Australian Government

Department of Agriculture, Fisheries and Forestry

Final pest risk analysis report for the importation of fresh island cabbage leaves from the Pacific (Cook Islands, Fiji, Samoa, Tonga and Vanuatu)

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Cover image: Island cabbage (*Abelmoschus manihot*) growing in Port Vila, Vanuatu. Photographed by DAFF officer, May 2011.

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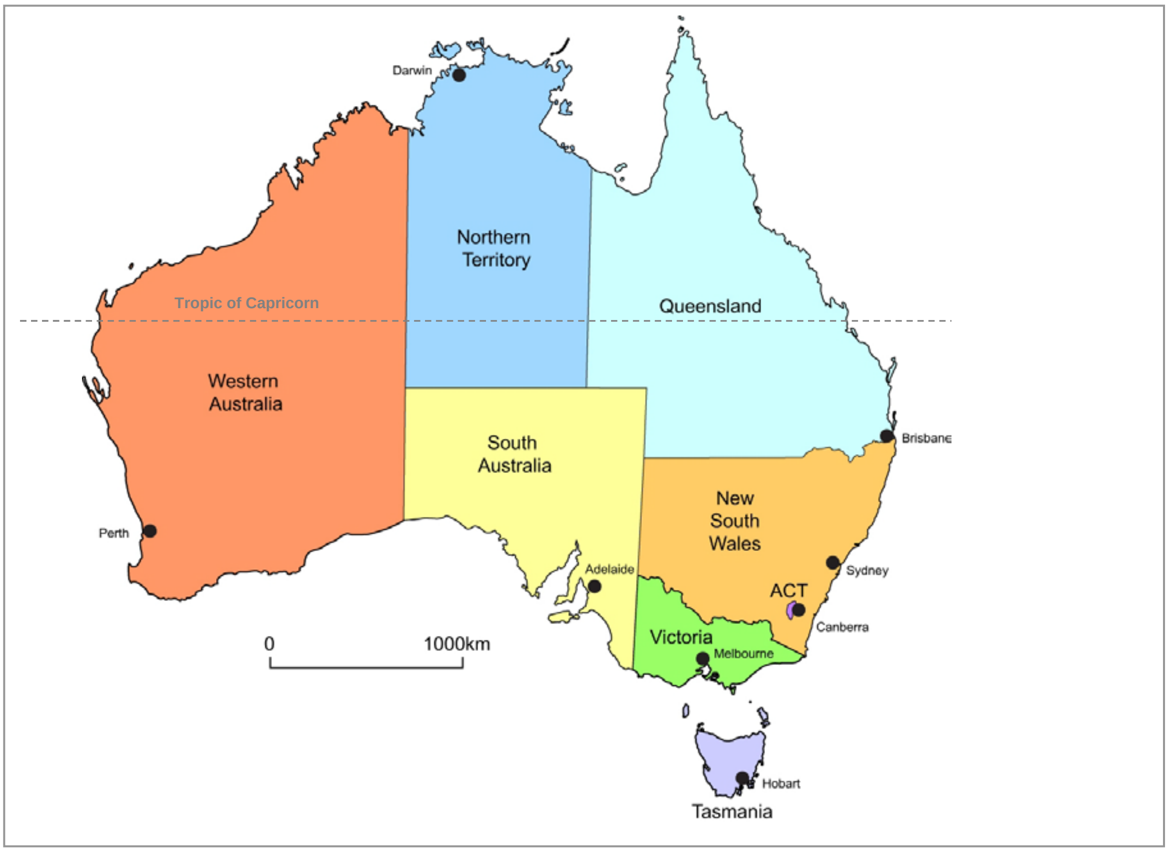
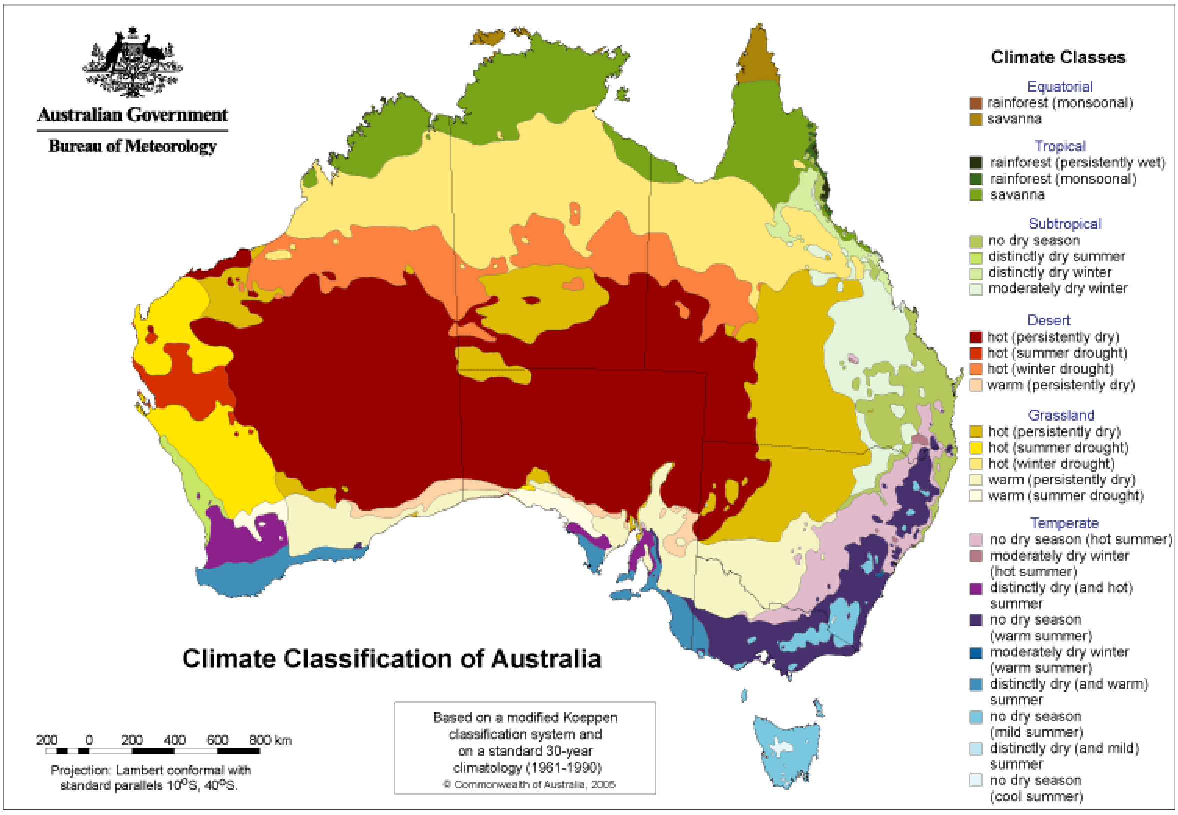


Figure 2 A guide to Australia's bio-climate zones



Acronyms and abbreviations

Term or abbreviation	Definition
ALOP	Appropriate level of protection
APPD	Australian Plant Pest Database (Plant Health Australia)
CABI	CAB International, Wallingford, UK
CMI	Commonwealth Mycological Institute
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
FAO	Food and Agriculture Organization of the United Nations
IPC	International Phytosanitary Certificate
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
IRA	Import Risk Analysis
ISPM	International Standard for Phytosanitary Measures
NPPO	National Plant Protection Organization
NSW	New South Wales
NT	Northern Territory
PRA	Pest Risk Analysis
Qld	Queensland
SA	South Australia
Tas.	Tasmania
Vic.	Victoria
WA	Western Australia
WTO	World Trade Organisation

Abbreviations of units

Term or abbreviation	**Definition**
ºC	degree Celsius
cm	centimetre
km	kilometre
m	metre
mm	millimetre

Summary

The Department of Agriculture, Fisheries and Forestry (DAFF) has assessed the quarantine risks associated with the importation of fresh island cabbage (*Abelmoschus manihot*) leaves from the Cook Islands, Fiji, Samoa, Tonga and Vanuatu. This report proposes phytosanitary measures for the importation of fresh island cabbage leaves from these countries. Australia has only considered the importation of cut leaves (with leaf stems), with no main stem material.

Australia has a system of operational procedures to ensure quarantine standards are met. These include: provisions for traceability to enable tracing of consignments to critical points of the pathway; packaging and labelling requirements to ensure material is not contaminated by quarantine pests or other regulated articles; and pre-export phytosanitary certification.

Three quarantine pests have been identified as requiring measures to manage the risks to a very low level in order to achieve Australia's appropriate level of protection. The pests are whitefly (*Bemisia tabaci* 'Nauru' biotype), tortoise scale (*Coccus capparidis*) and Pacific mealybug (*Planococcus minor*). Island cabbage leaves must be subject to phytosanitary inspection to ensure that consignments are free of whiteflies, scales, mealybugs or any other regulated articles. Where quarantine pests or other regulated articles are detected, consignments will be subject to appropriate remedial action.

1 Introduction

1.1 Australia's biosecurity policy framework

Australia's biosecurity policies aim to protect Australia against the risks that may arise from exotic pests[1] entering, establishing and spreading in Australia, thereby threatening Australia's unique flora and fauna, as well as those agricultural industries that are relatively free from serious pests.

The pest risk analysis process is an important part of Australia's biosecurity policies. It enables the Australian Government to formally consider the risks that could be associated with proposals to import new products into Australia. If the risks are found to exceed Australia's appropriate level of protection (ALOP), risk management measures are proposed to reduce the risks to an acceptable level. But, if it is not possible to reduce the risks to an acceptable level, then no trade will be allowed.

Successive Australian Governments have maintained a conservative, but not a zero risk, approach to the management of biosecurity risks. This approach is expressed in terms of Australia's ALOP, which reflects community expectations through government policy and is currently described as providing a high level of protection aimed at reducing risk to a very low level, but not to zero.

Australia's pest risk analyses are undertaken by DAFF using teams of technical and scientific experts in relevant fields, and involves consultation with stakeholders at various stages during the process. The Biosecurity Plant Division provides recommendations for animal and plant quarantine policy to Australia's Director of Animal and Plant Quarantine (the Secretary of the Australian Department of Agriculture, Fisheries and Forestry). The Director, or delegate, is responsible for determining whether or not an importation can be permitted under the *Quarantine Act 1908*, and if so, under what conditions.

More information about Australia's biosecurity framework is provided in Appendix C of this report and in the *Import Risk Analysis Handbook 2011* located on the DAFF website http://daff.gov.au.

[1] A pest is any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2012).

1.2 This pest risk analysis

1.2.1 Background

The governments of the Cook Islands, Fiji, Samoa, Tonga and Vanuatu originally sought market access for island cabbage (*Abelmoschus manihot*) to New Zealand. The Food and Agriculture Organization of the United Nations (FAO) provided assistance in preparing a market access submission in 2009 (Fa'anunu 2009). The possibility of undertaking the risk analysis as a joint project between Australia and New Zealand, and expanding the request to include access to Australia, was considered at the Australia and New Zealand Technical Plant Quarantine Meeting in September 2009. The proposed approach was endorsed at a meeting of the Consultative Group on Biosecurity Cooperation (CGBC) in Sydney in October 2009.

The widespread cultivation of *Abelmoschus manihot* and the diversity of languages in the Pacific region has resulted in a large number of vernacular names for the plant, including aibika, pele, bele, neka, nabele, slippery cabbage, sunset hibiscus and island cabbage (or aelan cabis) (Preston 1998). This report uses the common name island cabbage.

1.2.2 Scope

This report assesses the biosecurity risks associated with the importation of fresh island cabbage leaves for human consumption. The assessment is restricted to leaves and petioles (leaf stems) only, and does not include the main stems containing lateral buds, which can be used for propagation purposes and could provide a pathway for the introduction of additional pests.

Details of typical production practices for island cabbage in the Pacific are described in Section 3.

1.2.3 Existing policy

Australia does not currently permit the importation of fresh island cabbage leaves for human consumption. Small volumes of frozen island cabbage leaves are imported from Pacific countries.

There is existing policy for the importation of fresh leaves of a number of other plant species, which are currently permitted from Pacific countries. This includes cassava (*Manihot esculenta*), taro (*Colocasia esculenta*), roselle (*Hibiscus sabdariffa*), bael (*Aegle marmelos*), drumstick (*Moringa oleifera*), silverbeet (*Beta vulgaris* var. *flavescens*), chicory (*Cichorium intybus*) and many *Brassica* spp. varieties. All these fresh leaf commodities are subject to quarantine inspection on arrival. The history of trade in these commodities indicates that most interceptions at the border are contaminant pests such as ants, springtails, mirids, ladybird beetles, spiders, armyworms and parasitic wasps. Some pests of quarantine concern (aphids, mealybugs, planthoppers) are occasionally detected, but other significant polyphagous pests such as rose beetle, coreid bugs, whiteflies and scales are not encountered on these leaf commodities.

1.2.4 Contaminating pests

In addition to the pests of island cabbage from the Pacific that are identified in this report, there are other organisms that may arrive with the island cabbage leaves. These organisms could include pests of other crops or predators and parasitoids of other arthropods. DAFF considers these organisms to be contaminating pests that could pose sanitary and phytosanitary risks. These risks are addressed by existing operational procedures.

1.2.5 Consultation

A draft pest categorisation table was distributed to the relevant state departments for comment to identify any regional pest concerns during preparation of the draft report. The draft report was released on 13 December 2012 (BA2012/26) for stakeholder comment for a period of 60 days that concluded on 11 February 2013.

Written submissions were received from the Department of Food and Agriculture Western Australia (DAFWA), the Queensland Department of Agriculture, Fisheries and Forestry, and AUSVEG. Submissions have been considered and material matters raised have been included in the present report.

Following stakeholder consultation, some amendments have been made to the final report.

- Additional information about island cabbage propagation has been added to Section 3.
- The title has been amended to make it clear that the assessment is for leaves only.
- The mariana mite, *Tetranychus marianae*, has been confirmed as being present in Western Australia as well as other Australian states, and the pest categorisation table has been updated to reflect this. The pest risk assessment and management measures for this mite have been removed from the report as it is not considered to be a quarantine pest.
- For coreid bugs, the rating for probability of importation has been lowered from ‘high’ to ‘moderate’ to reflect the fact that these are active pests that will fly (adults) or crawl (nymphs) from the leaves if disturbed at harvest or during pre-export preparation, and so are unlikely to be present on the importation pathway. Coreid bugs are not detected on other imported leaf commodities such taro and cassava that are hosts of the bugs. Eggs are the most likely life stage to be present on the leaves.
- The rating for the potential consequences for coreid bugs has been increased to ‘moderate’. The overall estimate for unrestricted risk remains below ALOP.
- In the draft report, the section on management for whitefly incorrectly stated that the unrestricted risk estimate for *Bemisia tabaci* ‘Nauru’ biotype was ‘low’. This has been corrected to ‘moderate’.

2 Method for pest risk analysis

In accordance with the International Plant Protection Convention, the technical component of a plant risk analysis is termed a 'pest risk analysis' (PRA). DAFF has conducted this PRA in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: *Framework for Pest Risk Analysis* (FAO 2007) and ISPM 11: *Pest Risk Analysis for Quarantine Pests, including analysis of environmental risks and living modified organisms* (FAO 2004).

A PRA is 'the process of evaluating biological or other scientific and economic evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it' (FAO 2012). A pest is 'any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products' (FAO 2012).

Quarantine risk consists of two major components: the probability of a pest entering, establishing and spreading in Australia from imports; and the consequences should this happen. These two components are combined to give an overall estimate of the risk.

Unrestricted risk is estimated taking into account the existing commercial production practices of the exporting country and that, on arrival in Australia, DAFF will verify that the consignment received is as described on the commercial documents and that its integrity has been maintained.

Restricted risk is estimated with phytosanitary measure(s) applied. A phytosanitary measure is 'any legislation, regulation or official procedure having the purpose to prevent the introduction and spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests' (FAO 2012).

A glossary of the terms used is provided at the back of this report.

PRAs are conducted in three consecutive stages: initiation, pest risk assessment and pest risk management.

2.1 Stage 1: Initiation

Initiation identifies the pest(s) and pathway(s) that are of quarantine concern and should be considered for risk analysis in relation to the identified PRA area.

The pests assessed for their potential to be on the exported commodity (produced using commercial production and packing procedures) are listed in column 1 of Appendix A. Appendix A does not present a comprehensive list of all the pests associated with the entire plant, but concentrates on the pests that could be on the assessed commodity. Pests that are determined to not be associated with the commodity are not considered further. Contaminating pests that have no specific relation to the commodity or the export pathway have not been listed and would be addressed by Australia's current approach to contaminating pests.

The identity of the pests is given in Appendix A. The species name is used in most instances, but a lower taxonomic level is used where appropriate. Synonyms are provided where the current scientific name differs from that provided by the exporting countries NPPO or where the cited literature uses a different scientific name.

For this report, the 'PRA area' is defined as Australia for pests that are absent, or of limited distribution and under official control. For areas with regional freedom from a pest, the 'PRA area' may be defined on the basis of a state or territory of Australia or may be defined as a region of Australia consisting of parts of a state or territory or several states or territories.

For pests that had been considered by DAFF in other risk assessments and for which import policies already exist, a judgement based on the specific circumstances was made on the likelihood of entry of pests on the commodity and whether existing policy is adequate to manage the risks associated with its import. Where appropriate, the previous risk assessment was taken into consideration when developing the new policy.

2.2 Stage 2: Pest risk assessment

A pest risk assessment (for quarantine pests) is: 'the evaluation of the probability of the introduction and spread of a pest and of the likelihood of associated potential economic consequences' (FAO 2012).

In this report, pest risk assessment was divided into the following interrelated processes:

2.2.1 Pest categorisation

Pest categorisation identifies which of the pests with the potential to be on the commodity are quarantine pests for Australia and require pest risk assessment. A 'quarantine pest' is a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled, as defined in ISPM 5: *Glossary of phytosanitary terms* (FAO 2012).

The pests identified in Stage 1 were categorised using the following primary elements to identify the quarantine pests for the commodity being assessed:

- presence or absence in the PRA area
- regulatory status
- potential for establishment and spread in the PRA area
- potential for economic consequences (including environmental consequences) in the PRA area.

The results of pest categorisation are set out in Appendix A. The quarantine pests identified during pest categorisation were carried forward for pest risk assessment and are listed in Table 4.1.

2.2.2 Assessment of the probability of entry, establishment and spread

Details of how to assess the 'probability of entry', 'probability of establishment' and 'probability of spread' of a pest are given in ISPM 11 (FAO 2004). A summary of this process is given below, followed by a description of the qualitative methodology used in this report.

Probability of entry

The probability of entry describes the probability that a quarantine pest will enter Australia as a result of trade in a given commodity, be distributed in a viable state in the PRA area and subsequently be transferred to a host. It is based on pathway scenarios depicting necessary steps in the sourcing of the commodity for export, its processing, transport and storage, its use in Australia and the generation and disposal of waste. In particular, the ability of the pest to survive is considered for each of these stages.

The probability of entry estimates for the quarantine pests for a commodity are based on the use of the existing commercial production, packaging and shipping practices of the exporting country. Details of the existing commercial production practices for the commodity are set out in Section 3. These practices are taken into consideration by DAFF when estimating the probability of entry.

For the purpose of considering the probability of entry, DAFF divides this step of this stage of the risk assessment into two components:

- **Probability of importation**: the probability that a pest will arrive in Australia when a given commodity is imported
- **Probability of distribution**: the probability that the pest will be distributed, as a result of the processing, sale or disposal of the commodity, in the PRA area and subsequently transfer to a susceptible part of a host.

Factors considered in the probability of importation include:

- distribution and incidence of the pest in the source area
- occurrence of the pest in a life-stage that would be associated with the commodity
- mode of trade (e.g. bulk, packed)
- volume and frequency of movement of the commodity along each pathway
- seasonal timing of imports
- pest management, cultural and commercial procedures applied at the place of origin
- speed of transport and conditions of storage compared with the duration of the lifecycle of the pest
- vulnerability of the life-stages of the pest during transport or storage
- incidence of the pest likely to be associated with a consignment
- commercial procedures (e.g. refrigeration) applied to consignments during transport and storage in the country of origin, and during transport to Australia.

Factors considered in the probability of distribution include:

- commercial procedures (e.g. refrigeration) applied to consignments during distribution in Australia
- dispersal mechanisms of the pest, including vectors, to allow movement from the pathway to a host
- whether the imported commodity is to be sent to a few or many destination points in the PRA area
- proximity of entry, transit and destination points to hosts
- time of year at which import takes place

- intended use of the commodity (e.g. for planting, processing or consumption)
- risks from by-products and waste.

Probability of establishment

Establishment is defined as the 'perpetuation for the foreseeable future, of a pest within an area after entry' (FAO 2012). In order to estimate the probability of establishment of a pest, reliable biological information (lifecycle, host range, epidemiology, survival, etc.) is obtained from the areas where the pest currently occurs. The situation in the PRA area can then be compared with that in the areas where it currently occurs and expert judgement used to assess the probability of establishment.

Factors considered in the probability of establishment in the PRA area include:

- availability of hosts, alternative hosts and vectors
- suitability of the environment
- reproductive strategy and potential for adaptation
- minimum population needed for establishment
- cultural practices and control measures.

Probability of spread

Spread is defined as 'the expansion of the geographical distribution of a pest within an area' (FAO 2012). The probability of spread considers the factors relevant to the movement of the pest, after establishment on a host plant or plants, to other susceptible host plants of the same or different species in other areas. In order to estimate the probability of spread of the pest, reliable biological information is obtained from areas where the pest currently occurs. The situation in the PRA area is then carefully compared with that in the areas where the pest currently occurs and expert judgement used to assess the probability of spread.

