samoa NRF; Tonga NRF; Vanuatu NRF		UOR	y	**Y**	Y
Aphelenchoides bicaudatus (Aphelenchoididae)	foliar nematode		Y: Yeates 2010; not in PPIN 2010	Orton Williams 1980	Cook Is. NRF; Fiji Bridge 1988; Samoa Bridge 1988; Tonga Orton Williams 1980, Bridge 1988; Vanuatu NRF		UOR	y	n	Na
Aphelenchoides sp. (Aphelenchoididae)	foliar nematode	B	N:	Orton Williams 1980	Cook Is. NRF; Fiji Preston 1998, Orton Williams 1980; Samoa Fa'anunu 2009; Tonga Orton Williams 1980; Vanuatu NRF		UOR	y	**Y**	Na
Nematoda: Secernentia: Tylenchida										
Criconemella denoudeni (synonym of *Criconemoides denoudeni*) (Criconematidae)	ring nematode		N: not in Yeates 2010, PPIN 2010	Orton Williams 1980	Cook Is. NRF; Fiji Preston 1998; Orton Williams 1980; Samoa NRF; Tonga NRF; Vanuatu NRF		UOR	y	n	Na
Criconemella onoensis (syn of *Criconemoides onoensis*) (Criconematidae)	ring nematode		N: not in Yeates 2010, PPIN 2010	Orton Williams 1980	Cook Is. NRF; Fiji Preston 1998; Orton Williams 1980; Samoa NRF; Tonga NRF; Vanuatu NRF		UOR	y	n	Na
Ditylenchus sp. (Anguinidae)	nematode		See PPIN 2010; Yeates 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998; Orton Williams 1980; Samoa NRF; Tonga NRF; Vanuatu NRF		UOR	y	n	Na
Helicotylenchus crenacauda (Hoplolaimidae)	spiral nematode		N: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998; Orton Williams 1980; Samoa Bridge 1988; Tonga NRF; Vanuatu NRF		UOR	y	n	Na
Helicotylenchus dihystera (Hoplolaimidae)	spiral nematode		Y: Yeates 2010, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Orton Williams 1980; Samoa Preston 1998, Orton Williams 1980; Tonga Orton Williams 1980; Vanuatu Ruabete 2003			y	n	Na
Helicotylenchus indicus (Hoplolaimidae)	spiral nematode		N: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998; Orton Williams 1980; Samoa Bridge 1988; Tonga Bridge 1988; Vanuatu NRF		UOR	y	n	Na
Helicotylenchus microcephalus (Hoplolaimidae)	spiral nematode		N: not in Yeates 2010; recorded as absent in PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998; Orton Williams 1980; Samoa Bridge 1988; Tonga Fa'anunu 2009, Bridge 1988; Vanuatu NRF		UOR	y	n	Na
Helicotylenchus mucronatus	spiral nematode		N:not in Yeates 2010; recorded as absent in PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Bridge 1988; Samoa Bridge 1988; Tonga Orton Williams 1980,		UOR	y	n	Na