Factors considered in the probability of spread include:

- suitability of the natural and/or managed environment for natural spread of the pest
- presence of natural barriers
- potential for movement with commodities, conveyances or by vectors
- intended use of the commodity
- potential vectors of the pest in the PRA area
- potential natural enemies of the pest in the PRA area.

Assigning qualitative likelihoods for the probability of entry, establishment and spread

In its qualitative risk assessments, DAFF uses the term 'likelihood' for the descriptors it uses for its estimates of probability of entry, establishment and spread. Qualitative likelihoods are assigned to each step of entry, establishment and spread. Six descriptors are used: high; moderate; low; very low; extremely low; and negligible (Table 2.1). Descriptive definitions for these descriptors and their indicative probability ranges are given in Table 2.1. The indicative probability ranges are only provided to illustrate the boundaries of the descriptors.

These indicative probability ranges are not used beyond this purpose in qualitative risk analyses. The standardised likelihood descriptors and the associated indicative probability ranges provide guidance to the risk analyst and promote consistency between different risk analyses.

Table 2.1 Nomenclature for qualitative likelihoods

Likelihood	Descriptive definition	Indicative probability (P) range
High	The event would be very likely to occur	0.7 < P ≤ 1
Moderate	The event would occur with an even probability	0.3 < P ≤ 0.7
Low	The event would be unlikely to occur	0.05 < P ≤ 0.3
Very low	The event would be very unlikely to occur	0.001 < P ≤ 0.05
Extremely low	The event would be extremely unlikely to occur	0.000001 < P ≤ 0.001
Negligible	The event would almost certainly not occur	0 ≤ P ≤ 0.000001

The likelihood of entry is determined by combining the likelihood that the pest will be imported into the PRA area and the likelihood that the pest will be distributed within the PRA area, using a matrix of rules (Table 2.2). This matrix is then used to combine the likelihood of entry and the likelihood of establishment, and the likelihood of entry and establishment is then combined with the likelihood of spread to determine the overall likelihood of entry, establishment and spread.

For example, if the probability of importation is assigned a likelihood of 'low' and the probability of distribution is assigned a likelihood of 'moderate', then they are combined to give a likelihood of 'low' for the probability of entry. The likelihood for the probability of entry is then combined with the likelihood assigned to the probability of establishment (e.g. 'high') to give a likelihood for the probability of entry and establishment of 'low'. The likelihood for the probability of entry and establishment is then combined with the likelihood assigned to the probability of spread (e.g. 'very low') to give the overall likelihood for the probability of entry, establishment and spread of 'very low'.

Table 2.2 Matrix of rules for combining qualitative likelihoods

	High	Moderate	Low	Very low	Extremely low	Negligible
High	High	Moderate	Low	Very low	Extremely low	Negligible
Moderate		Low	Low	Very low	Extremely low	Negligible
Low			Very low	Very low	Extremely low	Negligible
Very low				Extremely low	Extremely low	Negligible
Extremely low					Negligible	Negligible
Negligible						Negligible

Time and volume of trade

One factor affecting the likelihood of entry is the volume and duration of trade. If all other conditions remain the same, the overall likelihood of entry will increase as time passes and the overall volume of trade increases.

DAFF normally considers the likelihood of entry on the basis of the estimated volume of one year's trade. This is a convenient value for the analysis that is relatively easy to estimate and allows for expert consideration of seasonal variations in pest presence, incidence and behaviour to be taken into account. The consideration of the likelihood of entry, establishment and spread and subsequent consequences takes into account events that might happen over a number of years even though only one year's volume of trade is being considered. This reflects biological and ecological facts, for example where a pest or disease may establish in the year of import but spread may take many years.

These considerations have been taken into account when setting up the matrix. Therefore any policy based on this analysis does not simply apply to one year of trade. Policy decisions that are based on DAFF's method that uses the estimated volume of one year's trade are consistent with Australia's policy on appropriate level of protection and meet the Australian Government's requirement for ongoing quarantine protection. Of course, if there are substantial changes in the volume and nature of the trade in specific commodities then DAFF has an obligation to review the risk analysis and, if necessary, provide updated policy advice.

2.2.3 Assessment of potential consequences

The objective of the consequence assessment is to provide a structured and transparent analysis of the likely consequences if the pests or disease agents were to enter, establish and spread in Australia. The assessment considers direct and indirect pest effects and their economic and environmental consequences. The requirements for assessing potential consequences are given in Article 5.3 of the SPS Agreement (WTO 1995), ISPM 5 (FAO 2012) and ISPM 11 (FAO 2004).

Direct pest effects are considered in the context of the effects on:

- plant life or health
- other aspects of the environment.

Indirect pest effects are considered in the context of the effects on:

- eradication, control, etc
- domestic trade
- international trade
- environment.

For each of these six criteria, the consequences were estimated over four geographic levels, defined as:

- **Local**: an aggregate of households or enterprises (a rural community, a town or a local government area).
- **District**: a geographically or geopolitically associated collection of aggregates (generally a recognised section of a state or territory, such as 'Far North Queensland').
- **Regional**: a geographically or geopolitically associated collection of districts in a geographic area (generally a state or territory, although there may be exceptions with larger states such as Western Australia).
- **National**: Australia wide (Australian mainland states and territories and Tasmania).

For each criterion, the magnitude of the potential consequence at each of these levels was described using four categories, defined as:

- **Indiscernible**: pest impact unlikely to be noticeable.
- **Minor significance**: expected to lead to a minor increase in mortality/morbidity of hosts or a minor decrease in production but not expected to threaten the economic viability of production. Expected to decrease the value of non-commercial criteria but not threaten the criterion's intrinsic value. Effects would generally be reversible.
- **Significant**: expected to threaten the economic viability of production through a moderate increase in mortality/morbidity of hosts, or a moderate decrease in production. Expected to significantly diminish or threaten the intrinsic value of non-commercial criteria. Effects may not be reversible.
- **Major significance**: expected to threaten the economic viability through a large increase in mortality/morbidity of hosts, or a large decrease in production. Expected to severely or irreversibly damage the intrinsic 'value' of non-commercial criteria.

The estimates of the magnitude of the potential consequences over the four geographic levels were translated into a qualitative impact score (A–G)[2] using Table 2.3[3]. For example, a consequence with a magnitude of 'significant' at the 'district' level will have a consequence impact score of D.

Table 2.3 Decision rules for determining the consequence impact score based on the magnitude of consequences at four geographic scales

		Geographic scale			
		Local	District	Region	Nation
Magnitude	Indiscernible	A	A	A	A
	Minor significance	B	C	D	E
	Significant	C	D	E	F
	Major significance	D	E	F	G

The overall consequence for each pest is achieved by combining the qualitative impact scores (A–G) for each direct and indirect consequence using a series of decision rules (Table 2.4). These rules are mutually exclusive, and are assessed in numerical order until one applies.

[2] In earlier qualitative risk analyses, the scale for the impact scores went from A to F and did not explicitly allow for the rating 'indiscernible' at all four levels. This combination might be applicable for some criteria. In this report, the impact scale of A-F has changed to become B-G and a new lowest category A ('indiscernible' at all four levels) was added. The rules for combining impacts in Table 2.4 were adjusted accordingly.

[3] The decision rules for determining the consequence impact score are presented in a simpler form in Table 2.3 from earlier risk analyses, to make the table easier to use. The outcome of the decision rules is the same as the previous table and makes no difference to the final impact score.

Table 2.4 Decision rules for determining the overall consequence rating for each pest

Rule	The impact scores for consequences of direct and indirect criteria	Overall consequence rating
1	Any criterion has an impact of ‘G’; or more than one criterion has an impact of ‘F’; or a single criterion has an impact of ‘F’ and each remaining criterion an ‘E’.	Extreme
2	A single criterion has an impact of ‘F’; or all criteria have an impact of ‘E’.	High
3	One or more criteria have an impact of ‘E’; or all criteria have an impact of ‘D’.	Moderate
4	One or more criteria have an impact of ‘D’; or all criteria have an impact of ‘C’.	Low
5	One or more criteria have an impact of ‘C’; or all criteria have an impact of ‘B’.	Very Low
6	One or more but not all criteria have an impact of ‘B’, and all remaining criteria have an impact of ‘A’.	Negligible

2.2.4 Estimation of the unrestricted risk

Once the above assessments are completed, the unrestricted risk can be determined for each pest or groups of pests. This is determined by using a risk estimation matrix (Table 2.5) to combine the estimates of the probability of entry, establishment and spread and the overall consequences of pest establishment and spread. Therefore, risk is the product of likelihood and consequence.

When interpreting the risk estimation matrix, note the descriptors for each axis are similar (e.g. low, moderate, high) but the vertical axis refers to likelihood and the horizontal axis refers to consequences. Accordingly, a ‘low’ likelihood combined with ‘high’ consequences, is not the same as a ‘high’ likelihood combined with ‘low’ consequences – the matrix is not symmetrical. For example, the former combination would give an unrestricted risk rating of ‘moderate’, whereas, the latter would be rated as a ‘low’ unrestricted risk.

Table 2.5 Risk estimation matrix

Likelihood of pest entry, establishment and spread						
High	Negligible risk	[redacted]	Low risk	Moderate risk	High risk	Extreme risk
Moderate	Negligible risk	[redacted]	Low risk	Moderate risk	High risk	Extreme risk
Low	Negligible risk	Negligible risk	[redacted]	Low risk	Moderate risk	High risk
Very low	Negligible risk	Negligible risk	Negligible risk	[redacted]	Low risk	Moderate risk
Extremely low	Negligible risk	Negligible risk	Negligible risk	Negligible risk	[redacted]	Low risk
Negligible	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	[redacted]
	Negligible	Very low	Low	Moderate	High	Extreme
	Consequences of pest entry, establishment and spread					

2.2.5 Australia’s appropriate level of protection (ALOP)

The SPS Agreement defines the concept of an ‘appropriate level of sanitary or phytosanitary protection (ALOP)’ as the level of protection deemed appropriate by the WTO Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory.

Australia expresses its ALOP in qualitative terms. Australia’s ALOP, which reflects community expectations through government policy, is currently expressed as providing a high level of sanitary or phytosanitary protection aimed at reducing risk to a very low level, but not to zero. The band of cells in Table 2.5 marked ‘very low risk’ represents Australia’s ALOP.

2.3 Stage 3: Pest risk management

Pest risk management describes the process of identifying and implementing phytosanitary measures to manage risks to achieve Australia's ALOP, while ensuring that any negative effects on trade are minimised.

The conclusions from pest risk assessment are used to decide whether risk management is required and if so, the appropriate measures to be used. Where the unrestricted risk estimate exceeds Australia’s ALOP, risk management measures are required to reduce this risk to a very low level. The guiding principle for risk management is to manage risk to achieve Australia’s ALOP. The effectiveness of any proposed phytosanitary measure (or combination of measures) is evaluated, using the same approach as used to evaluate the unrestricted risk, to ensure it reduces the restricted risk for the relevant pest or pests to meet Australia’s ALOP.

ISPM 11 (FAO 2004) provides details on the identification and selection of appropriate risk management options and notes that the choice of measures should be based on their effectiveness in reducing the probability of entry of the pest.

Examples given of measures commonly applied to traded commodities include:

- options for consignments – e.g., inspection or testing for freedom from pests, prohibition of parts of the host, a pre-entry or post-entry quarantine system, specified conditions on preparation of the consignment, specified treatment of the consignment, restrictions on end-use, distribution and periods of entry of the commodity
- options preventing or reducing infestation in the crop – e.g., treatment of the crop, restriction on the composition of a consignment so it is composed of plants belonging to resistant or less susceptible species, harvesting of plants at a certain age or specified time of the year, production in a certification scheme
- options ensuring that the area, place or site of production or crop is free from the pest – e.g., pest-free area, pest-free place of production or pest-free production site
- options for other types of pathways – e.g., consider natural spread, measures for human travellers and their baggage, cleaning or disinfestation of contaminated machinery
- options within the importing country – e.g., surveillance and eradication programs
- prohibition of commodities – if no satisfactory measure can be found.

Risk management measures are identified for each quarantine pest where the risk exceeds Australia's ALOP. These are presented in the 'Pest Risk Management' section of this report.

3 Commercial production practices for island cabbage

This chapter provides information on the pre-harvest, harvest and post-harvest practices for island cabbage considered to be commercial production practices in the Pacific. The export capabilities of the Pacific Island countries are also outlined.

3.1 Assumptions used in estimating unrestricted risk

The following information on the commercial production practices in the Pacific have been taken into consideration when estimating the unrestricted risk of pests likely to be associated with the import of island cabbage produced in the Pacific.

DAFF officers observed the production practices for island cabbage in Fiji, Samoa, Tonga and Vanuatu in 2011, examining the cultivation and harvesting methods, proposed pest control, processing, packaging and transport protocols to produce and export island cabbage to Australia.

The unrestricted risk estimate makes few assumptions about the production practices involved, acknowledging that there may be multiple ways to produce, harvest, prepare and transport the commodity. No assumptions have been made about the use of pesticides or other in-field pest management measures. While it is likely that most export production would come from established commercial growers, it has not been discounted that smaller producers may be able to supply the market. Backyard production is typically for domestic consumption only.

Import conditions for fresh horticultural produce require that the commodity is securely packaged on arrival in Australia. Following release from quarantine, the product may not be secure in the supply chain within Australia. However, island cabbage leaves desiccate easily so would typically be kept wrapped/boxed and chilled where possible to minimise exposure to the environment. One exporter has proposed packaging leaves in sealed polythene bags ready for retail sale.

3.2 Climate in production areas

The Cook Islands, Fiji, Samoa, Tonga and Vanuatu all have a tropical maritime climate, with a distinct wet season (November to April) and dry season (May to October) (Fa’anunu 2009). There are, however, many local climatic variations in these countries. Island cabbage ideally requires even rainfall distribution, and does poorly in dry conditions (Fa’anunu 2009). It thrives in tropical lowland environments up to 500 m altitude (Preston 1998). In Papua New Guinea, island cabbage has been recorded as high as 2110 m above sea level, although plant growth is slower and insect damage more severe at higher altitudes (Preston 1998).

3.3 Pre-harvest

3.3.1 Cultivars

Island cabbage is a fast growing erect perennial shrub that belongs to the tribe Hibisceae of the family Malvaceae. The plants resemble okra (also in the genus *Abelmoschus*), but show great variability in the shape, size and colour of the leaves, petioles and stems, and branching and flowering habit (Preston 1998). Its taxonomy is complex and contested due to the considerable polymorphism and infraspecific variations (Preston 1998). Two subspecies were recognised by van Borssum Waalkes (1966) to distinguish the cultivated (*Abelmoschus manihot* subsp. *manihot*) and wild (*Abelmoschus manihot* subsp. *tetraphyllus*) types. Wild types have prickly stems, pedicels, petioles and even leaf nerves (Preston 1998). However, the boundary between these subspecies is not discrete. Subspecies *tetraphyllus* is sometimes considered a separate species (*Abelmoschus tetraphyllus*). A variety from West Africa (known as West African okra) is now considered a distinct species (*Abelmoschus caillei*) (Preston 1998). The species being considered in this assessment is the cultivated variety known as *Abelmoschus manihot* (or *Abelmoschus manihot* subsp. *manihot*).

Island cabbage lacks named varieties, but is defined by variations in leaf form and colour. While there are many different varieties (more than 70 in Vanuatu alone), there are three main types grown across the Cook Islands, Fiji, Samoa, Tonga and Vanuatu (Fa'anunu 2009). These types can be distinguished by having either cordate, palmate or pedate shaped leaves, which are light to dark green or reddish green in colour (Figure 3). There are many additional variations within these three basic types such as the size of the leaves and the colour of the leaf veins, which can be green or red. These variations are not considered to significantly affect the relative pest risks from a quarantine perspective, although some varieties potentially may have greater resistance to particular pests.

3.3.2 Cultivation practices

Island cabbage is grown as both a commercial crop and as a common garden plant in Fiji, Tonga and Vanuatu (Fa'anunu 2009). It is a more recent introduction to the Cook Islands and Samoa (Fa'anunu 2009), where commercial production is less prevalent.

Island cabbage is normally propagated by stem cuttings taken from the top and middle portions of healthy mature stems (Preston 1998). Traditionally these were 30–60 cm in length, with 4–8 nodes. The stems are directly planted in the field, with 2–6 of the nodes being buried, depending on the length of the stem. Longer stems and deeper planting assists with establishment in dry conditions (Preston 1998). Shorter cuttings (10–40 cm) with fewer nodes can be planted where irrigation is used. Some varieties produce small numbers of seeds, but seedling growth is slow (Preston 1998; Fa'anunu 2009), so vegetative propagation is preferred.

No available information indicates that island cabbage can be propagated from just the leaves and petioles. Westwood and Kesavan (1982) conducted propagation trials using island cabbage stems of various lengths with varying numbers of leaf nodes on the stems. It was possible to propagate from stems 50 mm in length with two leaf nodes (one above the soil, one below), but a stem length of 85–365 mm with at least four leaf nodes (planted with two nodes below the soil) was considered the best planting material (Westwood and Kesavan 1982).

Island cabbage prefers sandy loam and clay loam soils with pH between five and seven, but can tolerate a wide range of soil types. However, it grows poorly on the highly alkaline soils of coral atolls because of nutrient deficiencies (Preston 1998). Island cabbage can grow up to five metres in height (Fa'anunu 2009), but is usually around 1–1.5 m when grown for food production.

Like many Pacific crops, island cabbage is commonly intercropped with other plants such as sweet potato, taro, papaya, kava and eggplant.

Figure 3 Leaf shape variation: cordate (top), palmate (centre) and pedate (bottom)

3.3.3 Pest management

In backyard and semi-commercial production, island cabbage is usually intercropped with a range of other plants to minimise crop losses from pests. Generally, pesticides are not used. Only Fiji has attempted spray programs for control of island cabbage pests (Fa'anunu 2009).

Island cabbage growers in Vanuatu are known to employ more active pest management measures. These include the use of weed matting on the ground to prevent growth of weeds and reduce numbers of damaging soil-borne pests such as beetle larvae, and use of micro netting of plants to prevent feeding damage to the foliage by adult beetles, weevils and bugs.

3.4 Harvesting and handling procedures

Harvesting can start three months after planting (Preston 1998). When mature, the individual leaves can be plucked, or the entire terminal stem can be removed 6–8 leaves below the terminal bud (Fa'anunu 2009). Cutting the apical stem encourages growth of new branches and production of more leaves as lateral buds become active (Fa'anunu 2009; Preston 1998). Harvesting may be done weekly or fortnightly for each plant, and is repeated 4–8 times before quality starts to decline (Fa'anunu 2009; Preston 1998).

3.5 Post-harvest

As there is no established export trade for island cabbage from the Pacific, it is difficult to anticipate future postharvest procedures. This section will collate some of the observations made on field visits to Fiji, Samoa, Tonga and Vanuatu. For local consumption, island cabbage is commonly sold in fresh food markets and roadside stalls as bundled stems with leaves (Figure 4).

Island cabbage can be easily propagated from stems with lateral buds. The likelihood of introducing systemic pests and diseases is increased if imported plant material is diverted to growing purposes. Therefore, Australia is only considering the importation of cut leaves and petioles (leaf stems), which cannot be readily propagated. Leaves that are still attached to the main stem containing lateral buds, will not be permitted.

3.5.1 Packing house

The island cabbage is prepared for export in the packing house. There is no current standard process for the export of island cabbage leaves. As with other imported fresh leafy vegetables, Australia requires that the leaves are clean and free of all pests, diseases and contaminants, and it is up to individual exporters to determine the best way to meet that requirement.

3.5.2 Transport

Island cabbage wilts easily following harvest, and has a limited shelf life (Preston 1998). Airfreight is the most feasible way to export fresh island cabbage to the Australian market.

Figure 4 Bundled island cabbage leaves with stems attached on sale in market, Port Vila, Vanuatu.

4 Pest risk assessments for quarantine pests

Quarantine pests associated with island cabbage leaves from the Pacific (Cook Islands, Fiji, Samoa, Tonga and Vanuatu) are identified in Appendix A. This chapter assesses the probability of the entry, establishment and spread of these pests and their likely potential economic, including environmental, consequences.

Pest categorisation identified 10 quarantine pests associated with island cabbage leaves from the Pacific. Of these quarantine pests, six are of national concern and four are of regional concern. Table 4.1 identifies these quarantine pests and full details of the pest categorisation are provided in Appendix A. Pests are listed according to their taxonomic classification, consistent with Appendix A.

Table 4.1 Quarantine pests for island cabbage from the Pacific

Pest	Common name	Countries
Leaf beetles [Coleoptera: Chrysomelidae]		
Aulacophora indica (Gmelin, 1790)	Pumpkin beetle	Fiji, Samoa, Tonga, Vanuatu
Scarab beetles [Coleoptera: Scarabaeidae]		
Adoretus versutus Harold, 1869	Rose beetle	Cook Islands, Fiji, Samoa, Tonga, Vanuatu
Bugs [Hemiptera: Coreidae]		
Amblypelta cocophaga China, 1934	Coconut bug	Fiji
Brachylybas variegatus (Le Guillou, 1841)	Brown coreid bug	Fiji, Tonga
Whiteflies [Hemiptera: Aleyrodidae]		
Bemisia tabaci (Gennadius, 1889) 'Nauru' biotype	Whitefly	Fiji, Samoa, Tonga
Soft scales [Hemiptera: Coccidae]		
Coccus capparidis (Green, 1904)	Tortoise scale	Samoa, Tonga
Armoured scales [Hemiptera: Diaspididae]		
Pseudaulacaspis pentagona (Targioni Tozzetti, 1886)[WA]	White peach scale	Fiji, Samoa, Tonga, Vanuatu
Unaspis citri (Comstock, 1883)[WA]	Citrus snow scale	Cook Islands, Fiji, Samoa, Tonga, Vanuatu
Mealybugs [Hemiptera: Pseudococcidae]		
Planococcus minor (Maskell, 1897)[WA]	Pacific mealybug	Cook Islands, Fiji, Samoa, Tonga, Vanuatu
Leaf rollers [Lepidoptera: Crambidae]		
Haritalodes derogata (Fabricius, 1775)[WA]	Cotton leaf roller	Fiji, Samoa

4.1 Pumpkin beetle

Aulacophora indica

Aulacophora indica is a leaf beetle belonging to the Galerucinae subfamily of Chrysomelidae. There are around 160 described species of *Aulacophora* beetles, four of which are considered to be pests in parts of the Pacific: *Aulacophora indica* (synonym: *Aulacophora similis*), *Aulacophora hilaris*, *Aulacophora abdominalis* and *Aulacophora quadrimaculata* (Waterhouse and Norris 1987). A number of species in the genus are commonly known as pumpkin beetles or cucurbit beetles because of their association with plants of the Cucurbitaceae family.

The biology of many *Aulacophora* spp., including *Aulacophora indica*, is poorly described. Much of the following information is extrapolated from other closely related species.

Only the adult beetles feed on the foliage of island cabbage and other hosts. The larvae live in the soil beneath the plants, feeding on the root system. The full-grown *Aulacophora indica* larva is around 10 mm in length, and the head is around 0.7–0.8 mm wide (CABI 2012). In *Aulacophora hilaris*, the larvae are cream-coloured and slender, with a light brown sclerotised head capsule and dorsal plate at the end of the abdomen, and short thoracic legs (Waterhouse and Norris 1987). The head and anterior part of the body are embedded in the plant tissues while feeding (Waterhouse and Norris 1987). *Aulacophora indica* has four larval instar stages occurring over 14–25 days. At the end of the fourth instar, the larva forms an earthen chamber and enters the pupal stage, which lasts between 7 and 20 days before the adult emerges (Tsatsia and Jackson 2011).

The adult beetles are around 6–8 mm in length. The head, apex of the abdomen and elytra (hardened forewings) are shiny and yellow-orange in colour, with darker legs and antennae (CABI 2012). Adults of the related *Aulacophora hilaris* can live as long as ten months, with several overlapping generations each year (Hely *et al*. 1982). The female can produce as many as 500 eggs, with oviposition occurring over many months. The eggs are laid in small clusters on dead leaves or moist soil under host plants, and hatch in around ten days (Hely *et al.* 1982).

The adult beetles have a tendency to gregariousness when feeding, severely damaging individual leaves while leaving others untouched (Waterhouse and Norris 1987). Pumpkin beetles chew round holes in the leaves between the veins, and in heavy infestations may skeletonise the leaves before moving on to new leaves to repeat the process (Tsatsia and Jackson 2011; Waterhouse and Norris 1987). The adult beetles of the related *Aulacophora foveicollis* are reported to move to the undersides of host leaves when the sunlight is brightest in the middle of the day, but feed on the upper surfaces of the leaves at other times (Waterhouse and Norris 1987). The beetles may leave the host plant at night to shelter in nearby vegetation (Waterhouse and Norris 1987). Pumpkin beetles are strong fliers, and quickly take to the wing if disturbed (Waterhouse and Norris 1987).

In cooler regions, pumpkin beetles can overwinter during the egg and adult stages, with the adult beetles hibernating under loose bark or in other sheltered places (Hely *et al.* 1982; Waterhouse and Norris 1987). However, in many Pacific countries where there is no distinct winter period, breeding may be continuous, resulting in four or more overlapping generations each year (Waterhouse and Norris 1987).

While pumpkin beetles are most commonly associated with plants of the Cucurbitaceae family, they do attack a number of other plants. The native hosts on which the beetles fed prior to European settlement and the introduction of new host plants are largely unknown, but pumpkin beetles have successfully transferred their attacks to all kinds of domesticated cucurbits (Waterhouse and Norris 1987). Other hosts of *Aulacophora indica* include plants of the Brassicaceae family, common beans, broad beans, mung beans, soybeans, peanuts, cassava, spinach, sweet potato, corn, rice and wheat (French 2006; Waterhouse and Norris 1987; CABI 2012).

Aulacophora indica has a wide distribution in the Pacific, and has been reported in the Federated States of Micronesia, Fiji, Guam, New Caledonia, Niue, Papua New Guinea, Solomon Islands, Tonga, Vanuatu and the Territory of the Wallis and Futuna Islands (Waterhouse and Norris 1987; CABI 2012). Unlike the other pumpkin beetles found in the region, *Aulacophora indica* is not known to be present in Australia.

4.1.1 Probability of entry

Probability of importation

The likelihood that *Aulacophora indica* will arrive in Australia with the importation of island cabbage from any country where this pest is present is: **VERY LOW**.

- *Aulacophora indica* is present in a number of Pacific countries where island cabbage is grown, including Fiji, Samoa, Tonga and Vanuatu (Waterhouse and Norris 1987; CABI 2012). No *Aulacophora* spp. have been reported in the Cook Islands (Waterhouse and Norris 1987).
- Adult *Aulacophora indica* beetles were one of the most common pests observed on island cabbage plants during a visit to Efate, Vanuatu in May 2011. No pumpkin beetles were found on island cabbage plants surveyed at a number of sites on Tongatapu and Vava'u in Tonga in May 2011.
- Only adult pumpkin beetles are likely to be present on island cabbage leaves. Eggs, larvae and pupae are found on or in the ground (Waterhouse and Norris 1987).
- Adult pumpkin beetles are strong fliers and will attempt to fly away if disturbed (Hely *et al*. 1982). They are unlikely to remain on the leaves at harvest and during pre-export handling.
- Adult pumpkin beetles are brightly coloured and around 6–8 mm in length, so are conspicuous on the green leaves of island cabbage. They would be easily spotted at harvest, during pre-export preparation or phytosanitary inspection.

Probability of distribution

The likelihood that *Aulacophora indica* will be distributed in Australia, in a viable state, as a result of the processing, sale or disposal of island cabbage from any country where this pest is present, is: **MODERATE.**

- Island cabbage leaves would be distributed to various destinations in Australia, although predominantly to the larger population centres. The leaves are most likely to be sold through small specialty grocery stores and fresh food markets catering for the Asian and Pacific Islander communities.
- Island cabbage leaves are intended for human consumption, so are likely to be transported and stored under conditions that maintain their freshness. This will reduce opportunities

for pumpkin beetles to leave the commodity to seek out new hosts for much of the distribution chain. Leaves at wholesale or retail markets may be less secure.

- The majority of island cabbage leaf waste discarded in urban areas is likely to be disposed of via municipal waste management systems and potentially buried amongst other waste. Pumpkin beetles in waste material are unlikely to be dumped in the vicinity of suitable host plants, but adult beetles are capable of flight, and any surviving adults may be able to fly to nearby vegetation.
- Small volumes of island cabbage leaves may be disposed of in backyard gardens or the environment where suitable hosts may be present. Pumpkins, melons, spinach and beans are commonly grown in urban backyards.
- *Aulacophora* spp. are active beetles and take wing quickly when disturbed (Hely *et al*. 1982. They are likely to fly from the island cabbage leaves at the earliest opportunity.
- Beetles may remain hidden in bundles of leaves, but are likely to emerge if leaves are stored in the dark (e.g. in freight containers, warehouses) or are disturbed. They are unlikely to be on the island cabbage leaves at the point of retail sale to consumers.
- *Aulacophora indica* feeds on a wide range of plants (CABI 2012), many of which are common in Australia.

Overall probability of entry (importation x distribution)

The likelihood that *Aulacophora indica* will enter Australia and be distributed in a viable state to a suitable host, as a result of trade in island cabbage from any country where this pest is present, is: **VERY LOW**.

4.1.2 Probability of establishment

The likelihood that *Aulacophora indica* will establish in Australia, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction, is: **HIGH**.

- Female pumpkin beetles can lay many eggs over a number of months. Females that had mated prior to arrival in Australia could still produce many viable eggs, thereby establishing a population.
- Pumpkin beetles are gregarious feeders, so if infested island cabbage is imported, it is possible that a number of adult beetles will be present on that material. This would increase the likelihood of sexual reproduction occurring, allowing establishment of a population.
- *Aulacophora indica* beetles are brightly coloured to deter potential predators from eating them (Waterhouse and Norris 1987).
- Pumpkin beetles have evolved mechanisms to circumvent the toxic cucurbitacins found in the foliage of Cucurbitaceae, and these compounds accumulate in their tissues, making the beetles distasteful to predators (Waterhouse and Norris 1987).
- Other closely related pumpkin beetle species, including *Aulacophora hilaris*, *Aulacophora abdominalis* and *Aulacophora quadrimaculata* are already present in Australia (Hely *et al*.

1982; Waterhouse and Norris 1987), so it is possible that *Aulacophora indica* could also establish if introduced.

4.1.3 Probability of spread

The likelihood that *Aulacophora indica* will spread throughout Australia, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest, is: **HIGH**.

- Once established, *Aulacophora indica* is likely to spread, at least in the warmer parts of Australia. This species has a wide distribution through Asia, the Indian Subcontinent and the Pacific (CABI 2012).
- The adult beetles are strong fliers with good dispersal powers, facilitating spread (CABI 2012). Gradual unassisted expansion into new areas would be expected.
- Movement of infested plant materials, particularly cucurbits, brassicas and other crop plants, would facilitate longer distance spread within Australia.
- Eggs, larvae and pupae could be transported long distances via soil, leaf litter or other ground material in which they could be sheltering.

4.1.4 Overall probability of entry, establishment and spread

The likelihood that *Aulacophora indica* will enter Australia as a result of trade in island cabbage from any country where this pest is present, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia, is: **VERY LOW**.

4.1.5 Consequences

Assessment of the potential consequences (direct and indirect) of *Aulacophora indica* for Australia is: **LOW**.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level Damage caused by *Aulacophora indica* can sometimes be serious (CABI 2012). Pumpkin beetles can cause severe damage to seedlings (Hely *et al*. 1982), particularly melons, pumpkins and cucumber. The feeding adult beetles chew large holes in the leaves, and may totally defoliate the plants. They sometimes attack the flowers as well. The larvae can also be injurious to cucurbitaceous plants, gnawing at the roots and lower parts of the stem (CABI 2012). Maize and wheat have also been recorded as hosts of *Aulacophora indica*, but the impacts on these crops are not known. Significant impacts of other related pumpkin beetle species on native flora are not reported.
Other aspects of the environment	**Impact score: A** – indiscernible at the local level Direct impacts are limited to effects on plant health (see above). No other direct impacts on the environment associated with *Aulacophora indica* have been reported. There are no reported direct environmental impacts from other pumpkin beetle species in Australia.
Indirect	
Eradication, control etc.	**Impact score: B** – minor significance at the local level Existing measures employed against other pumpkin beetle species would be effective against *Aulacophora indica*. It is important to protect young cucurbit plants from infestation (Hely *et al*. 1982).
Domestic trade	**Impact score: B** – minor significance at the local level Given the similarities of *Aulacophora indica* in host range and pest behaviour to other pumpkin beetle species already present in Australia, additional impacts on domestic trade would not be expected.

Criterion	Estimate and rationale
International trade	**Impact score: B** – minor significance at the local level *Aulacophora indica* is present in much of Asia and the Indian subcontinent, but is absent from the Americas and most of Europe (CABI 2012). Given the similarities of *Aulacophora indica* in host range and pest behaviour to other pumpkin beetle species already present in Australia, additional impacts on international trade would not be expected.
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level There are no significant indirect environmental or non-commercial effects caused by *Aulacophora indica*. Infestations of backyard gardens by pumpkin beetles may result in increased pesticide spraying at a local level. In countries where this pest is present, there are no reported effects other than the direct effects reported above. Similarly, other pumpkin beetles already present in Australia are not known to cause indirect effects on the environment or non-commercial plants.

4.1.6 Unrestricted risk estimate

The unrestricted risk of *Aulacophora indica* is: **VERY LOW**.

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the outcome of overall consequences, using the risk estimation matrix shown in Table 2.5.

The unrestricted risk estimate for *Aulacophora indica* of ‘very low’ achieves Australia’s ALOP. Therefore, specific risk management measures are not required for this pest.

4.2 Rose beetle

Adoretus versutus

Adoretus versutus is a beetle of the Scarabaeidae family. It is a serious polyphagous pest in the South Pacific that attacks a number of crop plants including cocoa, coffee and rose (Walker 2007).

Adoretus versutus has four life stages: egg, larva, pupa and adult beetle. Development is influenced by temperature and the organic matter content of the soil. The eggs are laid individually in the soil, with the female burrowing seven to ten centimetres down to deposit them. Hatching occurs in 12 to 14 days, but can be as little 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 reported to last 12–14, 12–14 and 28–33 days respectively in Samoa. However, in Fiji these larval stages are reported to take up to 120 days in total (Waterhouse and Norris 1987). 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 in breadth (Kumar *et al*. 2009). They are reddish chestnut in colour, and covered with sparse grey decumbent hairs (Kumar *et al*. 2009). 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). The beetles breed all year round in Samoa, but in Fiji the 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.

During the day, the 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. The beetles can do considerable damage to the leaves, perforating them with sieve-like holes or skeletonising them (Waterhouse and Norris 1987). Populations of over 7000 beetles have been reported feeding on a single tree in Samoa. The beetles return to the soil or other shelter before sunrise (Waterhouse and Norris 1987).

Adoretus versutus is native to the Indian subcontinent, originating in India and Sri Lanka. It has spread to a number of countries in the Pacific region, including American Samoa, the Cook Islands, Fiji, Samoa, Tonga, Vanuatu, and the territory of Wallis and Futuna Islands (CABI 2012; Walker 2007). It was first reported in Fiji in 1906, although was likely to have been introduced in the late nineteenth century (CABI 2012). 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).

Adoretus versutus is rarely reported as a pest on the Indian subcontinent, but has become a serious pest in a number of Pacific countries (Waterhouse and Norris 1987). The larvae can attack the roots of sugarcane and other grasses, but it is the adult beetles that do the most economic damage. Severe attacks on the foliage of crops including cocoa, coffee, cowpea, eggplant, fig, ginger, grape, guava, pear, plum and sugarcane, as well as ornamentals such as rose have been reported (Waterhouse and Norris 1987). *Adoretus versutus* is considered to be one of the most damaging pests of Vanuatu and French Polynesia (Waterhouse and Norris 1987) and a serious quarantine risk to islands where it does not already occur (Watt 1986).

4.2.1 Probability of entry

Probability of importation

The likelihood that *Adoretus versutus* will arrive in Australia with the importation of island cabbage from any country where this pest is present is: **VERY LOW**.

- *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 adult beetles feed on the leaves of island cabbage (Stout 1982; Watt 1986). The eggs, larvae and pupae are only found in the soil, and are not associated with the leaves.
- The beetles are nocturnal feeders, only feeding during daylight if released after starvation (Waterhouse and Norris 1987). During the day, they shelter in the soil or under leaf litter, stones and twigs. They are unlikely to be present on the leaves during harvest, and have a very low likelihood of being packed amongst the leaves for export.
- The beetles drop to the ground if disturbed (Waterhouse and Norris 1987), so are unlikely to remain on the leaves during harvest, pre-export handling (such as removal of stems and sorting), and transport prior to export.
- *Adoretus versutus* has a history of accidental introductions to new environments. In the cases of the introductions to Vanuatu and Futuna Island (Territory of the Wallis and Futuna Islands), it is likely that the beetles were transported by boats, attracted by the lights of port facilities at night (Aberlenc *et al*. 2004). Introductions via trade in fresh foliar commodities such as island cabbage are not reported.

Probability of distribution

The likelihood that *Adoretus versutus* will be distributed in Australia, in a viable state, as a result of the processing, sale or disposal of island cabbage from any country where this pest is present, is: **MODERATE.**

- Island cabbage leaves would be distributed to various destinations in Australia, although predominantly to the larger population centres. The leaves are most likely to be sold through small specialty grocery stores and fresh food markets catering for the Asian and Pacific Islander communities.
- Island cabbage leaves are intended for human consumption, so are likely to be transported and stored under conditions that maintain their freshness. This will reduce opportunities for rose beetles to leave the commodity to seek out new hosts for much of the distribution chain. Leaves at wholesale or retail markets may be less secure.
- The majority of island cabbage leaf waste discarded in urban areas is likely to be disposed of via municipal waste management systems and potentially buried amongst other waste. Rose beetles in waste material are unlikely to be dumped in the vicinity of suitable host plants, but adult beetles are capable of flight, and any surviving adults may be able to fly to nearby vegetation.

- A small amount may be disposed of through backyard composting. Rose beetles present on island cabbage leaves that are discarded in the environment may disperse to new hosts.
- *Adoretus versutus* feeds on a wide range of plants, many of which are common in Australia.
- *Adoretus versutus* beetles drop to the ground if disturbed (Waterhouse and Norris 1987), so are likely to fly from the island cabbage at the earliest opportunity to seek shelter or find a host. They are unlikely to be on the island cabbage leaves at the point of retail sale to consumers.
- The beetles are nocturnal, and if exposed to bright light they will seek shelter. Beetles may remain hidden in bundles of leaves, but are likely to emerge if leaves are stored in the dark (e.g. in freight containers, warehouses).

Overall probability of entry (importation x distribution)

The likelihood that *Adoretus versutus* will enter Australia and be distributed in a viable state to a suitable host, as a result of trade in island cabbage from any country where this pest is present, is: **VERY LOW**.

4.2.2 Probability of establishment

The likelihood that *Adoretus versutus* will establish in Australia, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction, is: **MODERATE**.

- *Adoretus versutus* established in Fiji, Samoa, Tonga, Vanuatu, Futuna Island (Territory of the Wallis and Futuna Islands), and some islands in French Polynesia following accidental introductions (Jackson and Klein 2006; Waterhouse and Norris 1987). The beetle has more recently established in New Caledonia, but has yet to become a pest there (Aberlenc *et al.* 2004).
- This pest has a mostly tropical distribution, with its southerly limits being the Cook Islands and Tonga in the Pacific and Réunion Island in the Indian Ocean. It is likely that the beetle could establish in much of northern Australia where suitable hosts and adequate rainfall were present.
- The beetle's lifecycle is influenced by climatic factors such as temperature and monsoonal rains (Kumar *et al*. 2009). The beetle develops much faster in Samoa (78–89 days from egg to emergence of adult) than it does in Fiji (where the larval instar stages alone take around 120 days) (Waterhouse and Norris 1987). Fiji has a moderately cooler and more varied climate. Much of southern Australia would have an unsuitable climate for the rose beetle, which would make establishment difficult.
- Establishment would be less likely in areas with dry soils with little organic material. The larvae prefer moist soils, and feed on roots, manure and other organic matter in the soil (Waterhouse and Norris 1987).

4.2.3 Probability of spread

The likelihood that *Adoretus versutus* will spread throughout Australia, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest, is: **MODERATE**.

- Once established, the rose beetle is likely to spread, although probably restricted to parts of northern Australia that have a suitable climate.
- *Adoretus versutus* is a polyphagous species that feeds on a large range of host plants. Many of these plants are common and widely distributed within Australia, such as apple, avocado, banana, beans, cashew, citrus, fig, ginger, grape, pear, plum, rose, sorghum and sugarcane (CABI 2012).
- The adult beetles are capable of flight. They are unlikely to travel considerable distances if host plants are available, but a gradual unassisted expansion into new areas would be expected.
- Adult rose beetles are phototactic at night, and habitually visit artificial lights (Waterhouse and Norris 1987). The beetles may alight on trucks or other vehicles if attracted by lights, enabling longer distance spread. It is likely that the beetles were introduced to Vanuatu and Futuna Island after they were attracted to illuminated port facilities and landed on boats destined for these islands (Aberlenc *et al.* 2004).
- Eggs, larvae, pupae and adult beetles could be transported long distances via movement of soil, leaf litter or other ground material in which they could be sheltering.

4.2.4 Overall probability of entry, establishment and spread

The likelihood that *Adoretus versutus* will enter Australia as a result of trade in island cabbage from any country where this pest is present, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia, is: **VERY LOW**.

4.2.5 Consequences

Assessment of the potential consequences (direct and indirect) of *Adoretus versutus* for Australia is: **MODERATE**.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** – major significance at the district level *Adoretus versutus* feeds on many plants including apple, avocado, banana, beans, cashew, citrus, fig, ginger, grape, pear, plum, rose, sorghum, sugarcane and taro (Waterhouse and Norris 1987; Aberlenc *et al*. 2004). The larvae are generally not considered to be significant pests, but do occasionally cause minor damage to the roots of sugarcane and grasses (Waterhouse and Norris 1987). Rose beetles could potentially affect native flora such as acacia species. The adult beetles mainly feed on the leaves of host plants, but also damage the flowers of ornamentals such as rose (Kumar *et al.* 2009). The adult beetles can severely damage plants, with a report from Fiji of up to 90 percent of cocoa seedlings in a crop being damaged, with 10–15 percent of the young trees dying (CABI 2012). Damage of up to 80 percent has been reported for a ginger crop in Tonga (CABI 2012). However, damage is usually localised (Waterhouse and Norris 1987).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level Direct impacts are limited to effects on plant health (see above). No other direct impacts on the environment associated with rose beetles have been reported.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level The rose beetle is very difficult to control, as the immature stages mostly live underground, and the adult beetles shelter in the soil or under leaf litter during the day. There are no practical measures available to attack the underground stages (Waterhouse and Norris 1987). Insecticide spraying of soil and young plants has been attempted, using dieldrin, DDT, BHC, aldrin, carbaryl, malathion, diazinon, acephate or permethrin. Cultural methods such as erecting protective structures around seedlings or manually removing beetles at night can be effective, but are only feasible at a domestic level, or where labour is cheap (Waterhouse and Norris 1987).
Domestic trade	**Impact score: D** – minor significance at the region level There may be some interstate restrictions on movement of some commodities if the rose beetle established in Australia.
International trade	**Impact score: D** – minor significance at the region level *Adoretus versutus* is a quarantine pest for many countries, which could affect access to overseas markets for a number of commodities known to be hosts of this pest. The rose beetle is absent from many of Australia's major export markets, and this species would affect many horticulture crops grown in Australia.
Environmental and non-commercial	**Impact score: B** – minor significance at the local level There are no significant indirect environmental or non-commercial effects caused by the rose beetle. The use of pesticides to control this pest may have a minor impact on the environment at a local level.