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(Hoplolaimidae)					Bridge 1988; Vanuatu NRF					
Helicotylenchus multicinctus (Hoplolaimidae)	spiral nematode		N: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Bridge 1988; Samoa Bridge 1988; Tonga Orton Williams 1980, Bridge 1988; Vanuatu Bridge 1988		UOR	y	n	Na
Hemicriconemoides cocophilus (Criconematidae)	sheathoid nematode		Y: Yeates 2010; Wouts 2006	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Orton Williams 1980; Samoa Bridge 1988; Tonga NRF; Vanuatu NRF		UOR	y	n	Na
Hoplolaimus seinhorsti (Hoplolaimidae)	lance nematode		N: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Orton Williams 1980; Samoa Bridge 1988; Tonga NRF; Vanuatu NRF		UOR	y	n	Na
Meloidogyne arenaria (Heteroderidae)	peanut root-knot nematode		Y: PPIN 2010; Yeates 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Orton Williams 1980; Samoa Bridge 1988; Tonga NRF; Vanuatu NRF			y	n	Na
Meloidogyne incognita (Heteroderidae)	root-knot nematodes		Y: PPIN 2010; Yeates 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Orton Williams 1980; Samoa Bridge 1988; Tonga Fa'anunu 2009, Bridge 1988; Vanuatu NRF			y	n	Na
Meloidogyne javanica (Heteroderidae)	root-knot nematodes		Y: PPIN 2010; Yeates 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998; Orton Williams 1980; Samoa Bridge 1988; Tonga Fa'anunu 2009, Bridge 1988			y	n	Na
Pratylenchus brachyurus (Pratylenchidae)	lesion nematodes		N: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. Fa'anunu 2009; Fiji Preston 1998, Orton Williams 1980; Samoa Fa'anunu 2009, Bridge 1988; Tonga Orton Williams 1980; Vanuatu Ruabete 2003		UOR	y	n	Na
Pratylenchus zeae (Pratylenchidae)	lesion nematodes		N: not in Yeates 2010, PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Orton Williams 1980; Samoa Bridge 1988; Tonga Bridge 1988; Vanuatu NRF		UOR	y	n	Na
Quinisulcius sp (is a syn of *Tylenchorhynchus*) (Belonolaimidae)	stunt nematode		N:	Ruabete 2003	Cook Is. NRF; Fiji NRF; Samoa NRF; Tonga NRF; Vanuatu Ruabete 2003			y	n	Na
Radopholus similis (Pratylenchidae)	burrowing nematode		N: recorded as absent in PPIN 2010; not in Yeates 2010	Preston 1998	Cook Is. Fa'anunu 2009; Fiji Preston 1998, Orton Williams 1980; Samoa NRF; Tonga Orton Williams 1980; Vanuatu NRF		UOR	y	n	Na
Rotylenchulus reniformis (Hoplolaimidae)	reniform nematode		N: recorded as absent in PPIN 2010	Preston 1998	Cook Is. Fa'anunu 2009; Fiji Preston 1998, Orton Williams 1980; Samoa Preston 1998, Orton Williams 1980; Tonga Orton Williams 1980; Vanuatu Ruabete 2003		UOR	y	n	Na
Tylenchorhynchus sp. (Belonolaimidae)	stylet or stunt nematodes			?	NRF			y	n	Na

Pathogens

Scientific name	Common name	Group	Presence in NZ	Association with Pele-ref	Presence in exporting countries	Vector?	Unwanted or controlled?	Potential for establishment and impact	Hazard?	Risk?
BACTERIA										
Actinobacteria: Actinomycetales										
Brevibacterium sp.	bacteria		N: not in Pennycook 1989, PPIN 2010, NZFungi 2010	Preston 1998	NRF			y	n	Na
Erwinia carotovora subsp. *carotovora*	bacteria		Y: PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Dingley et al 1981- as Bacterium carotovorum; Samoa NRF; Tonga NRF; Vanuatu NRF			y	n	Na
Escherichia freundii (syn of *Citrobacter freundii*)	bacteria		NRF	Preston 1998	NRF			y	n	Na
Pseudomonas cichorii	bacteria		Y: PPIN 2010; NZFungi 2010	Preston 1998	NRF			y	n	Na
FUNGI										
Ascomycota										
Hymenella sp. (hyphomycete (anamorph))	cephalosporium leaf stripe- Fa'anunu 2009		not in PPIN 2010	Fa'anunu 2009	Cook Is. NRF; Fiji NRF; Samoa NRF; Tonga NRF; Vanuatu Fa'anunu 2009			y	n	Na
Sarcopodium vanillae (incertae sedis (hyphomycete))	anamorph		N: not in NZFungi 2010, PPIN 2010	Preston 1998	NRF				n	Na
Oidium abelmoschi (hyphomycete) (Ascomycetes: Erysiphales)	anamorph; powdery mildew	F	N: NZFungi 2010; not in PPIN 2010	on A. esculentus NZFungi 2010	Cook Is. NRF; Fiji NZFungi; Samoa NRF; Tonga NRF; Vanuatu NRF			y	**Y**	Y
Oidium sp. (hyphomycete) (Ascomycetes: Erysiphales)	powdery mildew		Y: NZFungi 2010	Preston 1998	Cook Is. NZFungi; Fiji NZFungi; Samoa NRF; Tonga NZFungi; Vanuatu NZFungi			y	n	Na
Phyllosticta sp. (coelomycete) (Dothideomycetes: Botryosphaeriales)			Y: NZFungi 2010	Preston 1998	Cook Is. NRF; Fiji HerbIMI; Samoa HerbIMI; Tonga NRF; Vanuatu HerbIMI			y	n	Na
Pseudocercospora abelmoschi (hyphomycete) (Dothideomycetes: Capnodiales)	anamorph	F	N: NZFungi 2010; not in PPIN 2010	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Dingley et al 1981; Samoa Preston 1998, Dingley et al 1981; Tonga Preston 1998, Dingley et al 1981; Vanuatu Preston 1998, McKenzie 1989		UOR	y	**Y**	Y