4.2.6 Unrestricted risk estimate

The unrestricted risk of *Adoretus versutus* is: **VERY LOW**.

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the outcome of overall consequences, using the risk estimation matrix shown in Table 2.5.

The unrestricted risk estimate for *Adoretus versutus* of 'very low' achieves Australia's ALOP. Therefore, specific risk management measures are not required for this pest.

4.3 Coreid bugs

Amblypelta cocophaga

Brachylybas variegatus

These coreid bug species have been grouped for this assessment due to their similar biology.

Amblypelta cocophaga and *Brachylybas variegatus* belong to the family Coreidae, commonly known as true bugs or leaf-footed bugs. The family contains at least 250 genera and 1800 species. Coreid bugs are found worldwide but are most abundant in the tropics and sub-tropics (Schuh and Slater 1996). Relatively few species of coreid bugs are of economic importance. Species that have caused significant crops losses attack grain, legumes, garden vegetables, soft fruits and nuts (Cassis and Gross 1995; Mitchell 2000). Two subspecies of *Amblypelta cocophaga* have been described: *Amblypelta cocophaga cocophaga* and *Amblypelta cocophaga malaitensis* (Brown 1958a; Mitchell 2000).

Amblypelta cocophaga has three life stages: egg, nymph (with five instars) and adult (Phillips 1940). Adult *Amblypelta cocophaga* have a pale green head, dark brown eyes and are 15 mm long (China 1934).

Mating occurs 9–14 days after adult emergence. The female will produce more than 100 eggs over two months (Phillips 1940; Mitchell 2000). Oviposition begins a few days after mating, usually 15–19 days after female emergence. The eggs are laid singly on or near the host plant. On coconut, the eggs are laid on the underside of the palm fronds, rarely with more than a single egg on each frond (Brown 1959). Brown (1959) reported up to 26 eggs per plant on coconut palms examined in Solomon Islands. However, a high proportion (70–80 percent) of the eggs either failed to hatch or were parasitised or damaged (Brown 1959). It is not known if this oviposition behaviour occurs on island cabbage or other host plants, although Brown (1959) does report *Amblypelta cocophaga* eggs being laid singly under the petioles on cassava stems.

The eggs hatch after six or seven days. First instar nymphs can survive and moult without any food, but require water. The first instar stage lasts 3–4 days, the second, third and fourth instar stages each last for around 6–7 days, while the fifth instar stage is 7–8 days. The total life span of *Amblypelta cocophaga* is approximately 12–13 weeks (Phillips 1940).

Limited information on the lifecycle of *Brachylybas variegatus* is available. However, like other species in the genus, *Brachylybas variegatus* is likely to have three life stages: egg, nymph (with five instars) and adult.

Adults of *Amblypelta cocophaga* are capable of active flight and do not feed in one spot for long periods (Bigger 1985). *Amblypelta* spp. adults migrate from breeding sites in adjacent native habitats to feed on crop plants (Waite and Huwer 1998). The *Amblypelta cocophaga* nymphs do not have wings (Phillips 1940), but they are active crawlers.

Most coreid bugs feed on plant vascular systems (Schuh and Slater 1996). *Amblypelta cocophaga* attacks a wide variety of plants including coconut, cacao and eucalypts (Phillips 1940; Brown 1958b; Bigger 1985). Brown (1958b) published a detailed plant host list for *Amblypelta cocophaga*. *Brachylybas variegatus* has been reported as a pest of taro, pumpkin, tomato and giant passionfruit in Fiji (Lever 1947).

Amblypelta species feed on the fruit, stem and petiole of hosts. A sunken brown scar may develop around the feeding area on fruit, and some fruit may drop prematurely (Brown 1958b). Feeding on the stem causes wilting of the shoot; shoots that survive feeding may develop cankerous symptoms. If the damage is severe, lateral shoots may grow to replace the damaged terminal shoot (Brown 1958b; Mitchell 2000). Feeding on pawpaw petioles results in cracks up to 10 cm long, while on cassava feeding on the petioles causes pronounced drooping of the leaves (Brown 1958b).

Several authors have observed the impacts on host plants caused by *Amblypelta* species is disproportionate to both the direct damage caused by feeding and the number of insects feeding on the host. *Amblypelta cocophaga* has been reported to cause severe immature coconut fall with less than one insect per tree (Brown 1958b; Brown 1959). Some *Eucalyptus* timber plantations in Solomon Islands had to be abandoned as a result of damage from *Amblypelta cocophaga* (Bigger 1985).

Coreid bugs are not known to transmit viruses, but have been implicated in the infection of plants by other pathogens. Feeding wounds caused by coreid bugs leave the plant vulnerable to infection by fungi and bacteria (Mitchell 2000).

4.3.1 Probability of entry

Probability of importation

The likelihood that *Amblypelta cocophaga* or *Brachylybas variegatus* will arrive in Australia with the importation of island cabbage from any country where these pests are present is: **MODERATE**.

- *Amblypelta cocophaga* and *Brachylybas variegatus* have been recorded in Fiji (Lever 1947; Brown 1958a). *Brachylybas variegatus* is also reported to be present in Tonga (Engelberger and Foliaki 1992).
- Both *Amblypelta cocophaga* and *Brachylybas variegatus* have been reported in association with island cabbage (French 2006; Walton 1986; Engelberger and Foliaki 1992).
- Coreid bugs mainly feed on leaves, shoots and fruits. All coreid bug life stages may be found on foliage of host plants (Stout 1982; Carver *et al*. 1991; Mitchell 2000).
- Adults of *Amblypelta cocophaga* are winged and actively fly (Bigger 1985). The adults are likely to be disturbed during harvesting and handling, so are unlikely to remain on the leaves during preparation for export.
- Coreid bugs (particularly nymphs and eggs) that are not removed during harvesting, cleaning, bundling of leaves etc, may survive and remain viable on the commodity, particularly if free moisture is available. *Amblypelta cocophaga* females lay single eggs on the leaves of host plants, so it is likely that eggs would only be present in small numbers. The eggs are around 2.5 mm in length (Brown 1959) and easily visible to the naked eye, but may escape detection.
- Damage to host plants is apparent on immature coconuts, cacao and potted legumes attacked by *Amblypelta cocophaga* (Phillips 1940; Brown 1958b). Island cabbage leaves showing obvious signs of feeding damage are likely to be removed from consignments being prepared for export, thereby excluding the coreid bugs from the pathway.

- Island cabbage leaves wilt easily. Various methods are applied to extend the shelf life of leaves including ventilation and keeping them cool, as well as wrapping them in banana leaves or plastic (Preston 1998). This is unlikely to adversely affect any coreid bugs present on the commodity, and may assist their survival by retaining moisture.

Probability of distribution

The likelihood that *Amblypelta cocophaga* or *Brachylybas variegatus* will be distributed in Australia, in a viable state, as a result of the processing, sale or disposal of island cabbage from any country where these pests are present, is: **MODERATE.**

- Island cabbage leaves would be distributed to various destinations in Australia, although predominantly to the larger population centres. The leaves are most likely to be sold through small specialty grocery stores and fresh food markets catering for the Asian and Pacific Islander communities.
- Island cabbage leaves are intended for human consumption, so are likely to be transported and stored under conditions that maintain their freshness. This will limit opportunities for coreid bugs to leave the commodity to seek out new hosts.
- Coreid bugs on island cabbage leaves that are discarded in the environment may disperse to new hosts.
- The majority of island cabbage leaf waste discarded in urban areas is likely to be disposed of via municipal waste management systems and potentially buried amongst other waste. Coreid bugs in waste material are unlikely to be dumped in the vicinity of suitable host plants, but adult bugs are capable of flight, and any surviving adults may be able to fly to nearby vegetation.
- Some island cabbage leaves may be disposed of through backyard composting. Adult *Amblypelta cocophaga* are capable of active flight (Bigger 1985). *Amblypelta* spp. adults migrate from breeding sites in adjacent native habitats to crops (Waite and Huwer 1998). Adult coreid bugs introduced into the environment would be able to fly to nearby host plants.
- Nymphs of *Amblypelta cocophaga* do not have wings (Phillips 1940), but are active crawlers. They have limited ability to disperse under their own locomotion to seek out new host plants.
- Both *Amblypelta cocophaga* and *Brachylybas variegatus* have broad host ranges. Hosts include coconut, fig, pawpaw, sugarcane, passionfruit, taro, pumpkin, tomato and eucalypts (Lever 1947; Brown 1958b; Bigger 1985). Many of these hosts are popular garden plants commonly found in urban and semi-urban environments, or agricultural crops that may be widely distributed throughout Australia. Eucalypts are significant potential hosts because foliage is available all year (Waite and Huwer 1998).

Overall probability of entry (importation x distribution)

The likelihood that *Amblypelta cocophaga* or *Brachylybas variegatus* will enter Australia and be distributed in a viable state to a suitable host, as a result of trade in island cabbage from any country where these pests are present, is: **LOW**.

4.3.2 Probability of establishment

The likelihood that *Amblypelta cocophaga* or *Brachylybas variegatus* will establish in Australia, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction, is: **LOW**.

- Coreids reproduce sexually. Establishment would require both reproductively viable female and male bugs to be present at the same time in close proximity.
- Alternatively, entry of an adult mated female capable of producing male and female offspring in the one generation could also result in establishment of a population. Egg laying in *Amblypelta cocophaga* begins about a week after mating, but the female will produce more than 100 eggs over two months (Phillips 1940; Mitchell 2000). This scenario is considered to be less likely as adult bugs would have a much lower likelihood of being present on the imported leaves. Adult bugs are active fliers that would flee at harvest or during pre-export preparation of the commodity.
- Nymphs (probably imported as eggs) are the most likely life stage to be distributed to suitable hosts on which they could complete development and reproduce to establish a population.
- It is likely that nymphs would only ever be present in very small numbers, as *Amblypelta cocophaga* eggs are laid singly on the leaves, and a high proportion fail to hatch (Brown 1959). This reduces the likelihood that both males and females would successfully find hosts, survive to complete development and be able to locate each other for mating to occur.
- Newly hatched nymphs would need to survive for at least six weeks before reaching the adult stage where they would be capable of reproduction.
- Adult coreids can overwinter in temperate regions, and overwintering eggs have been reported in some coreids (Mitchell 2000). The ability to overwinter enables coreid bugs to survive unfavourable conditions, increasing the likelihood of establishment.
- *Amblypelta cocophaga* and *Brachylybas variegatus* are tropical species. Tropical and sub-tropical areas of Australia may provide suitable climatic conditions to support the survival of these coreid bugs. Establishment in the cooler parts of southern Australia is less likely.
- Two subspecies of *Amblypelta cocophaga* have been described (Brown 1958a; Mitchell 2000). It is unclear if the morphological features separating these subspecies confer any survival advantage.
- There are few known natural predators of *Amblypelta cocophaga*, the most significant being ants and egg parasitoids (Phillips 1940). The ant *Oecophylla smaragdina* protects coconut palms from *Amblypelta cocophaga* nymphs and adults (Phillips 1940; Mitchell 2000). This ant is present in northern Australia (Shattuck 2008), which may reduce the likelihood of establishment of *Amblypelta cocophaga* if it were introduced into that region. No predators of *Brachylybas variegatus* have been reported in the available scientific literature.

4.3.3 Probability of spread

The likelihood that *Amblypelta cocophaga* or *Brachylybas variegatus* will spread throughout Australia, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest, is: **HIGH**.

- Once established, *Amblypelta cocophaga* and *Brachylybas variegatus* are likely to spread.
- The number of coreid bug generations per year varies according to species, geographic location, and the host plant suitability (Mitchell 2000).
- Adult coreids can overwinter in temperate zones, and in some species the eggs can also overwinter (Mitchell 2000). Coreid bugs are predominantly tropical and subtropical species, but may spread into temperate areas where hosts are abundant.
- Many coreid hosts are horticultural crops that are widely distributed throughout Australia.
- The known host range for *Amblypelta cocophaga* consists of 43 plant species in 30 families, but is estimated to be much greater than the current published list (Waite and Huwer 1998). It includes coconut, fig, pawpaw, sugarcane, passionfruit and eucalypts (Brown 1958b; Bigger 1985).
- The known host range for *Brachylybas variegatus* includes taro, pumpkin, tomato and passionfruit (Lever 1947).
- The adults of *Amblypelta* spp. are suspected of migrating to crops from breeding sites in adjacent native habitats (Waite and Huwer 1998). Adult coreids are likely to disperse without human assistance once established in Australia.
- Spread may be slowed by the presence of natural predators such as the ant *Oecophylla smaragdina*, which is found across northern Australia (Shattuck 2008) and known to attack *Amblypelta cocophaga* (Phillips 1940).

4.3.4 Overall probability of entry, establishment and spread

The likelihood that *Amblypelta cocophaga* or *Brachylybas variegatus* will enter Australia as a result of trade in island cabbage from any country where these pests are present, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia, is: **VERY LOW**.

4.3.5 Consequences

Assessment of the potential consequences (direct and indirect) of *Amblypelta cocophaga* and *Brachylybas variegatus* for Australia is: **MODERATE**.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** – significant at the regional level Both *Amblypelta cocophaga* and *Brachylybas variegatus* feed on a wide variety of hosts including important agricultural crops and popular garden fruits and vegetables (Lever 1947; Brown 1958b). *Amblypelta* spp. feeding on host fruit typically produces a sunken brown scar around the feeding entry, with some fruits dropping prematurely (Brown 1958b). *Amblypelta* spp. feeding on stems can result in wilting of damaged shoots, while others may develop cankerous symptoms. If damage is severe, lateral shoots may grow to replace the damaged terminal shoot (Brown 1958b; Mitchell 2000). *Eucalyptus* plantations in Solomon Islands have been abandoned due to feeding damage caused by *Amblypelta cocophaga* (Bigger 1985). *Eucalyptus* species form a major component of Australia's natural environment and occur throughout Australia, so native ecosystems could also be affected. Several authors have observed the damage caused by *Amblypelta* is disproportionate to the number of bugs feeding on a host. *Amblypelta cocophaga* can cause severe immature coconut fall with less than one active stage of insect per palm tree (Brown 1958b; Brown 1959).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level Direct impacts are limited to effects on plant health (see above). No other direct impacts on the environment associated with *Amblypelta cocophaga* and *Brachylybas variegatus* have been reported.
Indirect	
Eradication, control etc.	**Impact score: C** – minor significance at the district level Eradication of *Amblypelta cocophaga* and *Brachylybas variegatus* may not be possible, but temporary localised control is feasible. Treating infested crops is unlikely to eradicate or control the pests permanently, as adults are likely to subsequently migrate from alternative breeding sites and re-infest these crops (Phillips 1940; Waite and Huwer 1998). It is unlikely that coreid bugs infesting native eucalypts or other wild plants would be subject to control on a large scale. In coconut palms, females often lay their eggs on the underside of leaves. The oviposition site may be protected from some chemical treatments (Brown 1959).
Domestic trade	**Impact score: B** – minor significance at the local level *Amblypelta cocophaga* and *Brachylybas variegatus* feed on a wide variety of hosts including important agricultural crops and popular garden vegetable and fruit varieties (Lever 1947; Brown 1958b). The presence of these coreid bugs in Australia may result in some damage to crops but is unlikely to affect domestic trade. Movement of fresh produce is not currently restricted by the presence of closely related species already present in Australia.
International trade	**Impact score: C** – minor significance at the district level The establishment and spread of *Amblypelta cocophaga* and *Brachylybas variegatus* in Australia may affect international trade, but significant impacts are not anticipated. Some export commodities may require additional phytosanitary measures to mitigate the presence of coreid bugs.
Environmental and non-commercial	**Impact score: B** – minor significance at the local level Native plantations are an important component of ground water stabilisation to prevent salinity. Effects of feeding by *Amblypelta cocophaga* on plantations could have localised indirect environmental consequences.

4.3.6 Unrestricted risk estimate

The unrestricted risk of *Amblypelta cocophaga* and *Brachylybas variegatus* is: **VERY LOW**.

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the outcome of overall consequences, using the risk estimation matrix shown in Table 2.5.

The unrestricted risk estimate for *Amblypelta cocophaga* and *Brachylybas variegatus* of 'very low' achieves Australia's ALOP. Therefore, specific risk management measures are not required for this pest.

4.4 Whitefly

Bemisia tabaci 'Nauru' biotype

The whitefly is a phloem-feeding insect that lives predominantly on herbaceous plants (De Barro *et al*. 2011). It has become a serious agricultural pest of numerous vegetable, ornamental, grain and cotton crops in many parts of the world. It causes damage directly by feeding on plant hosts, which can result in irreversible physiological disorders, as well as indirect damage caused by vectoring of begomoviruses, and honeydew contamination, which encourages growth of sooty mould (De Barro *et al*. 1998).

The whitefly was first reported as a pest in 1889, but was generally considered to be relatively unimportant until the mid- to late 1970s, when a serious outbreak was first reported in Sudan, followed by an outbreak in the south-western United States in the early 1980s (De Barro *et al*. 2011). There was a major global invasion event in the late 1980s, facilitated by the trade in ornamental plants from the Middle East/Asia Minor, affecting at least 54 countries (De Barro *et al*. 2011).

It was apparent from these major outbreaks that the invading *Bemisia tabaci* behaved quite differently from indigenous populations, having different host ranges and being reproductively incompatible. Different biotypes were recognised, defined by a range of biological characteristics, including host range, fecundity, insecticide resistance, the capacity to disperse widely, the capacity to transmit begomoviruses, capacity to induce silverleafing and yellow vein in hosts, and the capacity to produce female offspring after inter-biotype mating (Hsieh *et al*. 2006; De Barro *et al*. 2011). At least 24 morphologically indistinguishable species have been recognised, which De Barro *et al*. (2011) have grouped into 11 well-defined high-level groups using phylogenetic analysis of DNA sequences.

The 'B' biotype is the most widely distributed of the *Bemisia tabaci* types, and the most devastating as a pest of agriculture. The 'B' biotype was first detected in Australia in 1994, and has become a major production constraint on a wide variety of horticultural, summer grain, oilseed and fibre crops, particularly cotton, in coastal Queensland and New South Wales (Sequeira *et al*. 2009). The 'Q' biotype was identified in north Queensland in late 2008 and in north western NSW in 2009 (DEEDI 2009). Additionally, the Australasian ('An') *Bemisia tabaci* biotype, which is likely to have originated in the Australasian region, is also present in the northern half of Australia (De Barro *et al*. 1998).

The 'Nauru' biotype has a wider host range than the 'An' biotype, and has been found on at least 29 species of wild plants, vegetables and ornamentals from 11 plant families in the Pacific (De Barro *et al*. 1998). The 'B' biotype has a much greater host range (CABI 2012). The 'B' biotype differs from the 'Nauru', 'An' and 'Q' biotypes in its capacity to induce physiological changes to its host plants, most significantly causing silverleafing in squash (De Barro *et al*. 2011).

The 'Nauru' biotype originated in Asia (Hsieh *et al*. 2006) but has spread to a number of Pacific countries including Fiji, Tonga, Samoa, American Samoa, Niue, Tuvalu, Kiribati, Nauru, Marshall Islands, Federated States of Micronesia (Pohnpei), Palau, Guam and Northern Mariana Islands (De Barro *et al*. 1998).

Whiteflies have six life stages – the egg, four nymphal stages and the adult. The adult female whitefly lays her eggs in circular groups on the underside of the leaves. The eggs are deposited into the mesophyll of the leaf tissue (Mau *et al*. 2007). Each female lays up to 160 eggs (CABI 2012). The length of time before hatching is influenced by the host plant species, temperature and humidity, but is usually around 5–9 days at 30 °C (CABI 2012). There are four nymphal stages in the lifecycle. The first three instar stages last around 2–4 days each, and the final pupation stage takes around six days (CABI 2012). The first instar crawler is the only mobile larval stage. Within a few days, it locates a suitable feeding location on the lower leaf surface where it undergoes its first moult, losing its legs in the process (EPPO 2012a). It is sessile for the remaining three nymphal stages, the last of which is a puparium in which metamorphosis into the adult occurs.

The adult female may live for up to 60 days, while males only live for around 9–17 days. The adult stage usually emerges from the pupal case in the morning (Mau *et al*. 2007). They can begin mating 12–20 hours after emergence, and will usually mate several times during their lifetime. However, reproduction can occur without copulation, with unmated females reproducing by parthenogenesis, which typically produces only male progeny (Mau *et al*. 2007). A generation can be completed in two to three weeks (De Barro 2005), with up to 15 overlapping generations occurring within one year (CABI 2012).

4.4.1 Probability of entry

Probability of importation

The likelihood that *Bemisia tabaci* 'Nauru' biotype will arrive in Australia with the importation of island cabbage from any country where this pest is present is: **HIGH**.