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Cercospora apii [syn: *Cercospora malayensis*] (hyphomycete) (Dothideomycetes: Dothideales)	anamorph		Y: NZFungi 2010; not in PPIN 2010	Preston 1998 (as C. malayensis)	Cook Is. NRF; Fiji NZFungi (on A. esculentus); Samoa NRF; Tonga NZFungi (on H. esculentus); Vanuatu NRF		UOR	y	n	Na
Cochliobolus lunatus (Pleosporaceae) (Dothideomycetes: Pleosporales)			Y: NZFungi 2010	Preston 1998	Cook Is. NZFungi; Fiji NZFungi; Samoa NZFungi; Tonga NRF; Vanuatu NRF			y	n	Na
Corynespora cassiicola (hyphomycete) (Dothideomycetes: Pleosporales)	anamorph		Y: NZFungi 2010	Preston 1998	Cook Is. NZFungi; Fiji NZFungi; Samoa Fa'anunu 2009, NZFungi; Tonga NZFungi; Vanuatu NZFungi			y	n	Na
Pleospora sp. (Pleosporaceae) (Dothideomycetes: Pleosporales)			NRF	Farr & Rossman 2010	NRF			y	n	Na
Verticillium intertextum (Plectosphaerellaceae) (Incertae sedis)			N: NZFungi 2010; PPIN 2010 (one sp. listed-N)	Preston 1998	NRF			y	n	Na
Sphaerotheca fuliginea (Leotiomycetes: Erysiphales) (syn of *Podosphaerea fuliginea*)			Y: NZFungi 2010	Farr & Rossman 2010	Cook Is. NZFungi 2010; Fiji NZFungi 2010; Samoa NZFungi 2010; Tonga NZFungi 2010; Vanuatu NZFungi 2010			y	n	Na
Fusarium bullatum (Sordariomycetes: Hypocreales)			N: not in NZFungi 2010; PPIN 2010	Farr & Rossman 2010	NRF			y	n	Na
Fusarium oxysporum (hyphomycete) (Sordariomycetes: Hypocreales)			Y: NZFungi 2010	Preston 1998	Cook Is. Dingley et al 1981; Fiji Dingley et al 1981; Samoa NRF; Tonga NRF; Vanuatu Preston 1998, NZFungi culture			y	n	Na
Fusarium solani (Sordariomycetes: Hypocreales) (see *Nectria hematococca* var. *brevicona*)	Anamorph		Y: NZFungi 2010	Preston 1998	Cook Is. NRF; Fiji NRF; Samoa NRF; Tonga NRF; Vanuatu Preston 1998			y	n	Na

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Fusarium vasinfectum (Sordariomycetes: Hypocreales) [synonymous with *F.oxysporum* f.sp. *vasinfectum*, which is subordinate taxon of *F. oxysporum*- NZFungi 2010]			Y: NZFungi 2010 (found on pea in Wanganui)	Farr & Rossman 2010	Cook Is. NRF; Fiji Dingley et al 1981- on cotton; Samoa NRF; Tonga NRF; Vanuatu NRF			y	n	Na
Fusarium viticola (Sordariomycetes: Hypocreales)			N: Not in NZFungi 2010; PPIN 2010	Farr & Rossman 2010	NRF			y	n	Na
Myrothecium roridum (hyphomycete) (Sordariomycetes: Hypocreales)			Y: NZFungi 2010	Preston 1998	Cook Is. NRF; Fiji NZFungi; Samoa Dingley et al. 1981; Tonga Dingley et al. 1981; Vanuatu NZFungi			y	n	Na
Myrothecium verrucaria (hyphomycete) (Sordariomycetes: Hypocreales)			Y: NZFungi 2010	Preston 1998	NRF			y	n	Na
Nectria haematococca var. *brevicona* (Nectriaceae) (Sordariomycetes: Hypocreales)	Teleomorph		Y: NZFungi 2010	Preston 1998	Cook Is. NRF; Fiji Dingley et al 1981 as F. solani; Samoa Dingley et al 1981 as F. solani; Tonga Dingley et al 1981 as F. solani; Vanuatu NRF			y	n	Na
Tubercularia sp. (Sordariomycetes: Hypocreales)			Y: NZFungi 2010	Farr & Robinson 2010	NRF			y	n	Na
Glomerella cingulata (Glomelleraceae) (Sordariomycetes: Hypocreomycetidae/Sordariomycetidae)	Teleomorph		Y: NZFungi 2010	Preston 1998	Cook Is. NZFungi; Fiji NZFungi; Samoa NZFungi; Tonga NZFungi; Vanuatu NZFungi			y	n	Na
Colletotrichum sp. (coelomycete) (Sordariomycetes: Phyllachorales)			Y: NZFungi 2010	Preston 1998	Cook Is. Dingley et al 1981; Fiji Dingley et al 1981; Samoa Dingley et al 1981; Tonga Dingley et al 1981; Vanuatu NRF			y	n	Na
Basidiomycota										
Athelia rolfsii (Atheliaceae)			Y: NZFungi 2010	Preston 1998	Cook Is. NZFungi; Fiji NZFungi; Samoa NZFungi; Tonga NZFungi; Vanuatu			y	n	Na