- *Bemisia tabaci* 'Nauru' biotype has been reported on island cabbage in Tonga (Engelberger and Foliaki 1992).
- *Bemisia tabaci* 'Nauru' biotype is present in a number of Pacific countries where island cabbage is grown including Fiji, Samoa and Tonga (De Barro *et al*. 1998).
- Eggs are laid in circular groups on the underside of the leaves (CABI 2012). The length of time before hatching is influenced by the host plant species, temperature and humidity, but is usually around 5–9 days at 30 °C (CABI 2012). Eggs laid shortly before harvest may not hatch until after arrival in Australia.
- Whitefly development occurs at temperatures between 10 °C and 32 °C, with an optimum of 27 °C (Mau *et al*. 2007). Low temperatures increase egg mortality. The impact on the whiteflies due to chilling or refrigeration of the leaves during transit is unknown, but it may slow development.
- The nymphs are 0.3–0.6 mm in length (CABI 2012) and creamy white to light green in colour (Mau *et al*. 2007), so may be difficult to spot on the leaf surface. The puparium is around 0.7 mm in length (CABI 2012).
- The adult whiteflies are around 1 mm in length, with a pale yellow body and two pairs of white wings (Mau *et al*. 2007). Adults may fly off the leaves if disturbed when the leaves are harvested.

Probability of distribution

The likelihood that *Bemisia tabaci* 'Nauru' biotype will be distributed in Australia, in a viable state, as a result of the processing, sale or disposal of island cabbage from any country where this pest is present, is: **MODERATE**.

- Island cabbage leaves would be distributed to various destinations in Australia, although predominantly to the larger population centres. The leaves are most likely to be sold through small specialty grocery stores and fresh food markets catering for the Asian and Pacific Islander communities.
- Some island cabbage leaves will be discarded as waste. Disposal of waste is likely to be via municipal or commercial waste systems, where pests would have limited opportunity to be in the proximity of host plants.
- The only active stages are the first instar nymphs and the adults.
- Newly hatched crawlers do not typically move any significant distance from where they hatched. They could possibly wander off the island cabbage leaves, but do not have the capacity to move significant distances to locate a suitable host.
- The second, third and fourth instar nymphs are sessile, and likely to remain on the leaves throughout the distribution chain, as they do not have legs. These life stages cannot locate or move onto a new host.
- Adult whiteflies do not fly very efficiently, but once airborne they can be transported several kilometres by the wind (De Barro 2005; EPPO 2012a; Mau *et al*. 2007). The direction of flight is primarily dictated by the wind. Whiteflies land on particular plants mostly by chance, electing to stay on suitable hosts, or moving on from those that are not to seek another host (Mau *et al*. 2007).
- In the Pacific region, *Bemisia tabaci* (‘Nauru’ biotype) is known to feed on at least 29 host plant species from eleven plant families (De Barro *et al*. 1998). It is reported from an additional 16 host species and another five plant families in Taiwan (Hsieh *et al*. 2006).
- Known plant hosts that are grown commercially and in household gardens in Australia include *Cucumis sativus* (cucumber), *Cucurbita moschata* (gramma trombone squash), *Lycopersicon esculentum* (tomato) and *Solanum melongena* (eggplant) (De Barro *et al*. 1998; Hsieh *et al*. 2006).
- Other plant hosts are common weeds in many parts of Australia, including *Achyranthes bidentata*, *Ageratum houstonianum*, *Bidens pilosa*, *Boehmeria nivea*, *Emilia sonchifolia*, *Hibiscus sabdariffa*, *Humulus japonicus*, *Ipomoea acuminata*, *Lantana camara*, *Sonchus oleraceus* and *Xanthium strumarium* (Hsieh *et al*. 2006; Randall 2007).
- Given the range of plant hosts that are common in many parts of Australia, whiteflies that enter the environment via imported island cabbage leaves could potentially locate a new host.

Overall probability of entry (importation x distribution)

The likelihood that *Bemisia tabaci* ‘Nauru’ biotype will enter Australia and be distributed in a viable state to a suitable host, as a result of trade in island cabbage from any country where this pest is present, is: **MODERATE**.

4.4.2 Probability of establishment

The likelihood that *Bemisia tabaci* ‘Nauru’ biotype will establish in Australia, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction, is: **HIGH**.

- *Bemisia tabaci* ('Nauru' biotype) originated in Asia (Hsieh *et al*. 2006) but has established in a number of Pacific countries including Fiji, Tonga, Samoa, American Samoa, Niue, Tuvalu, Kiribati, Nauru, Marshall Islands, Pohnpei (Federated States of Micronesia), Palau, Guam and Northern Marianas (De Barro *et al*. 1998).
- *Bemisia tabaci* has a history of establishing in new environments via trade in planting materials, foliage and cut flowers (EPPO 2012a).
- Reproduction can occur without mating (Mau *et al*. 2007), so a single female could potentially establish a population.
- There is no firm evidence to indicate a capacity for the 'Nauru' biotype to successfully interbreed with the other biotypes (An, B, Q) that are already present in Australia, but a partial mating compatibility may be possible. Mating studies with other biotypes suggest a very low rate of interbreeding, with such events typically producing sterile female progeny (De Barro *et al*. 2011).

4.4.3 Probability of spread

The likelihood that *Bemisia tabaci* 'Nauru' biotype will spread throughout Australia, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest, is: **HIGH**.

- Once established, *Bemisia tabaci* 'Nauru' biotype is likely to spread. The 'Nauru' biotype is the most common whitefly biotype found in the Pacific, and has spread through much of the Pacific region (De Barro *et al*. 1998).
- The *Bemisia tabaci* 'B' biotype has already spread widely in Australia following its introduction in 1994. The 'Nauru' biotype has a broad host range, so a similar spread may be possible.
- Known plant hosts of the 'Nauru' biotype are common and widespread in Australia.
- *Bemisia tabaci* can disperse by short flights, but can be passively carried over distances of many kilometres by air currents (Mau *et al*. 2007).
- Transportation on ornamental plants is the major means of spread over long distances (DEEDI 2009). The international spread of *Bemisia tabaci* largely occurred via the trade in ornamental plants, particularly *Euphorbia pulcherrima* (poinsettia) (De Barro *et al*. 1998). Movement of infested plant material within Australia would facilitate the spread of whiteflies.

4.4.4 Overall probability of entry, establishment and spread

The likelihood that *Bemisia tabaci* 'Nauru' biotype will enter Australia as a result of trade in island cabbage from any country where this pest is present, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia, is: **MODERATE**.

4.4.5 Consequences

Assessment of the potential consequences (direct and indirect) of *Bemisia tabaci* 'Nauru' biotype for Australia is: **MODERATE**.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** – significant at the regional level Feeding by the 'Nauru' biotype whitefly does not induce the damaging physiological changes to host plants normally associated with the 'B' biotype. Damage would not be more severe, or affect more plant hosts, than that already caused by other closely related whiteflies in Australia. However, feeding and production of honeydew still affects the vitality of host plants. Feeding by adults and nymphs causes chlorotic spots to appear on the leaf surface. Honeydew produced by the nymphs disfigures flowers and covers the leaf surface, encouraging mould growth, which reduces the plant's photosynthetic potential (EPPO 2012a). *Bemisia tabaci* is also known to be a vector of more than 60 plant viruses, particularly begomoviruses (formerly known as geminiviruses) (De Barro *et al*. 2011; EPPO 2012a). Begomoviruses cause a range of symptoms including yellow mosaics, yellow veining, leaf curling, stunting and vein thickening (EPPO 2012a). Whilst viruses specifically vectored by the 'Nauru' biotype have not been identified, most biotypes are likely to transmit most viruses that are associated with *Bemisia tabaci* (De Barro *et al.* 2011). The major begomoviruses vectored by *Bemisia tabaci* in Europe, North America and Africa are not known to be present in the Pacific (Davis and Ruabete 2010), although little, if any, research has been done on begomoviruses in the Pacific Islands. Other exotic plant viruses could potentially be introduced, and viruses already present in Australia could increase their range with the introduction of a new vector.
Other aspects of the environment	**Impact score: A** – indiscernible at the local level Direct impacts are limited to effects on plant health (see above). No other direct impacts on the environment associated with *Bemisia tabaci* have been reported.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level Control of *Bemisia tabaci* is very difficult. Resistance to pesticides is a common problem in managing whitefly populations. Several parasites attack *Bemisia tabaci*, but attempts at biological control have not sufficiently brought infestation levels down to level that stops virus transmission (EPPO 2012a).
Domestic trade	**Impact score: B** – minor significance at the local level Establishment of this pest would possibly elicit controls on the movement of produce to prevent spread, although efforts to contain other whitefly biotypes have been ineffective. Many potential hosts are already subject to restrictions in Tasmania to mitigate the *Bemisia tabaci* B biotype.
International trade	**Impact score: C** – minor significance at the district level Establishment of this pest in Australia may result in additional measures being imposed on Australian exports of some fresh commodities in markets where the pest is not already present, including Europe and the Americas.
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level There is no evidence to indicate that *Bemisia tabaci* would have significant indirect impacts on the environment or non-commercial activities. Potential impacts to plant life are likely to be minor and localised, and would not result in discernible changes to plant communities, ecological processes or human recreational uses.

4.4.6 Unrestricted risk estimate

The unrestricted risk of *Bemisia tabaci* 'Nauru' biotype is: **MODERATE**.

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the outcome of overall consequences, using the risk estimation matrix shown in Table 2.5.

The unrestricted risk estimate for *Bemisia tabaci* 'Nauru' biotype of 'moderate' exceeds Australia's ALOP. Therefore, specific risk management measures are required for this pest.

4.5 Tortoise scale

Coccus capparidis

Coccus capparidis, the tortoise scale or capparis soft scale, is a sap-sucking insect in the Coccidae family, which are closely related to mealybugs and armoured scales. Although soft scales lack the protective covering of the armoured scales, their skin is hardened by a wax-like secretion, forming a shell that cannot be separated from the scale (Fasulo and Brooks 2004). There are at least 1090 described soft scale species, which are most abundant in the tropics and subtropics (Hodgson 1994). In warm climates, many soft scales are capable of rapid reproduction, and may have several overlapping generations.

Soft scales mainly feed on perennial plants, particularly woody plants, and a number are important pests in agriculture, horticulture and forestry (Hodgson 1994). Scales feed on foliage, fruit and twigs of host plants. The depletion of sap by scale feeding reduces the vigour of host plants (Fasulo and Brooks 2004), which may also be affected by toxins introduced by the scales. Additionally, soft scales produce honeydew that is forcibly ejected over the foliage of the host. This provides a substrate for the growth of sooty moulds, which reduces the photosynthetic rate of the host plant (Hodgson 1994).

Adult soft scales grow in size and often change in appearance between maturation and the completion of oviposition (Gill 1988). However, soft scale species of the *Coccus* genus, including *Coccus capparidis*, are viviparous or ovoviviparous (Williams and Watson 1990), giving birth to either live nymphs or nymphs covered in a thin membranous envelope that hatch within a few minutes (CABI 2012).

The females of most scale species undergo three nymphal instar stages. The immature third instar females are very similar in appearance to the adults (Williams 1997). All stages have well developed legs and are capable of moving from one location to another (Gill 1988). The first instar ‘crawler’ is the dispersal stage and generally the most active (Williams 1997). The principal natural means of dispersal from one host plant to another within an area and between habitats is transport of crawlers on air currents (Greathead 1997). Crawlers emerge from beneath the female shortly after dawn. In most soft scale species, the crawlers wander for less than a day before settling (Greathead 1997). The crawlers move up the plant to feed on the younger leaves, where they are also more likely to be dislodged by air currents (Greathead 1997).

Development of soft scales is influenced by climatic conditions. In cooler regions, there may only be one generation annually, with the eggs and crawlers (first instar nymphs) being produced in spring and summer. The immature scales then overwinter on twigs as third instar nymphs, reaching the adult stage in the following spring (Gill 1988). In warmer regions, or in greenhouses, there is no overwintering stage, and there may be multiple generations per year (Gill 1988).

Adult females of *Coccus capparidis* are up to 3.6 mm in length, broadly oval in shape and bright green in colour (Williams and Watson 1990). The female is reported to reproduce parthenogenetically; males are not described (Ben-Dov 1993). *Coccus capparidis* is mildly polyphagous, feeding on hosts from at least 21 plant families (Ben-Dov 1993). Citrus and bananas are the main economic hosts (Ben-Dov 1993). *Coccus capparidis* is present in Hawaii, Kiribati, Samoa, Tonga, Florida, the Bahamas, Honduras, Egypt, Israel, India and Sri Lanka (Ben-Dov 1993).

4.5.1 Probability of entry

Probability of importation

The likelihood that *Coccus capparidis* will arrive in Australia with the importation of island cabbage from any country where this pest is present is: **HIGH**.

- *Coccus capparidis* is present in Samoa and Tonga (Williams and Watson 1990). It has been reported on island cabbage in Kiribati (Williams and Watson 1990).
- *Coccus capparidis* has been reported feeding on the underside of the leaves of host plants (Ben-Dov 1993), so could be present on imported fresh island cabbage leaves.
- Crawlers, nymphs and adults may be present on the leaves. *Coccus* spp. gives birth to live young rather than laying eggs (Williams and Watson 1990).
- The small size and cryptic colouring of scales make them hard to detect, especially those in the crawler or early instar stages (Hodgson 1994). The adult females grow up to 3.6 mm in length (Williams and Watson 1990), but larval stages would be smaller. *Coccus capparidis* is bright green in colour and lays flat against the leaf (Williams and Watson 1990), so may not be readily visible.
- Scales are often found in groups (Gill 1988), which would increase the likelihood of detection during pre-export preparation or phytosanitary inspection.
- All scale stages have legs and are capable of moving (Gill 1988), but they will likely remain fixed to the leaves unless disturbed. First instar crawlers are usually the most active stage in soft scales (Williams 1997).

Probability of distribution

The likelihood that *Coccus capparidis* will be distributed in Australia, in a viable state, as a result of the processing, sale or disposal of island cabbage from any country where this pest is present, is: **MODERATE.**

- Island cabbage leaves would be distributed for sale to various destinations in Australia, although predominantly to the larger population centres. The leaves are most likely to be sold through small specialty grocery stores and fresh food markets catering for the Asian and Pacific Islander communities.
- While all stages are capable of movement, the most active stage is the first instar crawler, particularly in its first 24 hours (Greathead 1997). Soft scale crawlers are positively phototropic, and will crawl towards light (Greathead 1997). Newly emerging crawlers may wander off the island cabbage leaves during distribution.
- Adult scales and second and third instar nymphs are likely to remain on the leaves throughout the distribution chain unless disturbed.
- The majority of island cabbage leaf waste discarded in urban areas is likely to be disposed of via municipal waste management systems and potentially buried amongst other waste. Scales in waste material are unlikely to be dumped in the vicinity of suitable host plants.
- Crawlers may be carried by wind to new hosts. Crawlers typically climb to the upper parts of host plants to assist wind dispersal (Greathead 1997). Crawlers on leaves discarded on

the ground or on a compost heap would be less successfully carried by the wind, and have higher mortality from predation and environmental factors.

- Second and third instar nymphs and adult scales could crawl to new hosts, but leaves would need to be discarded in close proximity to suitable plant hosts.
- *Coccus capparidis* feeds on plant hosts from at least 21 plant families (Ben-Dov 1993). Some of these hosts, including citrus, lantana and oleander (Ben-Dov *et al*. 2012), are common in many parts of Australia.

Overall probability of entry (importation x distribution)

The likelihood that *Coccus capparidis* will enter Australia and be distributed in a viable state to a suitable host, as a result of trade in island cabbage from any country where this pest is present, is: **MODERATE**.

4.5.2 Probability of establishment

The likelihood that *Coccus capparidis* will establish in Australia, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction, is: **HIGH**.

- *Coccus capparidis* has a predominantly tropical and subtropical distribution, although it has also established in the Mediterranean climates of Egypt and Israel. Establishment in the warmer parts of Australia would be feasible.
- *Coccus capparidis* is an oriental species (Miller *et al.* 2005) that has established in Florida, the Bahamas, Honduras, Egypt, Israel, and the Pacific (Kiribati, Tonga, Samoa, Hawaiian islands) (Ben-Dov 1993).
- *Coccus capparidis* reproduces parthenogenetically (Ben-Dov 1993), so a single scale may be able to establish a population.
- Coccids are attended by ants, which improves the survival and reproductive capacity of the scales. Most honeydew-seeking ants will tend to any scale species they come across, although some have more specific relationships (Gullan 1997).
- Ants protect scales from natural enemies, particularly predatory wasps and beetles (Gullan 1997), and remove honeydew. In the absence of ants, scales may become engulfed in their honeydew and die from asphyxiation or from some effect of the sooty mould growth arising from honeydew contamination (Gullan 1997).
- Arboreal weaver ants such as *Oecophylla smaragdina* commonly build silk shelters over scale insects on exposed foliage (Gullan 1997), providing shelter from predators. *Oecophylla smaragdina* and other ants known to associate with *Coccus* spp. are present in northern Australia (CSIRO 2010).
- *Coccus capparidis* can be attacked by the encyrtid wasp *Metaphycus swirskii* (Blumberg and Swirski 1984), which is used as a biological control agent against a number of scale species in Europe (EPPO 2012b). *Metaphycus swirskii* is not known to be present in Australia (APPD 2012). However, other *Metaphycus* spp. that are commercially available for biological control of soft scales, including *Metaphycus helvolus* and *Metaphycus lounsburyi* are present in parts of Australia (APPD 2012; EPPO 2012b). Predation of scales by wasps, spiders and birds would reduce the likelihood of establishment.

4.5.3 Probability of spread

The likelihood that *Coccus capparidis* will spread throughout Australia, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of this pest, is: **HIGH**.

- Once established, *Coccus capparidis* is likely to spread.
- Host plants such as citrus, lantana and oleander are common and widely distributed in Australia.
- Crawlers can be dispersed over considerable distances on wind currents (Greathead 1997). Crawlers of the related species *Coccus hesperidum* have been trapped 55 m downwind from their source, while airborne crawlers of *Icerya seychellarum* were reported 3.5 km downwind of an infestation (Greathead 1997).
- Spread over greater distances is likely to occur through the movement of infested cuttings, nursery stock and produce (Greathead 1997).
- Some scales are known to be transported by ants to new feeding sites on the host plant or to uninfested plants. A number of *Coccus* spp. are transported by the ants *Oecophylla smaragdina* and *Solenopsis geminata*, as well as some *Crematogaster* species (Gullan 1997), which have been reported in Australia (APPD 2012; CSIRO 2012).
- *Coccus capparidis* is likely to have several overlapping generations a year in tropical areas. Development may be slower in temperate areas, and the scale may only complete one and a partial second generation annually. The related species *Coccus hesperidum* can overwinter as adults in cooler environments (CABI 2012), while many other scales are known to overwinter as second or third instar nymphs (Gill 1988).
- Some *Coccus* spp. have become common greenhouse pests (Williams and Watson 1990) and so *Coccus capparidis* may be capable of spreading into cooler regions of southern Australia if introduced into greenhouses.
- The small size and cryptic colouring of *Coccus capparidis* means that an infestation may not be detected until it is too late to eradicate it.
- Infestations of *Coccus capparidis* on non-commercial plants, such as the noxious weed lantana, are likely to go unchecked, allowing scale populations to grow rapidly.

4.5.4 Overall probability of entry, establishment and spread

The likelihood that *Coccus capparidis* will enter Australia as a result of trade in island cabbage from any country where this pest is present, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia, is: **MODERATE**.

4.5.5 Consequences

Assessment of the potential consequences (direct and indirect) of *Coccus capparidis* for Australia is: **LOW**.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: C** – minor significance at the district level Several soft scale species can be significant pests, but typically are less economically important than armoured scales (Gill 1997). Soft scales rarely seriously injure mature trees, but can be harmful to nursery stock (Fasulo and Brooks 2004). *Coccus capparidis* is not widely considered to be a pest of economic importance, although it may be a nuisance and cause minor damage. *Coccus capparidis* is considered to only be a minor pest of citrus in the United States (Miller *et al*. 2005) and of little or no importance in Israel (Gill 1997). Soft scales damage the host plant by removing fluids and nutrient materials from the phloem, resulting in decreased vigour (Gill 1997; Hodgson 1994), affecting plant health. The scales also produce copious amounts of honeydew that is excreted over the foliage, which serves as a substrate for sooty mould growth (Gill 1997). Sooty mould on the leaf surface blocks sunlight, interfering with the photosynthetic process and reducing plant vigour (Gill 1988, 1997). Australian native flora is not represented in the known host families. Besides commercial production and gardens, this scale would not have a discernible impact.
Other aspects of the environment	**Impact score: A** – indiscernible at the local level Direct impacts are limited to effects on plant health (see above). No other direct impacts on the environment associated with *Coccus capparidis* have been reported.
Indirect	
Eradication, control etc.	**Impact score: B** – minor significance at the local level Existing control measures adopted for other scale pests already present in Australia, such as *Coccus hesperidum*, are likely to reduce local populations of *Coccus capparidis* in orchards and greenhouses. Native and introduced predators, particularly encyrtid wasps, may have some effect in controlling scale numbers.
Domestic trade	**Impact score: B** – minor significance at the local level Establishment of this species in Australia may result in some restrictions on interstate movement of plant material, particularly citrus. Sooty mould growth on honeydew excreted by the scales can cover fruit surfaces, causing it to look stained and dirty, which reduces the quality and saleability of the fruit (Gill 1997).
International trade	**Impact score: C** – minor significance at the district level Establishment of *Coccus capparidis* in Australia may result in additional measures being imposed on Australian exports of some fresh commodities, particularly citrus, in markets where *Coccus capparidis* is not already present.
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level There is no evidence to indicate that *Coccus capparidis* would have significant indirect impacts on the environment or non-commercial activities. Potential impacts to plant life are likely to be minor and localised, and would not result in discernible changes to plant communities, ecological processes or human recreational uses.

4.5.6 Unrestricted risk estimate

The unrestricted risk of *Coccus capparidis* is: **LOW**.

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the outcome of overall consequences, using the risk estimation matrix shown in Table 2.5.