Scientific name	Common name	Group	Presence in NZ	Association with Pele-ref	Presence in exporting countries	Vector?	Unwanted or controlled?	Potential for establishment and impact	Hazard?	Risk?
(Agaricomycetes: Atheliales)					NZFungi					
Zygomycota										
Choanephora cucurbitarum (Choanephoraceae) (Mucorales)	Blossom blight and rot, leaf blight, leaf and fruit rots	F	N: NZFungi 2010; recorded as absent in PPIN 2010	Preston 1998	Cook Is. NZFungi; Fiji NZFungi; Samoa NRF; Tonga NZFungi; Vanuatu NZFungi		UOR	y	**Y**	Y
Choanephora infundibula (Choanephoraceae) (Mucorales)			N: not in NZFungi 2010; not in PPIN 2010	Preston 1998	NRF			y		Na
Choanephora infundibulifera (Choanephoraceae) (Mucorales)		F	N: NZFungi 2010; not in PPIN 2010	Preston 1998	Cook Is. NRF; Fiji NZFungi; Samoa NRF; Tonga NRF; Vanuatu NZFungi		UOR	y	**Y**	Y
HETEROKONTOPHYTA										
Oomycota										
Phytophthora nicotianae (Pythiaceae)			Y: NZFungi	Farr & Rossman 2010	Cook Is. NZFungi 2010; Fiji Farr & Rossman 2010; Samoa NRF; Tonga Fa'anunu 2009; Vanuatu NRF			y	n	Na
Phytophthora nicotianae var. *nicotianae* (Pythiaceae)			Y: NZFungi 2010	Preston 1998	Cook Is. Stout 1982; Fiji Preston 1998; Dingley et al 1981; Samoa NRF; Tonga Wright 2005; Vanuatu NRF			y	n	Na
VIRUS										
undescribed viruses	"white, mottling leaf"	G	NRF	Fa'anunu 2009	Cook Is. NRF; Fiji NRF; Samoa Fa'anunu 2009; Tonga Fa'anunu 2009; Vanuatu NRF			y	n	n
Undescribed potyvirus		G	NRF	Preston 1998	Vanuatu- Preston 1998; NRF for other countries			y		n
Undescribed potexvirus		G	NRF	Preston 1998	Vanuatu- Preston 1998; NRF for other countries			y		n
Hibiscus chlorotic ringspot virus (Tombusviridae: Carmovirus)	HCRSV	G	Y: PPIN 2010; but n in Pearson et al 2006; y in Tang et al 2008	Preston 1998	Cook Is. NRF; Fiji Preston 1998, Pearson & Grisoni 2002, Davis & Ruabete 2010; Samoa NRF; Tonga NRF; Vanuatu Preston 1998; Pearson & Grisoni 2002; Davis & Ruabete 2010			y	n	n

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Appendix 2 Excluded organisms

Note: If there is a change in circumstances for any of these organisms, *e.g.* if they are reported from the exporting country or further information becomes available regarding commodity association, then those organisms may require assessment.

These organisms are excluded from further assessment as there is no record of presence found in the exporting countries	**These organisms are excluded from further assessment as they are either in NZ or there is insufficient evidence to suggest they are hazards on island cabbage leaves (*Abelmoschus manihot*)**
Acrocercops cathedrae	*Anomis flava*
Amblypelta costalis szentivanyyi	*Aphelenchoides bicaudatus*
Amblypelta gallegonis	*Athelia rolfsii*
Amblypelta lutescens papuensis	*Chrysodeixis eriosoma*
Amblypelta theobromae	*Coccus hesperidium*
Amrasca devastans	*Cochliobolus lunatus*
Anadastus albertisi	*Coelophora inaequalis*
Apirocalus ebrius ebrius	*Colletotrichum sp.*
Apirocalus terrestris terrestris	*Corynespora cassiicola*
Aspidiomorpha adhearens	*Criconemella denoudeni* (synonym of Criconemoides denoudeni)
Aspidiomorpha australasiae	*Criconemella onoensis* (synonym of Criconemoides onoensis)
Aspidiomorpha miliaris	*Crocidosema plebeiana (also spelt plebejana)*
Aspidiomorpha punctum	*Ditylenchus sp.*
Aspidiomorpha quadriradiata	*Dysdercus sp.*
Aspidiomorpha socia	*Dysdercus (Paradysdercus) cingulatus*
Aspidiomorpha testudinaria	*Euproctis sp.*
Atractomorpha crenaticeps	*Fusarium oxysporum*
Brevibacterium sp.	*Fusarium solani*
Caridophthalmus sp.	*Fusarium vasinfectum* (synonymous with F.oxysporum f.sp. vasinfectu
Cassena intermedia	*Glomerella cingulata*
Cassena papuana	*Helicotylenchus crenacauda*
Cassena sp.	*Helicotylenchus dihystera*
Cicadella sp.	*Helicotylenchus indicus*
Cleoporus hibisci	*Helicotylenchus microcephalus*
Colgar chlorospilum	*Helicotylenchus mucronatus*
Colgar missior	*Helicotylenchus multicinctus*
Epilachna signatipennis	*Helicotylenchus sp.*
Erwinia carotovora	*Hemicriconemoides cocophilus*
Erwinia carotovora subsp. carotovora	*Hibiscus chlorotic ringspot virus*
Escherichia freundii (syn of Citrobacter freundii)	*Hoplolaimus seinhorsti*
Fusarium bullatum	*Hymenella sp.*
Fusarium viticola	*Meloidogyne arenaria*
Glenea aluensis	*Meloidogyne incognita*
Monolepta sp.	*Meloidogyne javanica*
Nipaecoccus viridis	*Meloidogyne sp.*
Nisotra (=Podagrica) basselae	*Myrothecium roridum*
Nisotra (=Podagrica) obliterata	*Myrothecium verrucaria*
Oribius cruciatus	*Nezara viridula*
Oribius improvidus	*Nectria haematococca var. brevicona*
Oribius inimicus	*Oidium sp.*
Oribius spp.	*Oxycarenus (Oxycarenus) luctuosus*
Oxycarenus bicolor	*Paraputo leveri*
Peggioga sp.	*Parasaissetia nigra*
Platyacus ruralis	*Phyllosticta sp.*

These organisms are excluded from further assessment as there is no record of presence found in the exporting countries	These organisms are excluded from further assessment as they are either in NZ or there is insufficient evidence to suggest they are hazards on island cabbage leaves (***Abelmoschus manihot***)
Pleospora sp. *Rhyparidella sobrina* *Sarcopodium vanillae* *Seliza sp.* *Tetranychus marianae* *Tubercularia sp.* *Vermicularia hibiscina* *Verticillium intertextum*	*Phytophthora nicotianae* *Phytophthora nicotianae var. nicotianae* *Pratylenchus brachyurus* *Pratylenchus sp.* *Pseudomonas cichorii* *Pulvinaria psidii* *Radopholus similis* *Rotylenchulus reniformis* *Saisettia coffeae* *Sphaerotheca fuliginea (syn of Podosphaerea fuliginea)* *Spodoptera litura* *Tetranychus lambi* *Tylenchorhynchus sp.* *Xiphenema brevicolle* *Xiphinema ensiculiferum* *Xiphinema insigne* *Xiphinema krugi* *Xiphinema rivesi* *Linepithema humile* (hitchhiker) *Monomorium pharaonis* (hitchhiker) *Pheidole megacephala* (hitchhiker) *Tetramorium bicarinata* (hitchhiker)

Appendix 3 Vector organisms' analysis

In many countries, export commodities are grown in large monocultures with intensive in-field management and subsequent specialised post-harvest disinfestations and quarantine processes. In contrast, intercropping of plants and/or small subsistence polyculture plots are not uncommon in the Pacific Islands. Farmers are only registered and inspected for fruit fly host commodities. Island cabbage is not a fruit fly host and exports from the Pacific are likely to include leaves that have been harvested from backyards, or from small plots in close proximity to other plants. Therefore the likelihood of vectors moving between different hosts is increased.

In most risk analyses where vectors are assessed, the approach has been to limit the consideration of vectored viruses to those associated with the commodity. However, in this risk analysis, in consideration of differing agricultural practices, it is assumed that vectors are likely to be in contact with other plants that are potentially infected with viruses not associated with island cabbage (EFSA 2008).