The unrestricted risk estimate for *Coccus capparidis* of ‘low’ exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.6 Armoured scales

*Pseudaulacaspis pentagona**

*Unaspis citri**

* This pest is of quarantine concern to Western Australia

These armoured scale species have been grouped together because of their similar biology. They are predicted to pose a similar risk and require similar mitigation measures.

Pseudaulacaspis pentagona, the peach white scale, has previously been assessed with the importation of stone fruit from the United States (California, Idaho, Oregon and Washington), and capsicum fruit from Korea. In these assessments, the unrestricted risk estimates were found to be negligible and very low respectively, and no specific quarantine measures were determined to be necessary.

Unaspis citri, the citrus snow scale, has previously been assessed with the importation of Tahitian limes from New Caledonia. In that assessment, the unrestricted risk estimate was found to be very low, and no specific quarantine measures were determined to be necessary.

Members of the Diaspididae family are called ‘armoured scales’ because they produce a hard, fibrous, wax-like covering (Carver *et al*. 1991) that attaches them to the host plant. Unlike the soft scales, armoured scales do not produce the honeydew-like secretions that commonly cause sooty mould to develop (Beardsley and Gonzalez 1975).

Feeding by armoured scales affects their hosts by removing sap, and injected saliva contains toxic enzymes that can damage leaves, cambium and other tissues (Beardsley and Gonzalez 1975). Leaf chlorosis and other localised effects are often associated with armoured scale infestations (Beardsley and Gonzalez 1975). *Pseudaulacaspis pentagona* and *Unaspis citri* cause yellow spotting of the undersides of leaves, premature leaf drop, twig dieback and discolouration of bark (EPPO 2012c; Watson 2012). High populations of scales can cause the death of branches or even entire trees (Beardsley and Gonzalez 1975; Watson 2012).

Scale nymphs typically settle and feed on branches and leaves of the host plant, becoming immobile as they develop into late instar nymphs (Beardsley and Gonzalez 1975). Both *Pseudaulacaspis pentagona* and *Unaspis citri* are more commonly found on the trunk, branches and stems of hosts rather than the leaves and fruit (Waterhouse and Norris 1987; Watson 2012). The female reaches sexual maturity without undergoing true metamorphosis, remaining legless and immobile on the host plant. There is no pupal stage in the female lifecycle. The male scale has a pupal stage, emerging as a winged adult form. The female life stages are egg, nymph and adult, while the male has egg, nymph, pre-pupal, pupal and adult stages (Watson 2012).

The scale covering the mature adult female *Unaspis citri* is up to 2 mm in length (Waterhouse and Norris 1987). The mature male grows up to 1 mm in length, but is more readily visible than the female because of its distinctive white colouring. The males have three longitudinal ridges, likened to flakes of desiccated coconut, which can make the host plant’s trunk appear white when present in high numbers (Waterhouse and Norris 1987). The adult male is winged, does not feed at all, and does not survive for longer than 24 hours (Waterhouse and Norris 1987).

Reproduction in most armoured scales is sexual, although some reproduce by parthenogenesis, and some species have both sexual and parthenogenetic races (Beardsley and Gonzalez 1975; Watson 2012). The species assessed here reproduce sexually (Waterhouse and Norris 1987; Watson 2012). After fertilization, the female starts to lay eggs under her scale. The female can continue laying eggs for two or more months. *Unaspis citri* typically produces around 80 offspring, but up to 169 first instar larvae have been reported from a single female (Waterhouse and Norris 1987). *Pseudaulacaspis pentagona* requires mating for reproduction (Ben-Dov *et al*. 2012). It has been reported that unfertilized *Unaspis citri* females may eventually start to lay eggs, which yield only female progeny (Waterhouse and Norris 1987), but this is not widely supported in the literature, so may only be a rare occurrence. *Pseudaulacaspis pentagona* has one to four generations per year, depending on the climate (Watson 2012), while *Unaspis citri* has two to five generations (Waterhouse and Norris 1987; Watson 2012).

Crawlers, which are the first nymphal instar, are the primary dispersal stage and move to new areas of the plant after hatching, or disperse by wind, or via contact with flying insects or birds (Watson 2012). The crawlers can move up to a metre under their own locomotion (Watson 2012). At the end of the wandering period (the dispersal phase), crawlers secure themselves to a leaf or stem with their mouthparts. Once settled, the larvae draw their legs beneath the body and flatten themselves against the host (Koteja 1990). They then insert their piercing and sucking mouthparts into the plant tissue and start feeding on plant juices (Beardsley and Gonzalez 1975; Koteja 1990).

Pseudaulacaspis pentagona is polyphagous, and has been reported on plants from 115 genera in 55 plant families. However, not all these are considered to be true hosts, as the scale cannot complete development on some of these plants (Watson 2012). Additionally, host preferences vary from place to place throughout the world, so geographical strains may have adapted to attacking particular hosts (Waterhouse and Norris 1987). This species is a very destructive pest of deciduous fruit trees, especially cherry, mulberry and peach, as well as ornamentals (Watson 2012). *Pseudaulacaspis pentagona* is a tropical/subtropical species that originated in eastern Asia, but it has spread widely, and now has a cosmopolitan distribution. In colder regions it is only a pest in greenhouses (Watson 2012).

Unaspis citri is moderately polyphagous, attacking plant species from nine genera in seven plant families (Watson 2012). It is mostly a pest of *Citrus* spp. plants, but has also been reported on banana and a number of ornamental species (Waterhouse and Norris 1987). *Unaspis citri* is a tropical species that thrives in humid tropical conditions, and does not survive in regions with a marked dry season (Watson 2012). It is already present in eastern Australia, but is confined to the non-irrigated humid coastal regions of New South Wales and Queensland (Watson 2012).

4.6.1 Probability of entry

Probability of importation

The likelihood that *Pseudaulacaspis pentagona* or *Unaspis citri* will arrive in Western Australia with the importation of island cabbage from any country where this pest is present is: **MODERATE**.

- *Pseudaulacaspis pentagona* is present in Fiji, Samoa, Tonga and Vanuatu (Williams and Watson 1988a), as well as other Pacific countries where island cabbage is grown.

- *Unaspis citri* is present in the Cook Islands, Fiji, Samoa, Tonga and Vanuatu (Williams and Watson 1988a; Waterhouse and Norris 1987), and many other Pacific countries where island cabbage is grown.
- Both of these armoured scale species have been reported on island cabbage (Ben-Dov *et al.* 2012). However, they are more commonly associated with the trunks and stems of host plants, and are only rarely found on the leaves, usually when infestations are heavy (Waterhouse and Norris 1987; Watson 2012; Stout 1982).
- Adult males of both species do not live for more than a day, so are not likely to be present on imported island cabbage leaves, unless they emerge from pupation during transit.
- Only first instar crawlers and male adults are active, and may be dislodged during harvest and preparation for export.
- Other stages are sessile under a protective scale and unable to move. Preparation of the leaves for export is unlikely to remove these scales from the island cabbage leaves.
- The female lays eggs under her scale, so the eggs are likely to remain intact during pre-export preparation and transit. The eggs of *Pseudaulacaspis pentagona* hatch in 4–5 days in warm conditions (Waterhouse and Norris 1987). Scale development may be slowed if the leaves are kept cool during transport.
- Armoured scales are small and may be difficult to detect, particularly in low numbers. The scales covering the adult females of both *Pseudaulacaspis pentagona* and *Unaspis citri* are around 2 to 2.5 mm in length (Waterhouse and Norris 1987).

Probability of distribution

The likelihood that *Pseudaulacaspis pentagona* or *Unaspis citri* will be distributed in Western Australia, in a viable state, as a result of the processing, sale or disposal of island cabbage from any country where this pest is present, is: **LOW.**

- Island cabbage leaves could be distributed for sale to various destinations in Western Australia, although predominantly to the larger population centres. The leaves are most likely to be sold through small specialty grocery stores and fresh food markets catering for the Asian and Pacific Islander communities.
- *Pseudaulacaspis pentagona* and *Unaspis citri* eggs, larvae, pupae and adult females would remain fixed to leaves under their protective scales.
- Both species are likely to survive local storage and transportation, as they can tolerate cold temperatures. Adult females and eggs of *Pseudaulacaspis pentagona* overwinter in cold climates (Watson 2012), so may be unaffected by refrigeration during storage and transit.
- The majority of island cabbage leaf waste discarded in urban areas is likely to be disposed of via municipal waste management systems and potentially buried amongst other waste. Armoured scales in waste material are unlikely to be dumped in the vicinity of suitable host plants, and have little capacity to move to nearby vegetation.
- Some island cabbage leaves may be discarded in a domestic garden or other exposed outdoor environment where potential hosts may be present.
- Hosts of *Unaspis citri* include common plants such as avocado, banana, capsicum, citrus, hibiscus, mango and palms (Watson 2012). *Pseudaulacaspis pentagona* attacks an even

wider range of plants, and has been reported on plants from 115 different genera (Watson 2012), although it has been suggested that there are geographical strains adapted to attacking specific hosts (Waterhouse and Norris 1987).

- The main risk would be from crawlers moving from discarded leaves onto a nearby host plant. Crawler wandering generally serves to disperse young scales away from the mother onto new growth of the same host, and movement between plants seldom occurs unless such plants are in contact (Beardsley and Gonzalez 1975). Diaspid crawlers can only move for short distances, and with great difficulty, across sand or bare soil (Beardsley and Gonzalez 1975).
- Crawlers of *Pseudaulacaspis pentagona* can walk up to a metre, but can travel further if carried by the wind, or by flying insects or birds (Watson 2012). The crawler stage in *Pseudaulacaspis pentagona* lasts for 7–8 days after hatching (Ben-Dov *et al*. 2012).
- Aerial dispersal of crawlers is initiated from above ground plant parts, and tends to be downward and lateral. Such dispersal is much less likely to be successful for crawlers on leaves discarded on the ground. Crawlers that do not land on a host are likely to perish.
- The period of crawler mobility is limited by their small energy reserves and need to feed.
- The probability of armoured scales being distributed by means of non-propagative plant material such as leaves is low, as establishment would require the chance placement of infested material in close proximity to suitable growing hosts (Beardsley and Gonzalez 1975).

Overall probability of entry (importation x distribution)

The likelihood that *Pseudaulacaspis pentagona* or *Unaspis citri* will enter Western Australia and be distributed in a viable state to a suitable host, as a result of trade in island cabbage from any country where this pest is present, is: **LOW**.

4.6.2 Probability of establishment

The likelihood that *Pseudaulacaspis pentagona* or *Unaspis citri* will establish in Western Australia, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction, is: **MODERATE**.

- Both *Pseudaulacaspis pentagona* and *Unaspis citri* have already established in eastern and southern Australia. There are climatic regions in Western Australia that may be suitable for establishment of these armoured scales.
- *Pseudaulacaspis pentagona* is highly polyphagous, and the preferred citrus hosts of *Unaspis citri* are common in urban areas of Western Australia.
- An imported single gravid female may be all that is necessary to initiate an infection (Beardsley and Gonzalez 1975). Establishment would require both male and female crawlers to remain on the same host or settle on hosts in close proximity and complete their development, and then for the flying adult male to locate an adult female for mating. Receptive adult female scales release pheromones to attract males.
- Information on flight ability of *Pseudaulacaspis pentagona* and *Unaspis citri* is not available, but the males of California red scale (*Aonidiella aurantii*) have been recovered up to 189 m downwind and 92 m upwind from release points. However, they were unable

to fly upwind when the wind velocity exceeded 1 mile (1.6 km) per hour (Beardsley and Gonzalez 1975).

- Males only live for a few hours, so have a limited period in which to find a mate.
- Female armoured scales have a high fecundity, with *Pseudaulacaspis pentagona* laying about 100 eggs (Watson 2012). A female *Unaspis citri* typically produces around 80 offspring, but up to 169 crawlers from a single female have been reported (Waterhouse and Norris 1987).
- Waterhouse and Norris (1987) state that in the absence of a mate, adult female *Unaspis citri* scales can lay unfertilized eggs that will yield female progeny. This is not widely reported in the literature, so may only be a rare occurrence. In such a case, theoretically, a single female crawler that managed to find a host and complete development would be able to establish an asexual population. However, the existence of such populations is not reported in the literature, so would appear to be unlikely.

4.6.3 Probability of spread

The likelihood that *Pseudaulacaspis pentagona* or *Unaspis citri* will spread throughout Western Australia, based on a comparison of factors in the area of origin and in Western Australia that affect the expansion of the geographic distribution of the pest, is: **HIGH**.

- Once established, *Pseudaulacaspis pentagona* and *Unaspis citri* are likely to spread wherever suitable host plants and favourable climate occur.
- The armoured scale lifecycle is influenced by climatic factors such as temperature, rainfall and humidity. Development occurs more slowly at lower temperatures (Waterhouse and Norris 1987). While there may be four generations of *Pseudaulacaspis pentagona* per year in tropical regions, there may only be one generation in cold climates, with the species overwintering as adult females or eggs (Watson 2012).
- Natural spread would occur slowly through the movement of crawlers blown by the wind or carried by flying insects or birds (Watson 2012). Falling infested leaves blown by the wind can be an important means of dispersal within orchards in some armoured scale species (Beardsley and Gonzalez 1975).
- Long distance dispersal is likely to occur through movement of infested plant material such as nursery stock, and buds, leaves and fruit from infested trees (Waterhouse and Norris 1987; EPPO 2012c).
- The small size and sessile habits of these species mean that an infestation may not be discovered until it is too late to eradicate it (Beardsley and Gonzalez 1975).

4.6.4 Overall probability of entry, establishment and spread

The likelihood that *Pseudaulacaspis pentagona* or *Unaspis citri* will enter Western Australia as a result of trade in island cabbage from any country where this pest is present, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Western Australia, is: **LOW**.

4.6.5 Consequences

Assessment of the potential consequences (direct and indirect) of *Pseudaulacaspis pentagona* and *Unaspis citri* for Australia is: **LOW**.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – minor significance at the region level *Pseudaulacaspis pentagona* is highly polyphagous, and host plants such as *Vitis* spp. and *Acacia* spp. are common in many parts of Western Australia (FloraBase 2012). It is a destructive pest of cherry, mulberry, peach and other deciduous fruit trees (Watson 2012). It affects the stems, bark and fruit of host plants, but rarely the leaves or roots. Infested trees lose their vigour, and their lives may be shortened. Young plants may be killed as a result of infestation (Watson 2012). *Unaspis citri* attacks a number of plants, the most important being *Citrus* spp. Infestations usually occur on the trunk and main limbs of trees, but can spread to twigs, leaves and fruit in heavy infestations, which can result in leaf drop, die back of twigs and death of branches (EPPO 2012c). Infestation can render host trees susceptible to attack by boring insects or fungi (EPPO 2012c).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level Direct impacts are limited to effects on plant health (see above). No other direct impacts on the environment associated with these armoured scale species have been reported.
Indirect	
Eradication, control etc.	**Impact score: C** – minor significance at the district level The waxy protective scales, sessile nature, intermittent feeding and overlapping generations of armoured scales make chemical control difficult (EPPO 2012c). Crawlers are particularly susceptible to chemical attack, but the second stage nymphs and later nymphs are less so (Waterhouse and Norris 1987). Existing control programs for other pests may have some effectiveness against armoured scales on some host plants. There are a number of known natural enemies of *Unaspis citri* present in Western Australia that may have some effect in controlling scale outbreaks. These include *Encarsia* spp., *Aphytis chrysomphali*, *Aphelinus* spp. and *Batrachedra arenosella* (Waterhouse and Norris 1987). While there are many predators and parasites of *Pseudaulacaspis pentagona* reported internationally (Waterhouse and Norris 1987), few are known in Australia. Once established, eradication may not be possible, given the broad host range of these two species. They are likely to infest a number of wild and non-economic hosts that are unlikely to be subjected to pesticide application or other measures, and predation by natural enemies is likely to only suppress pest populations rather than eliminate them.
Domestic trade	**Impact score: B** – minor significance at the local level *Unaspis citri* is a regulated pest in South Australia, so if this species established in Western Australia, restrictions may be imposed on the movement of *Citrus* spp. and other host plant material. Trade with other states is unlikely to be affected, as these scale species are either present or not regulated in these states.
International trade	**Impact score: C** – minor significance at the district level *Unaspis citri* is considered to be a quarantine pest in many countries (EPPO 2012c; Watson 2012), but mostly in relation to movement of *Citrus* spp., *Fortunella* spp., and *Poncirus* spp. plant material other than fruit or seeds (CABI 2012). *Pseudaulacaspis pentagona* is also a quarantine pest in many countries (CABI 2012). Establishment of these scales may result in additional measures being imposed on exports to markets where these pests are not already present. However, commodities that are susceptible to these pests may already be exported from the eastern states, so impacts may be minor.
Environmental and non-commercial	**Impact score: B** – minor significance at the local level There are no significant indirect environmental or non-commercial effects caused by these armoured scale species. The use of pesticides to control these pests may have a minor impact on the environment at a local level.

4.6.6 Unrestricted risk estimate

The unrestricted risk of *Pseudaulacaspis pentagona* and *Unaspis citri* is: **VERY LOW**.

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the outcome of overall consequences, using the risk estimation matrix shown in Table 2.5.

The unrestricted risk estimate for *Pseudaulacaspis pentagona* and *Unaspis citri* of 'very low' achieves Australia's ALOP. Therefore, specific risk management measures are not required for this pest.

4.7 Pacific mealybug

*Planococcus minor**

* This pest is of quarantine concern to Western Australia

Planococcus minor, the Pacific mealybug, has previously been assessed with the importation of bananas from the Philippines (Biosecurity Australia 2008), grouped with three other mealybug species. In that assessment, the unrestricted risk assessment for the mealybugs was found to be low, with pre-clearance or on-arrival inspection recommended to check for presence of mealybugs, and appropriate remedial action if detected.

Mealybugs are important pests of agricultural crops, affecting host plants by depleting the sap through feeding, and sometimes injecting toxins that can stunt plant growth. Mealybugs can transmit plant virus diseases. They excrete sugary honeydew over leaves and fruit that acts as a substrate for the growth of sooty moulds, which impairs normal photosynthesis (Cox 1989; Williams 2004). They can reproduce rapidly in warm climates or in greenhouses (Cox 1989), so populations can quickly become a serious problem if unchecked. In their native habitats, mealybugs are usually attacked by a wide range of natural enemies including parasitic wasps and ladybird beetles. When transported to new environments where natural enemies are absent, serious outbreaks can occur (Cox 1989).

Planococcus minor is very closely related to *Planococcus citri*, and its existence as a separate species was not apparent until 1981 when it was first described as *Planococcus pacificus* Cox, 1981. This was later synonymised by Cox (1989) to *Planococcus minor* (Maskell) Cox, 1989. It is likely that many records of *Planococcus citri* are based on misidentifications, and may instead be *Planococcus minor* (Williams and de Willink 1992; Williams and Watson 1988b). The identification of *Planococcus* species is hindered by morphological variations within species due to the environmental conditions under which individuals develop (Cox 1989).

Adult female mealybugs are soft-bodied insects, with a white powdery wax coating (Williams 2004). *Planococcus minor* adult females are oval in shape, 1.3 to 3.2 mm in length and 0.8 to 1.9 mm wide, with well developed legs (Cox 1989). While adult males of *Planococcus minor* do occur in populations (Venette and Davis 2004), information on specific characteristics is not available. Adult male mealybugs are minute, without functional mouthparts, and they are morphologically degenerate (Williams 2004).

Details about the life stages of *Planococcus minor* are not well known. *Planococcus* spp. typically have four instar stages for females and five instars for males (Venette and Davis 2004). First instar mealybugs always possess legs (Williams 2004). *Planococcus minor* females produced between 65 and 425 eggs on varying hosts in laboratory studies (Venette and Davis 2004). The pre-oviposition period ranges from eight to twelve days, and the eggs hatch around three days after laying (Venette and Davis 2004). The time to complete one generation ranged from 31 to 50 days in a laboratory study, with females developing faster than males (Venette and Davis 2004).

Development time and the number of generations is highly variable, determined by the choice of plant host and feeding site, temperature, population density and the presence of predators (Venette and Davis 2004). The generation time of the related *Planococcus citri* ranges from four to six weeks in summer to around three months during winter, with around four to eight generations annually (Venette and Davis 2004).

Population densities may be influenced by the presence of ants. Ants feed on the honeydew excreted by mealybugs and protect the mealybugs from predators. *Planococcus minor* has been reported in association with the aggressive ant *Papyrius nitidus* (synonym: *Iridomyrmex nitidus*) in Papua New Guinea, which reduced the rate of parasitisation (Ben-Dov *et al*. 2012). This ant is present in Western Australia (APPD 2012).

Planococcus minor is the most widespread mealybug in the South Pacific region (Williams and Watson 1988b). The geographical origin of *Planococcus minor* is not clear, but is likely to be of Old World origin, and introduced to the Pacific through human activities (Williams and Watson 1988b; Cox 1989). The earliest record in the South Pacific was from Fiji in 1922 (Williams 1985). *Planococcus minor* is present in Australia, and is particularly common in Queensland, but is also found in New South Wales, the Northern Territory and South Australia (Williams 1985). It is not known how *Planococcus minor* arrived in Australia, but the earliest specimens were found on passionfruit in Cairns in 1931 (Williams 1985).

4.7.1 Probability of entry

Probability of importation

The likelihood that *Planococcus minor* will arrive in Western Australia with the importation of island cabbage from any country where this pest is present is: **HIGH**.