Aphis craccivora **Koch (Hemiptera: Aphididae)**

Exporting countries status: recorded from Cook Is, Fiji, Samoa, Tonga and Vanuatu (Waterhouse 1997)
New Zealand status: recorded (Teulon et al. 2004)
Commodity association: island cabbage (*Abelmoschus manihot*) (Preston 1998);
Plant associations: Polyphagous, preferred hosts are legumes, but hosts also include: cotton, lucerne, clover, vetch, citrus, turnip, peppers, tomato, potato, marigolds (CPC 2010)
Plant parts affected: growing points, leaves and whole plant (CPC 2010). Intercepted relatively frequently at the New Zealand border, usually on leaves.
Vectored viruses: the following viruses are known to be absent from New Zealand, present in the exporting Pacific countries and vectored by *Aphis craccivora*: Papaya ringspot virus-W(PRSV-W), Peanut mottle virus, Watermelon mosaic 1 virus (synonym of PRSV-W) and Wisteria vein mosaic virus (ICTVdb 2011; Davis and Ruabete 2010; CPC 2010; Pearson *et al.* 2006).

Hazard identification conclusion:
Given that**:**

- None of the above viruses are known from island cabbage;
- PRSV-p and PRSV-W, Peanut mottle, wisteria vein mosaic are potyviruses and appear to be transmitted in a non-persistent manner. This means that although the aphid can acquire the virus rapidly, within seconds to minutes of feeding on infected plants, it usually retains the virus in its mouthparts and or foregut for minutes to hours (van Emden and Harrington 2007);
- *Aphis craccivora* from Cook Is, Fiji, Samoa, Tonga and Vanuatu is unlikely to retain non-persistent viruses by the time it would be exposed to new hosts in New Zealand;

Aphis craccivora is not considered a hazard on fresh island cabbage leaves from Cook Is, Fiji, Samoa, Tonga and Vanuatu.

Aphis gossypii **Glover (Hemiptera: Aphididae)**

Exporting countries status: recorded from Cook Is, Fiji, Samoa, Tonga and Vanuatu (Waterhouse 1997)
New Zealand status: recorded (Teulon et al. 2004)
Commodity association: island cabbage (Abelmoschus manihot) (Preston 1998)
Plant associations: extremely polyphagous, main hosts are papaya, melon and cotton; but hosts also include okra, peppers, celery, tomato, stonefruit, pipfruit, brassicas, citrus, cucurbits, beans, sweet potato, lettuce, and avocado. *A. gossypii* has been intercepted numerous times at the border on leaves from the Pacific *e.g.*., on roselle (*Hibiscus sabdariffa*) leaves (C2005/229867), on tarua leaves (C2005/277487, C2003/58642) and on taro leaves (C2009/260936, C2010/268061, C2010/321318, C2010/321488)
Plant parts affected: *A. gossypii* is commonly associated with leaves
Vectored viruses: *A. gossypii* is reported to transmit over 50 non-persistent and persistent viruses. The following viruses are known to be absent from New Zealand, present in the exporting Pacific countries and vectored by *A. gossypii*: Hippeastrum mosaic potyvirus, Papaya ringspot virus, Peanut mottle virus, Turnip mosaic virus (Davis and Ruabete 2010, ICTVdb 2011, CPC 2010, Pearson et al. 2006)
Hazard identification conclusion:
Given that:

- None of the above viruses are known from island cabbage;
- Hippeastrum mosaic potyvirus, Papaya ringspot virus, Peanut mottle virus, Turnip mosaic virus are potyviruses and therefore likely to be transmitted in a non persistent manner;
- *A. gossypii* from Cook Is, Fiji, Samoa, Tonga and Vanuatu is unlikely to retain non-persistent viruses by the time it would be exposed to new hosts in New Zealand;

Aphis gossypii is not considered a hazard on fresh island cabbage leaves from Cook Is, Fiji, Samoa, Tonga and Vanuatu.