- *Planococcus minor* is present in the Cook Islands, Fiji, Samoa, Tonga and Vanuatu (Williams and Watson 1988b; Ben Dov *et al.* 2012), and a number of other Pacific countries where island cabbage is grown.
- Island cabbage is a host of *Planococcus minor* (Williams and Watson 1988b).
- *Planococcus minor* is commonly found on the leaves of host plants (Ben-Dov *et al.* 2012).
- *Planococcus minor* is likely to have spread throughout the Pacific region, and been introduced to eastern Australia, by human activities (Williams and Watson 1988b; Cox 1989).
- *Planococcus minor* is commonly intercepted on plant material entering the United States, with around 240 interceptions annually (Venette and Davis 2004). These interceptions are primarily associated with plant material carried by international airline passengers rather than cargo (Venette and Davis 2004).
- Adult female mealybugs are 1.3 to 3.2 mm in length and covered with a white powdery wax coating (Cox 1989), and are likely to be visible if present in large numbers. However, nymphal instars and adult males would be more difficult to detect on island cabbage leaves.
- Eggs are laid on the leaves, and usually hatch in around three days (Venette and Davis 2004), but development may be slowed if the island cabbage leaves are chilled during transit. Any eggs laid on the leaves prior to harvest may not have hatched by the time they arrive in Australia. Descriptions of the eggs are not available, but the closely related *Planococcus citri* lays its eggs in clumps of 5–20 inside egg sacs composed of white cottony-waxy filaments (Kerns *et al*. 2004).

Probability of distribution

The likelihood that *Planococcus minor* will be distributed in Western Australia, in a viable state, as a result of the processing, sale or disposal of island cabbage from any country where this pest is present, is: **MODERATE**.

- Island cabbage leaves may be widely distributed in Western Australia, but predominantly to the major population centres. The leaves are most likely to be sold through small specialty grocery stores and fresh food markets catering for the Asian and Pacific Islander communities.
- The majority of island cabbage leaf waste discarded in urban areas is likely to be disposed of via municipal waste management systems and potentially buried amongst other waste. Mealybugs in waste material are unlikely to be dumped in the vicinity of suitable host plants, and have limited ability to crawl to nearby vegetation.
- Some island cabbage leaves may be discarded in a domestic garden or other exposed outdoor environment where potential hosts may be present.
- *Planococcus minor* is a generalist feeder reported on more than 250 species from around 80 different plant families (Venette and Davis 2004). Mealybugs on discarded island cabbage leaves or packing materials may be able to locate a suitable host plant.
- Adult females and all nymphal stages of *Planococcus minor* are mobile, but are likely to remain on the leaves unless disturbed.
- First instar mealybugs possess legs (Williams 2004), while adult female *Planococcus* mealybugs are wingless (Cox 1989).
- Although movement under their own locomotion would be limited, mealybugs can be carried by the wind to new host plants (Williams 2004). First instar nymphs can easily be transported by wind. Later instar stages may be carried by leaves blown by the wind, as the females are often fixed to plant material by their mouthparts while feeding (Williams 2004).
- Male mealybugs are minute, without functional mouthparts, and morphologically degenerate (Williams 2004), so are unlikely to locate and settle on a new host unless carried by the wind.

Overall probability of entry (importation x distribution)

The likelihood that *Planococcus minor* will enter Western Australia and be distributed in a viable state to a suitable host, as a result of trade in island cabbage from any country where this pest is present, is: **MODERATE**.

4.7.2 Probability of establishment

The likelihood that *Planococcus minor* will establish in Western Australia, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction, is: **HIGH**.

- *Planococcus minor* has already established in eastern Australia after being accidentally introduced (Williams 1985). It has established in many places where it has been introduced, and is the most widespread mealybug of the south Pacific region (Williams and Watson 1988b).
- *Planococcus minor* reproduces sexually, and populations have both males and females (Venette and Davis 2004). However, some *Planococcus* species can reproduce asexually through parthenogenesis, which would increase the likelihood of establishment if

accidentally introduced (Venette and Davis 2004). Asexual reproduction has not been confirmed in *Planococcus minor*.

- Sexual reproduction by adult mealybugs introduced into Western Australia would require both males and females to establish on the same host plant, or on plants in very close proximity, which would have a low likelihood of occurring.
- A more likely scenario is that an introduced gravid female locates a suitable host plant and lays eggs, subsequently producing both male and female nymphs that could complete their lifecycle and establish a population. After mating there is a pre-oviposition period of around 8–12 days (Venette and Davis 2004), so a fertilized female could arrive on island cabbage leaves and lay eggs once it finds a host plant.
- Females have been reported producing between 65 and 425 eggs (Venette and Davis 2004), so a single gravid female could rapidly establish a population in Western Australia.
- The related *Planococcus citri* has been reported hybridizing with *Planococcus ficus* under laboratory conditions (Venette and Davis 2004). *Planococcus minor* is in the same monophyletic species-group as *Planococcus citri* and *Planococcus ficus* (Cox 1989). In the absence of a male to mate with, an introduced adult female *Planococcus minor* mealybug may be able to hybridize with another species. *Planococcus citri* is present in Western Australia (APPD 2012).
- Mealybugs are often attended by ants, which protect the mealybugs from predators and other natural enemies (Williams 2004). An aggressive ant species *Papyrius nitidus* has been reported in association with *Planococcus minor* in Papua New Guinea, which resulted in reduced rates of parasitisation (Ben-Dov *et al.* 2012). *Papyrius nitidus* is known to be present in Western Australia and other parts of Australia (APPD 2012), and could assist the establishment and spread of *Planococcus minor*.

4.7.3 Probability of spread

The likelihood that *Planococcus minor* will spread throughout Western Australia, based on a comparison of factors in the area of origin and in Western Australia that affect the expansion of the geographic distribution of the pest, is: **HIGH**.

- Once established, *Planococcus minor* is likely to spread to other parts of Western Australia where suitable hosts and favourable climate occur.
- In eastern Australia, it has not spread as rapidly as *Planococcus citri*, but is likely to eventually have a similar distribution range (Williams 1985).
- *Planococcus minor* has spread widely throughout the south Pacific, as well as the Afrotropical, Oriental, Austro-Oriental, Malagasian and Neotropical regions (Cox 1989). It probably exists in every country in the Neotropical region (Williams and de Willink 1992).
- Natural spread would occur slowly through the movement of mealybugs blown by the wind. Falling infested leaves blown by the wind are an important means of dispersal of mealybugs (Williams 2004).
- Ants may play a role in mealybug dispersal (Venette and Davis 2004; Williams 2004), although this has not been specifically reported for *Planococcus minor*.

- Long distance dispersal is likely to occur through movement of infested plant material (Williams 2004) such as nursery stock, and buds, leaves and fruit from infested trees.

4.7.4 Overall probability of entry, establishment and spread

The likelihood that *Planococcus minor* will enter Western Australia as a result of trade in island cabbage from any country where this pest is present, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Western Australia, is: **MODERATE**.

4.7.5 Consequences

Assessment of the potential consequences (direct and indirect) of *Planococcus minor* for Western Australia is: **LOW**.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – minor significance at the region level *Planococcus minor* is highly polyphagous, so a wide range of plants could be affected. It has been reported as a pest of more than 250 plant species, including important agricultural crops such as banana, citrus, cocoa, coffee, corn, grapes, mango, potato and soybean (Venette and Davis 2004). Mealybugs feed by sucking sap from the host plant, which can affect the vitality of the plant, causing stunting, discolouration and defoliation, and reducing yields and quality (Venette and Davis 2004). *Planococcus* mealybugs can transmit plant viruses (Williams and Watson 1988b). It is likely that some older records of viruses attributed to *Planococcus citri* were in fact vectored by *Planococcus minor*, as these mealybugs were not distinguished as separate species until the 1980s. Such viruses include swollen shoot virus of cacao (Cox 1989) and dasheen mosaic virus (Williams and Watson 1988b). The other main impact from mealybug feeding is caused by the sugary honeydew they excrete, which falls onto foliage, fruit and other plant parts. The honeydew provides a substrate for the growth of sooty moulds, which impairs photosynthesis in the leaves of the host plant. As well as affecting plant growth, sooty mould fouls the surface of plant produce, rendering them unsaleable (Williams 2004).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level Direct impacts are limited to effects on plant health (see above). No other direct impacts on the environment associated with *Planococcus minor* have been reported.
Indirect	
Eradication, control etc.	**Impact score: C** – minor significance at the district level Control measures may have some effect on populations of *Planococcus minor*. These measures include the use of pesticide sprays and biological control agents. Such measures may already be in place in regions where *Planococcus citri* or other mealybug pests are already present. Once established, eradication may not be possible, given its broad range of host species. *Planococcus minor* is likely to infest a number of wild and non-economic hosts that are unlikely to be subjected to pesticide application or other measures, and predation by natural enemies is only likely to suppress pest populations rather than eliminate them.
Domestic trade	**Impact score: A** – indiscernible at the local level *Planococcus minor* is present in New South Wales, Northern Territory, Queensland and South Australia, and is not a regulated pest in the other states, so domestic trade is unlikely to be affected.
International trade	**Impact score: C** – minor significance at the district level *Planococcus minor* is a quarantine pest in many countries. Establishment of this pest in Western Australia may result in the loss of markets where this pest is not already present. However, commodities that are susceptible to this pest can already be exported from the eastern states, so impacts are likely to be minor.
Environmental and non-commercial	**Impact score: B** – minor significance at the local level There are no significant indirect environmental or non-commercial effects caused by *Planococcus minor*. The use of pesticides to control this species may have a minor impact on the environment at a local level, although they are probably already being used against other pests.

4.7.6 Unrestricted risk estimate

The unrestricted risk of *Planococcus minor* is: **LOW**.

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the outcome of overall consequences, using the risk estimation matrix shown in Table 2.5.

The unrestricted risk estimate for *Planococcus minor* of ‘low’ exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.8 Cotton leaf roller

*Haritalodes derogata**

* This pest is of quarantine concern to Western Australia

Haritalodes derogata, the cotton leaf roller, is a pest of island cabbage in a number of Pacific Island countries. It is primarily associated with plants in the Malvaceae family, and is known to be a pest of okra (*Abelmoschus esculentus*) (Anioke 1989) and cotton (*Gossypium* spp.) (Arora *et al*. 2009), and has been reported feeding on cassava (*Manihot esculenta*), kenaf (*Hibiscus cannabinus*), hibiscus (*Hibiscus rosa-sinensis*), kapok (*Ceiba pentandra*) and jute (*Corchorus* spp.) (Silvie 1990).

The larval stage does the most damage, with the caterpillars feeding on the leaves of host plants. There are five (sometimes six) larval instars (Anioke 1989; Ahsan and Khalequssaman 1982). The caterpillars range in size from 1 mm after hatching, up to 30 mm in length prior to pupation. When they emerge from the egg, they are transparent to light yellow in colour, but soon turn green (Anioke 1989; Silvie 1990; Vennila *et al.* 2007; Ecoport 2012), with a brown head. The young larvae feed gregariously on the leaf epidermis under a loose web of threads strung between leaf hairs on the underside of the leaves (Anioke 1989; Silvie 1990). At about four days old, the larvae cut the leaf margins perpendicular to the vein, roll it under towards the midrib and fix it with silk. They then feed within the protection of the rolled leaf. The leaf remains green and open at the apex (Silvie 1990; Vennila *et al.* 2007; Arora *et al.* 2009). The larvae become dark pink in colour when they are ready to pupate. The pupation stage lasts around two weeks (Ecoport 2012), and usually occurs within the leaf roll, but sometimes can occur on shed leaves or in leaf litter on the ground (Vennila *et al.* 2007).

The adult moths are 11–13 mm long with a wingspan of 23–28 mm. Their wings are white to cream with brown markings, and the head and thorax have black spots. A female can lay 200–300 eggs, singly or less frequently in batches, usually on the undersides of leaves, but sometimes on the upper surface (Silvie 1990; Arora *et al.* 2009). The eggs are about 0.5 mm in diameter, with a yellow-green hue (Silvie 1990; Anioke 1989). The eggs hatch after 2–6 days. In Africa and India the lifecycle takes 22–53 days, with 5–6 generations per year (Anioke 1989; Arora *et al*. 2009; Vennila *et al*. 2007). Diapause has been reported in India, but is not known to occur in Africa (Silvie 1990).

Feeding and leaf rolling by the caterpillar reduces the leaf surface area, which affects photosynthesis by the plant. Rolled leaves on cotton can reduce seed production by 20–60 percent (Silvie 1990). Cotton bolls may ripen prematurely and bud formation may be impaired. Severe cotton leaf roller infestations can defoliate plants (Vennila *et al*. 2007).

Haritalodes derogata is present in Queensland and New South Wales (APPD 2012), but it has not been reported in Western Australia. In the Pacific region, it is found in the Caroline Islands (Federated States of Micronesia), Fiji, Papua New Guinea, Samoa and the Solomon Islands. It is distributed widely throughout Asia, the Indian Subcontinent and Africa (CABI 2012).

4.8.1 Probability of entry

Probability of importation

The likelihood that *Haritalodes derogata* will arrive in Western Australia with the importation of island cabbage from any country where this pest is present is: **HIGH**.

- *Haritalodes derogata* is present in a number of Pacific countries where island cabbage grows, including Fiji and Samoa.
- The eggs are normally laid on the undersides of the island cabbage leaves, usually singly rather than as aggregations. They are only around 0.5 mm in diameter, and would be well protected within a bundle of leaves. They would not be readily detected unless each leaf was inspected. The eggs take 2–6 days to hatch, so could potentially arrive in air-freighted leaves.
- The larvae feed on the underside of the island cabbage leaves. They are green in colour so would be difficult to see, particularly in the early instars when they are only a few millimetres long. They do not cut and roll the leaf margin before they are four days old (Silvie 1990), so the presence of young larvae may not be noticed when the leaves are harvested and processed for export.
- Mature larvae and pupae are found within a distinctive rolled leaf. It is likely that leaves with noticeably rolled margins would be discarded at harvest.
- The adult moths rest on the undersides of leaves during the daytime, but it is expected they would be disturbed during harvesting, sorting and packing.

Probability of distribution

The likelihood that *Haritalodes derogata* will be distributed in Western Australia, in a viable state, as a result of the processing, sale or disposal of island cabbage from any country where this pest is present, is: **LOW**.

- Island cabbage leaves could be widely distributed in Australia, but predominantly to the major population centres, including those in Western Australia. The leaves are most likely to be sold through small specialty grocery stores and fresh food markets catering for the Asian and Pacific Islander communities.
- There is a low likelihood that island cabbage leaves would be disposed of along roadsides or elsewhere in the environment.
- There is a low likelihood that island cabbage leaves with cotton leaf roller larvae would be discarded in the vicinity of a host plant.
- The majority of island cabbage leaf waste discarded in urban areas is likely to be disposed of via municipal waste management systems and potentially buried amongst other waste. Caterpillars in waste material are unlikely to be dumped in the vicinity of suitable host plants, and have limited ability to crawl to nearby vegetation.
- The larvae feed primarily on plants in the Malvaceae family. *Hibiscus* species are widely cultivated and common as garden plants in Australia, including many parts of Western Australia. There are at least 27 *Hibiscus* species present in Western Australia (FloraBase 2012). Other garden plants that could be potential hosts are *Althaea officinalis*

(marshmallow), *Abutilon hybridum*, *Abutilon megapotamicum* (Chinese lanterns), *Lavatera* spp. (hollyhocks) and *Pavonia* spp. (pavonias).

- Silvie (1990) notes that if the leaf is unrolled, the disturbed larvae move with agility and can fall to the ground, and then crawl to a new leaf and make another roll. Therefore it is assumed they have the ability to travel a small distance, which in some circumstances may be sufficient for them to locate a new host.
- There is a low likelihood that cotton leaf roller larvae would be disturbed and drop off the island cabbage leaves in the vicinity of a host plant.

Overall probability of entry (importation x distribution)

The likelihood that *Haritalodes derogata* will enter Western Australia and be distributed in a viable state to a suitable host, as a result of trade in island cabbage from any country where this pest is present, is: **LOW**.

4.8.2 Probability of establishment

The likelihood that *Haritalodes derogata* will establish in Western Australia, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction, is: **VERY LOW**.

- *Haritalodes derogata* is found in sub-tropical and tropical regions of Africa, Australia, India, Bangladesh and Pakistan.
- *Haritalodes derogata* has already established in coastal NSW and Queensland. 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. ED Edwards, Australian National Insect Collection, CSIRO, 16 June 2010).
- Bio-climatically, Western Australia is quite different to much of the eastern coastal region where *Haritalodes derogata* is present, which is likely to limit the likelihood of establishment. It is most likely to establish in the subtropical coastal region between Perth and Geraldton, or in the tropical region north of Derby.
- Establishment would require both male and female larvae at a similar stage of development finding hosts in close proximity, completing development, locating each other and mating. In laboratory studies, the adult lifespan of *Haritalodes derogata* moths was 3.73 days for females and 7.38 days for males (CABI 2012), so there is only a very narrow opportunity for this to occur. While such a scenario is feasible, it would appear to be unlikely.

4.8.3 Probability of spread

The likelihood that *Haritalodes derogata* will spread throughout Western Australia, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest, is: **MODERATE**.

- Once established, *Haritalodes derogata* is likely to spread, although predominantly confined to coastal areas in the west and northwest that are bio-climatically similar to other regions where the pest is found.

- Host plants, particularly *Hibiscus* spp., are common and widespread in Western Australia (FloraBase 2012).
- The larvae generally do not move from a host plant after hatching.
- The adult moths are capable of flight, so are likely to travel short distances to seek out a mate as well as new plants on which to lay eggs. However, the female moths only live for a few days, so natural spread would be relatively slow.
- Longer distance spread is likely to occur via movement of plant material containing eggs or larvae.

4.8.4 Overall probability of entry, establishment and spread

The likelihood that *Haritalodes derogata* will enter Western Australia as a result of trade in island cabbage from any country where this pest is present, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Western Australia, is: **VERY LOW**.

4.8.5 Consequences

Assessment of the potential consequences (direct and indirect) of *Haritalodes derogata* for Western Australia is: **VERY LOW**.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: C** – minor significance at the district level *Haritalodes derogata* affects a range of Malvaceae plants, the most important being cotton. It can be a serious pest, but outbreaks are sporadic. Reports of damage to 10–14 percent of plants have been reported in cotton farms in Nigeria (CABI 2012). Defoliation results in the premature ripening of bolls and impairs bud formation (CABI 2012). The leaf roller has been reported to completely defoliate island cabbage plants, although the severity of damage is seasonal (Preston 1998).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level Direct impacts are limited to effects on plant health (see above). No other direct impacts on the environment associated with *Haritalodes derogata* have been reported.
Indirect	
Eradication, control etc.	**Impact score: B** – minor significance at the local level *Haritalodes derogata* can be controlled by a range of synthetic pyrethroids and other pesticides (CABI 2012). The leaf roller has a number of natural enemies, although these are not effective in reducing pest populations during severe outbreaks (Preston 1998). Larval parasites in Papua New Guinea include an *Apantales* braconid wasp species (Preston 1998). There are at least three *Apantales* spp. braconids reported from Western Australia (APPD 2012), which may potentially feed on *Haritalodes derogata* larvae. Some varieties of cotton and okra are more resistant to the leaf roller (Preston 1998; CABI 2012).
Domestic trade	**Impact score: A** – indiscernible at the local level *Haritalodes derogata* is already present in NSW and Queensland, and is not a notifiable plant pest in any state or territory, so no impacts on domestic trade would be anticipated.
International trade	**Impact score: B** – minor significance at the local level *Haritalodes derogata* should not have a significant impact on exports to other countries. While it does feed on some economic crops, it is not likely to be present in exported commodities such as cotton.
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level There is no evidence to indicate that *Haritalodes derogata* would have significant indirect impacts on the environment or non-commercial activities. Potential impacts to plant life are likely to be minor and localised, and would not result in discernible changes to plant communities, ecological processes or human recreational uses.

4.8.6 Unrestricted risk estimate

The unrestricted risk of *Haritalodes derogata* is: **NEGLIGIBLE**.

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the outcome of overall consequences, using the risk estimation matrix shown in Table 2.5.

The unrestricted risk estimate for *Haritalodes derogata* of ‘negligible’ achieves Australia’s ALOP. Therefore, specific risk management measures are not required for this pest.

4.9 Pest risk assessment conclusions

The unrestricted risk posed by *Bemisia tabaci* 'Nauru' biotype, *Coccus capparidis* and *Planococcus minor* are estimated to exceed Australia's ALOP. Therefore, additional risk management measures for these pests are required to reduce the risks.

The unrestricted risk estimates for the other pests assessed are below Australia's ALOP and therefore risk management measures are not required. However, any pests of quarantine concern may still be subject to treatment if identified on arrival in Australia.

The results of these risk estimates are summarised in Table 4.2. The rationale for each value of the pest risk assessment, summarised in this table, is described in the relevant sections above.

The proposed risk management measures are discussed in Section 5.

Key to Table 4.2 (over page)	
Genus species state/territory	state/territory in which regional quarantine pests have been identified
Likelihoods for entry, establishment and spread	
N	negligible
EL	extremely low
VL	very low
L	low
M	moderate
H	high
P[EES]	overall probability of entry, establishment and spread
Assessment of consequences from pest entry, establishment and spread	
PLH	plant life or health
OE	other aspects of the environment
EC	eradication control etc
DT	domestic trade
IT	international trade
ENC	environmental and non-commercial
A-G	consequence impact scores are detailed in section 2.2.3
URE	unrestricted risk estimate. This is expressed on an ascending scale from negligible to extreme.