Myzus persicae **(Hemiptera: Aphididae)**

Exporting countries status: recorded from Cook Is, Fiji and Samoa (Waterhouse 1997) and Tonga (Stout 1982), taro leaves -C2010/322491
New Zealand status: recorded (Teulon *et al.* 2004)
Commodity association: island cabbage (*Abelmoschus manihot*) (Stout 1982)
Plant associations: highly polyphagous, okra, celery, asparagus, peppers, melons, brassicas, cucurbits, tomato, apple, stonefruit, roses, sweet potato
Plant parts affected: growing points, inflorescence, leaves and stems (CPC 2010). Has been intercepted on taro leaves from the Pacific (C2010/322491)
Vectored viruses: *Myzus persicae* has been shown to transmit well over 100 plant virus diseases, in about 30 different families, including many major crops (CPC 2010). The following viruses are known to be absent from New Zealand, present in the exporting Pacific countries and vectored by *M. persicae*: Hippeastrum mosaic potyvirus, Papaya ringspot virus, Peanut mottle potyvirus Turnip mosaic potyvirus, Vanilla mosaic potyvirus, Watermelon mosaic virus 1 (=Papaya ringspot virus W), Watermelon mosaic 2 potyvirus (=Watermelon mosaic virus), Wisteria vein mosaic virus, (Davis and Ruabete 2010, ICTVdB 2011, CPC 2010, Pearson et al. 2006)

Hazard identification conclusion
Given that:

- None of the above viruses are known from island cabbage;
- Hippeastrum mosaic potyvirus, Papaya ringspot virus, Peanut mottle potyvirus, Turnip mosaic potyvirus, Vanilla mosaic potyvirus, Watermelon mosaic virus 1 (=Papaya ringspot virus-W), Wisteria vein mosaic virus are all potyviruses and therefore are likely to be transmitted in a non-persistent manner;
- *Myzus persicae* from Cook Is, Fiji, Samoa, Tonga and Vanuatu is unlikely to retain non-persistent viruses by the time it would be exposed to new hosts in New Zealand;

Myzus persicae is not considered a hazard on fresh island cabbage leaves from Cook Is, Fiji, Samoa, Tonga and Vanuatu.

Area of uncertainty and residual risk
In the absence of certainty the following is assumed. There is a likelihood of *A. craccivora*, and or *A. gossypii* and or *M. persicae* having fed on other plants, some of which may have viruses that are either unknown, or are semi- persistent or persistent in manner of transmission. The risk may be partially offset by the bulk of the imported leaves being cooked and consumed. However a small amount may be discarded and there is a very low likelihood for a live, viraemic aphid to be part of that amount.

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Appendix 4 Undescribed viruses

There are three undescribed viruses in this risk analysis.

i) “unidentified rod-shaped virus particles observed in Samoa and Tonga” –Fa’anunu 2009, from the UNDP/FAO-SPEC Survey (Stout, 1982).

ii) An undescribed potyvirus infecting island cabbage plants in Vanuatu and Solomon Is. This virus has properties similar to potato virus Y and allied viruses. It has flexuous filamentous particles measuring about 12 x 750nm and is found only in island cabbage plants infected with Hibiscus chlorotic ringspot virus (HCRSV). “…it is likely this virus will be transmitted from infected to healthy plants in the non-persistent manner by one or more aphid species” (Preston 1998).

iii) An undescribed potexvirus infecting island cabbage plants in Vanuatu and Solomon Is. This virus has properties similar to potato virus X and similar viruses. It has filamentous particles measuring 12 x 550nm and is found infecting island cabbage plants infected with HCRSV. “The potexvirus is probably sufficiently infectious to be mechanically transmissible on contaminated hands and tools” (Preston 1998)

Hazard identification conclusion:
Given that:

- island cabbage leaves are expected to not have any part of the stem attached and will therefore not be propagable;
- harvested leaves are unlikely to be in a condition that would attract a sap-sucking potential vector;
- it is unlikely a mechanically transmitted virus would be transferred from leaves to hands and then to growing island cabbage plants without the virus becoming deactivated;

The above three undescribed viruses are not considered hazards in island cabbage leaves that have been trimmed of any stem, imported from Samoa, Tonga and Vanuatu.

However if other viruses are reported from island cabbage leaves from any of the exporting countries they will need to be assessed separately.

References for Appendix 4

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Appendix 5 Host species for Aphelenchoides besseyi

Table 1: Reported plant hosts of *Aphelenchoides besseyi.*

Host genus	Host species	Common name	Host family	*Refs.
Asarum	*canadense* L.	American wild ginger, Canadian snakeroot, wild ginger	Aristolochiaceae	10
Asplenium	*jamaicense* Jenm.		Aspleniaceae	4
Brassica	*oleracea* L. var. *capitata* L.	cabbage, red cabbage, white cabbage	Brassicaceae	2
Chrysanthemum	*hortorum* W. Mill.	garden chrysanthemum	Asteraceae	2, 6
Chrysanthemum	×*morifolium* Ramat.	chrysanthemum, mum, florist's chrysanthemum	Asteraceae	5
Chrysanthemum	sp.		Asteraceae	8
Cibotium	sp.		Dicksoniaceae	4
Dahlia	*pinnata* Cav.		Asteraceae	5
Dianthus	*caryophyllus* L.	carnation, clove pink, border carnation	Caryophyllaceae	2, 6
Digitalis	*sanguinalis*		Scrophulariaceae	5
Erechtites	*praealta* Raf.		Asteraceae	5
Ficus	*benjamina* L. var. *comosa* (Roxb.) Kurz		Moraceae	2
Ficus	*elastica* Roxb. ex Hornem.	India rubber fig, Indian rubber tree, rubber tree	Moraceae	5,8
Fragaria	sp.		Rosaceae	7
Hydrangea	*macrophylla*		Hydrangeaceae	5
Impatiens	*balsamina* L.	garden balsam, rose balsam, touch-me-not	Balsaminaceae	5
Jasminum	*simplicifolium* G.Forst.	wax jasmine, Australian wax jasmine	Oleaceae	9
Jasminum	sp.		Oleaceae	4
Lemna	sp.		Lemnaceae	4
Leucanthemum	*maximum* Ramond		Asteraceae	5, 3
Ligularia	*stenocephala* (Maxim.) Matsum. & Koidz.	ligularia	Asteraceae	10
Lycopodium	*clavatum* L.	club moss, elk moss, ground-pine	Lycopodiaceae	4
Lygodium	*circinatum* (Burm.f.) Sw.		Schizaeaceae	4, 5
Pluchea	*odorata* (L.) Cass. var.		Asteraceae	5

	odorata			
Polianthes	*tuberosa* L.	tuberose	Agavaceae	1
Rosa	sp.		Rosaceae	4
Rudbeckia	*hirta* L.	black-eyed-Susan	Asteraceae	4
Rudbeckia	*maxima* Nutt.	cabbage coneflower, giant coneflower	Asteraceae	10
Setaria	*viridis* (L.) Beauv.		Poaceae	5
Solenostemon	*scutellarioides* (L.) Codd	coleus, painted-nettle	Lamiaceae	5
Sporobolus	*indicus* (L.) R. Br. var. *indicus*	smut grass	Poaceae	4
Tagetes	sp.		Asteraceae	5
Tithonia	*diversifolia* (Hemsl.) Gray	Mexican-sunflower, shrub sunflower	Asteraceae	5
Torenia	*fournieri* Linden ex E. Fourn.	bluewings, wishbone flower	Scrophulariaceae	5
Tradescantia	*pallida* (Rose) D. R. Hunt	purpleheart	Commelinaceae	4
Vanda	sp.		Orchidaceae	5
Zinnia	*violacea* Cav.	common zinnia, youth-and-old-age	Asteraceae	2, 5

*References **1.** Chakraborti and Ghosh 1993; **2.** Crossman and Christie 1936; **3.** Dale 1972; **4.** Esser et al. 1988; **5.** Goodey et al. 1965; **6.** Juhl 1978; **7.** Locascio et al.1967; **8.** Marlatt 1966; **9.** Stokes 1979. **10.** Windham et al. 2005.

The full references can be found in Chapter 7 pg:

Appendix 6 Glossary of definitions and abbreviations

BORIC	Biosecurity Organisms Register for Imported Commodities
CPC	Crop Protection Compendium. Internet Database
Diapause	a physiological state of arrested development that enables an organism to survive more easily a period of unfavourable conditions
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.
Exposure	the process of the hazard organism moving from the commodity it arrived on to another host
Exotic	this word has different meanings in different fields, but in this document is defined as an animal, plant, pest or disease that is not indigenous to New Zealand.
Hitch-hiker organism	an organism that has an opportunistic association with a commodity or item with which it has no biological host relationship.
Indigenous	native; organism originating or occurring naturally in a specified area.
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.
IHS	Import Health Standard
IRA	Import risk analysis
MAF	Ministry of Agriculture and Forestry, New Zealand
MAFBNZ	MAF Biosecurity New Zealand
QuanCargo	database of commercial consignments and interceptions of pests made by quarantine inspection.
PPIN	Plant Pest Information Network database, MAF.
Regulated Pest	a pest of potential economic importance to New Zealand and not yet present here, or present but either not widely distributed and being officially controlled, having the potential to vector another organism, or a regulated non-quarantine pest.

Risk	in the context of this document risk is defined as the likelihood of the occurrence and the likely magnitude of the consequences of an adverse event.
USDA	United States Department of Agriculture.
Viable	capable of living; able to maintain a separate existence (on its own accord).
Vector	an organism or object that transfers a pest, parasite, pathogen or disease from one area or host to another.