Table 4.2 Summary of unrestricted risk estimates for quarantine pests associated with island cabbage from the Pacific

Pest name	Likelihood of						Consequences							URE
	Entry			Establishment	Spread	P[EES]	direct		indirect				Overall	
	importation	distribution	Overall				PLH	OE	EC	DT	IT	ENC		
Beetles [Coleoptera: Chrysomelidae]														
Aulacophora indica	VL	M	VL	H	H	VL	*D*	*A*	*B*	*B*	*B*	*A*	L	**VL**
Beetles [Coleoptera: Scarabaeidae]														
Adoretus versutus	VL	M	VL	M	M	VL	*E*	*A*	*D*	*C*	*D*	*B*	M	**VL**
Bugs [Hemiptera: Coreidae]														
Amblypelta cocophaga *Brachylybas variegatus*	M	M	L	L	H	VL	*E*	*A*	*C*	*B*	*C*	*B*	M	**VL**
Whiteflies [Hemiptera: Aleyrodidae]														
Bemisia tabaci 'Nauru' biotype	H	M	M	H	H	M	*E*	*A*	*D*	*B*	*C*	*A*	M	**M**
Scales [Hemiptera: Coccidae]														
Coccus capparidis	H	M	M	H	H	M	*C*	*A*	*B*	*B*	*C*	*A*	L	**L**
Armoured scales [Hemiptera: Diaspididae]														
Pseudaulacaspis pentagona[WA] *Unaspis citri*[WA]	M	L	L	M	H	L	*D*	*A*	*C*	*B*	*C*	*B*	L	**VL**
Mealybugs [Hemiptera: Pseudococcidae]														
Planococcus minor[WA]	H	M	M	H	H	M	*D*	*A*	*C*	*A*	*C*	*B*	L	**L**
Leaf rollers [Lepidoptera: Crambidae]														
Haritalodes derogata[WA]	H	L	L	VL	M	VL	*C*	*A*	*B*	*A*	*B*	*A*	VL	**N**

5 Pest risk management

This chapter provides information on the management of quarantine pests identified with an unrestricted risk exceeding Australia's appropriate level of protection (ALOP). The proposed phytosanitary measures are described below.

5.1 Pest risk management measures and phytosanitary procedures

Specific pest risk management measures and a system of operational procedures are proposed for fresh island cabbage leaves from the Cook Islands, Fiji, Samoa, Tonga and Vanuatu to reduce the restricted risk to a level that achieves Australia's ALOP.

The pest risk management measures proposed for fresh island cabbage leaves are summarised in Table 5.1.

Table 5.1 Phytosanitary measures proposed for quarantine pests for island cabbage from the Pacific

Pest	Common name	Measures
Arthropods		
Bemisia tabaci 'Nauru' biotype	Whitefly	Pre-export phytosanitary inspection and certification
Coccus capparidis	Tortoise scale	Pre-export phytosanitary inspection and certification
Planococcus minor	Pacific mealybug	Pre-export phytosanitary inspection and certification

5.1.1 Pest risk management for pests

Management for whitefly

The *Bemisia tabaci* 'Nauru' biotype has been assessed to have an unrestricted risk estimate of 'moderate' for island cabbage leaves imported from countries hosting this pest, and additional measures are therefore required to manage this risk.

The major risk from the *Bemisia tabaci* 'Nauru' biotype is that eggs and nymphs may be present on the leaves.

The proposed risk management measure is pre-export phytosanitary inspection of leaves to ensure that island cabbage leaves infested with whiteflies are identified and subjected to appropriate remedial action.

The objective of this measure is to reduce the likelihood of importation for the *Bemisia tabaci* 'Nauru' biotype to at least 'low'. The restricted risk would then be reduced to 'very low', which would achieve Australia's ALOP.

Management for tortoise scale

Coccus capparidis has been assessed to have an unrestricted risk estimate of 'low' for island cabbage leaves imported from countries hosting this pest, and additional measures are therefore required to manage this risk.

The major risk from *Coccus capparidis* is that nymphs and adults may be present on the leaves.

The proposed risk management measure is pre-export phytosanitary inspection of leaves to ensure that island cabbage leaves infested with scales are identified and subjected to appropriate remedial action. DAFF will verify this with a further inspection on arrival.

The objective of this measure is to reduce the likelihood of importation for *Coccus capparidis* to at least 'low'. The restricted risk would then be reduced to 'very low', which would achieve Australia's ALOP.

Management for Pacific mealybug

Planococcus minor has been assessed to have an unrestricted risk estimate of 'low' for island cabbage leaves imported from countries hosting this pest, and additional measures are therefore required to manage this risk.

The major risk from *Planococcus minor* is that eggs, nymphs and adults may be present on the leaves.

The proposed risk management measure is pre-export phytosanitary inspection of leaves to ensure that island cabbage leaves infested with scales are identified and subjected to appropriate remedial action. DAFF will verify this with a further inspection on arrival.

The objective of this measure is to reduce the likelihood of importation for *Planococcus minor* to at least 'low'. The restricted risk would then be reduced to 'very low', which would achieve Australia's ALOP.

5.1.2 Operational system for the maintenance and verification of phytosanitary status

A system of operational procedures is necessary to maintain and verify the phytosanitary status of island cabbage from the Pacific.

Packaging and labelling

The objectives of this requirement for packaging and labelling are to ensure that:

- fresh island cabbage leaves exported to Australia are not contaminated by quarantine pests or regulated articles (e.g. trash, soil and weed seeds)
- unprocessed packing material (which may vector pests not identified as being on the pathway) is not imported with the island cabbage leaves
- all wood used in the packaging of the commodity complies with DAFF conditions (see publication 'Cargo containers: Quarantine aspects and procedures').

Pre-export phytosanitary inspection and certification by a NPPO, or other relevant agency nominated by the NPPO

The objectives of phytosanitary certification are to ensure that:

- an International Phytosanitary Certificate (IPC) is issued for each consignment, consistent with ISPM 12 – Guidelines for Phytosanitary Certificates (FAO 2011), to provide formal documentation to DAFF verifying the relevant measures have been undertaken offshore
- each IPC includes a description of the consignment (including the country of origin)

Additional Phytosanitary Certificate declaration

Each consignment must be accompanied by an original IPC endorsed with the following additional declaration:

The island cabbage leaves have been inspected and found to be free of whitefly (*Bemisia tabaci* 'Nauru' biotype), tortoise scale (*Coccus capparidis*) and Pacific mealybug (*Planococcus minor*).

On-arrival DAFF inspection

A verification inspection of consignments covered by each phytosanitary certificate issued by the NPPO will be undertaken by DAFF on arrival of the consignment in Australia. The inspection will be conducted using the standard DAFF inspection protocol for the type of commodity using optical enhancement where necessary.

Remedial action for non-compliance – on-arrival verification

The objective of the proposed requirements for remedial action for non-compliance during on-arrival verification are to ensure that any quarantine risk is addressed by remedial action, as appropriate, for consignments that do not comply with import requirements.

5.2 Review of policy

Australia collects data on pests intercepted in trade and uses this data to validate import policy. Depending on the level and type of pest interceptions at the border, DAFF may consider further revisions of this policy and the operational requirements.

5.3 Uncategorised pests

If an organism is detected on island cabbage leaves during inspection, that has not been categorised, it will require assessment by DAFF to determine its quarantine status and if phytosanitary action is required. The detection of any pests of quarantine concern not already identified in the analysis may result in remedial action, as appropriate.

6 Conclusion

The findings of this final report are based on a comprehensive analysis of relevant scientific literature. DAFF considers that the risk management measures proposed in this report will provide an appropriate level of protection against the pests identified in this pest risk analysis. A range of risk management measures may be suitable to manage the risks associated with island cabbage leaves from the Pacific. DAFF will consider any other measures suggested by stakeholders that provide an equivalent level of phytosanitary protection.

Appendices

Appendix A Initiation and categorisation for pests of island cabbage from the Pacific

Initiation (columns 1 – 3) identifies the pests of island cabbage that have the potential to be on fresh leaves produced in the Pacific (Cook Islands, Fiji, Samoa, Tonga and Vanuatu) using commercial production and packing procedures.

Pest categorisation (columns 4 - 7) identifies which of the pests with the potential to be on island cabbage leaves are quarantine pests for Australia and require pest risk assessment.

The steps in the initiation and categorisation processes are considered sequentially, with the assessment terminating at the first 'No' for columns 3, 5 or 6 or 'Yes' for column 4.

Details of the method used in this risk analysis are given in Section 2: Method for pest risk analysis.

Contaminating pests are not considered under categorisation. Contaminant pests are addressed under existing standard operational procedures.

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
DOMAIN EUKARYA						
ANIMALIA (Animal Kingdom)						
ARTHROPODA: Arachnidia: Acari						
Order Acariformes (mites)						
Tetranychus marianae McGregor, 1950 [Tetranychidae] Mariana mite	Fiji (Hinckley 1965; Stout 1982).	Yes. This species has been reported on island cabbage in Solomon Islands (Walton 1986) and is a pest of island cabbage (Fa'anunu 2009). *Tetranychus* spp. spider mites feed on the undersides of the leaves, mainly near the veins (Carmichael *et al.* 2008).	Yes. Recorded in NT (NTDPIF 2001) and Qld (Davis 1968) and WA (unpublished NAQS survey data).			No
ARTHROPODA: Insecta						
Order Coleoptera (beetles)						
Adoretus versutus Harold, 1869 [Scarabaeidae] Rose beetle	Cook Islands (CABI 2012), Fiji (Hinckley 1965), Samoa (Stout 1982), Tonga (Engelberger and Foliaki 1992), Vanuatu (Waterhouse and Norris 1987).	Yes. This species has been reported on island cabbage in Tonga (Engelberger and Foliaki 1992), although it is unlikely to be present when leaves are harvested during daylight hours. Adults feed on the leaves, chewing holes (Stout 1982).	No record found.	Yes. *Adoretus versutus* is a polyphagous beetle and many of its host plants are present in Australia. Its distribution globally is mostly tropical, so it may establish in northern Australia.	Yes. The rose beetle is a destructive pest of ginger, cocoa, grapevines, avocados, oranges, papayas, citrus fruits, beans, lychees, cashews, bananas, sweet potatoes and apples (CABI 2012).	**Yes**

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Apirocalus cornutus cornutus (Pascoe, 1881) Note: the taxonomy of this genus has been revised, splitting *Apirocalus cornutus* into a number of distinct subspecies and giving *Apirocalus cornutus ebrius* full species status (Setliff 2007). [Curculionidae] Horned weevil	Record from Fiji appears doubtful. Pascoe gave the incorrect type-locality as Fiji when the species was first described (Thompson 1977).	Not known to be present in the countries being assessed. However, it has been reported on island cabbage in Papua New Guinea (French 2006). It eats the leaves of young plants (Hick 1980).	Yes. This species has been recorded in north Queensland (Maddison 1993), and is present on some islands in the Torres Strait (APPD 2012).	Yes. This species is already present in northern Queensland, and feeds on a broad range of plants that are present in Australia. However, its restricted distribution internationally does not suggest it is invasive or likely to spread.	No. Adult weevils feed on crop plants including banana, cassava, chilli, cabbage, lettuce, beetroot, carrot, sweet potato, coffee, apple, citrus and strawberry, although damage is often not serious. They can occasionally cause severe damage in coffee (French 2006).	No
Aulacophora indica (Gmelin, 1790) Synonym: *Aulacophora similis* Olivier, 1808 [Chrysomelidae] Pumpkin beetle	Fiji (Hinckley 1965), Samoa (Stout 1982), Tonga (Engelberger and Foliaki 1992), Vanuatu (CABI 2012).	Yes. Feeds on island cabbage leaves, although it is an active crawler unlikely to remain on leaves during postharvest preparation for export.	No record found.	Yes. This species feeds on plants that are common in Australia, particularly cucurbits. It has a wide distribution in tropical Asia, the Pacific and the Subcontinent, and could potentially establish in northern Australia.	Yes. Feeding beetles can totally defoliate plants. Larvae are also very injurious to cucurbits, attacking the roots and lower parts of the stems (CABI 2012). Related species *Aulacophora hilaris* and *Aulacophora abdominalis* are pests in Australia (Brown 2003).	**Yes**
Elytrurus griseus (Guérin-Méneville) Marshall, 1938 [Curculionidae] Broad-nosed weevil	Fiji (Zimmerman 1956).	Yes. The adult weevils feed on island cabbage leaves (Stout 1982; Fa'anunu 2009).	No record found.	No. While this species has spread among the Fijian islands, assisted by human activity (Zimmerman 1956), it does not appear to have established anywhere else. Reports are rare and information on hosts is not available.	No. At times this species may become a minor pest (Zimmerman 1956), but reports of it are rare and little information is available to indicate potential economic consequences.	No
Platysimus septentrionalis (Paulian, 1945) [Curculionidae] Grey weevil	Vanuatu (Kuschel 2008).	Yes. Adults feed on the leaves of host plants (Maddison 1993), although likely to drop to the ground when disturbed at harvest or during postharvest handling.	No record found.	Yes. Not a specialised feeder and reported on a range of plant hosts that are common in parts of Australia, e.g. citrus, hibiscus, taro (Kuschel 2008). However, it has limited distribution in the Pacific, found only in Vanuatu and parts of Solomon Islands (Kuschel 2008).	No. Not reported to be a pest (Maddison and Crosby 2009).	No

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Sphaerorhinus aberrans Fairmaire, L. 1881 [Curculionidae] Weevil	Tonga (Stout 1982).	Yes. Adults of this species have been reported feeding on island cabbage leaves in Tonga (Stout 1982).	No record found.	No. This species is poorly described in the literature. Information on its distribution and preferred hosts is not available. The lack of reports suggests that it is not an invasive species, and establishment and spread is unlikely.	No. There are no reports of this species being a pest. Information on hosts is not available.	No
Order Hemiptera (aphids, leafhoppers, mealybugs, phyllids, scales, true bugs, whiteflies)						
Amblypelta cocophaga China, 1934 [Coreidae] Coconut bug	Fiji (CABI 2012).	Yes. Reported on island cabbage in Papua New Guinea (French 2006). This species feeds on sap. Eggs are laid on the leaves (Hick 1980; French 2006).	No record found.	Yes. This bug has a wide host range, feeding on at least 43 plant species from 30 plant families (Waite and Huwer 1998). Hosts include eucalyptus, citrus, mango and pawpaw (CABI 2012), which are common in parts of Australia.	Yes. This species is a serious pest of coconut and cocoa in Solomon Islands (Mitchell 2000). It also attacks crops such as citrus, mango, melons, peach and papaya (CABI 2012).	**Yes**
Aphis craccivora Koch, 1854 [Aphididae] Cowpea aphid	Fiji (Hinckley 1965), Samoa (CABI 2012), Tonga (Carver *et al*. 1993).	Yes. Colonies are usually found on the growing points of host plants (CABI 2012).	Yes. Recorded in ACT, NSW, NT, Qld, Tas., Vic. and WA (AICN 2012).			No
Aphis fabae Scopoli, 1763 [Aphididae] Bean aphid	Reported to be in Tonga (Engelberger and Foliaki 1992), but this record may be an error. No other reports from Tonga or the Pacific region found. Presence appears doubtful as it is mostly found in temperate and Mediterranean climates (CABI 2012).		No record found.			No
Aphis gossypii Glover, 1877 [Aphididae] Cotton aphid	Cook Islands (Stout 1982), Fiji (Hinckley 1965), Samoa (Stout 1982), Tonga (Carver *et al*.1993), Vanuatu (CABI 2012).	Yes. Commonly recorded on island cabbage throughout the Pacific. Feeds on the leaves, stems and growing points of host plants (CABI 2012).	Yes. Recorded in ACT, NSW, NT, Qld, SA, Tas., Vic. and WA (AICN 2012).			No

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Bemisia tabaci (Gennadius, 1889) 'Nauru' biotype [Aleyrodidae] Whitefly	Fiji, Samoa, Tonga (De Barro 1998).	Yes. This species has been reported on island cabbage in Tonga (Engelberger and Foliaki 1992). Eggs are laid on the undersides of leaves. After hatching, the first instar nymphs feed on the lower leaf surface (CABI 2012).	The 'Nauru' biotype is not known to be present in Australia. However, the An, B, and Q biotypes are present in Australia (De Barro 1998; QDPIF 2009).	Yes. The B and Q *Bemisia tabaci* biotypes have established in Australia following their introduction (QDPIF 2009).	Yes. High populations can damage host plant growth through feeding and production of honeydew. A bigger threat is the introduction of plant viruses (QDPIF 2009).	**Yes**
Brachylybas variegatus (Le Guillou, 1841) [Coreidae] Brown coreid bug	Fiji (Bryan 1924), Tonga (Engelberger and Foliaki 1992).	Yes. This species has been reported on island cabbage in Tonga (Engelberger and Foliaki 1992), and may be found on the foliage (Stout 1982). Coreids are large bugs that mainly feed on leaves, shoots and fruits of hosts (Carver *et al*. 1991).	No record found.	Yes. Information on this species is scarce. Its limited distribution internationally suggests that it is not a particularly invasive species. However, known host plants, including tomato, pumpkin and taro (Lever 1947), are common in Australia.	Yes. There is no information on damage caused by this species. However, it is known to feed on commercial crop species so could potentially have commercial consequences.	**Yes**
Coccus capparidis (Green, 1904) [Coccidae] Tortoise scale	Samoa, Tonga (Williams and Watson 1990).	Yes. This species has been reported on island cabbage in Kiribati (Williams and Watson 1990). Island cabbage is a host, and the scale can be found on the undersurface of the leaves of host plants (Williams and Watson 1990).	No record found.	Yes. This species appears to have established in many countries following accidental introduction.	Yes. This species is a pest of citrus (Williams and Watson 1990).	**Yes**
Coccus hesperidum Linnaeus, 1758 [Coccidae] Brown soft scale	Cook Islands, Fiji, Samoa, Tonga (Williams and Watson 1990), Vanuatu (Ben-Dov *et al*. 2012).	Yes. This species has been reported on island cabbage in Kiribati (Williams and Watson 1990) and Papua New Guinea (French 2006). Island cabbage is a host (Ben-Dov *et al*. 2012).	Yes. Recorded in NSW, NT, Qld, SA, Tas., WA (AICN 2012; Ben-Dov *et al*. 2012).			No
Dysdercus cingulatus (Fabricius, 1775) [Pyrrhocoridae] Red cotton stainer	Vanuatu (CABI 2012).	No. Reported on island cabbage in Solomon Islands (Walton 1986). However, this species predominantly feeds on seeds and flowers (CABI 2012), and is not usually associated with the leaves. This species drops to the ground when disturbed (French 2006), so is unlikely to remain with the leaves in trade.	Yes. Recorded in NT, Qld (AICN 2012), NSW and SA (CABI 2012).			No

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Maconellicoccus hirsutus (Green, 1908) [Pseudococcidae] Pink hibiscus mealybug	Fiji (Hodgson and Lagowa 2011), Tonga (Williams and Watson 1988b), Samoa, Vanuatu (CABI 2012).	Yes. This species has been reported on island cabbage in Tonga (Williams and Watson 1988b), and may be found on the leaves of host plants (CABI 2012).	Yes. Recorded in NT, Qld, SA and WA (AICN 2012; Ben-Dov *et al.* 2012).			No
Myzus persicae (Sulzer, 1776) [Aphididae] Green peach aphid	Fiji (Hinckley 1965), Tonga (Carver *et al*. 1993), Cook Islands, Samoa (Ecoport 2012).	Yes. Has been reported on island cabbage in the Cook Islands, Fiji, French Polynesia, Kiribati, Mariana Islands, New Caledonia, Papua New Guinea, Samoa, Solomon Islands and Tonga (Ecoport 2012). May be found on the leaves (Stout 1982).	Yes. Recorded in NSW, NT, Qld, SA, Tas., Vic. and WA (AICN 2012).			No
Parasaissetia nigra (Nietner, 1861) [Coccidae] Nigra scale	Cook Islands, Fiji, Samoa, Tonga, Vanuatu (Williams and Watson 1990).	Yes. Reported on island cabbage in Federated States of Micronesia, Guam, Palau, Papua New Guinea and Tonga (Ecoport 2012). May be present on the stems (Stout 1982).	Yes. Recorded in NSW, NT, Qld (Ben-Dov *et al*. 2012), Vic. and WA (AICN 2012).			No
Pinnaspis strachani (Cooley, 1899) [Diaspididae] Hibiscus snow scale	Cook Islands, Fiji, Samoa, Tonga, Vanuatu (Watson 2012).	Yes. Island cabbage is a host (Williams and Watson 1988a). The scale is usually found on twigs, branches or trunks of host plants, but occasionally on leaves (Watson 2012).	Yes. Recorded in NT, Qld, WA (Donaldson 2002) and SA (Ben-Dov *et al*. 2012).			No
Planococcus minor (Maskell, 1897) Synonym: *Planococcus pacificus* Cox, 1981 [Pseudococcidae] Pacific mealybug	Cook Islands, Fiji, Samoa, Tonga, Vanuatu (Williams and Watson 1998b; Ben-Dov 1994).	Yes. Island cabbage is a host (Williams and Watson 1988b).	Yes. Recorded in ACT, NSW, NT, Qld and SA (AICN 2012).	Yes. This species has a very broad host range (Ben-Dov *et al.* 2012). It is already present in much of eastern Australia, so is likely to establish if introduced to parts of Western Australia.	Yes. This species feeds on many economically important plants, including citrus, cucurbits, grapevine, mango and potato (Ben-Dov *et al*. 2012).	**Yes (for WA)**
Pseudaulacaspis pentagona (Targioni Tozzetti, 1886) [Diaspididae] White peach scale	Fiji, Samoa, Tonga, Vanuatu (Williams and Watson 1988a; Watson 2012).	Yes. Island cabbage is a host (Williams and Watson 1988a). Usually found on stems of host plants, but rarely on leaves (Stout 1982; Watson 2012).	Yes. Recorded in NSW, Qld (AICN 2012; Watson 2012).	Yes. This species has a history of accidental introductions around the world, including Australia (CABI 2012), indicating that it can establish in new environments. It has already established in eastern Australia.	Yes. This scale is mainly a pest of deciduous fruits such as peach, currant, grape, kiwifruit and walnut. Affected plants lose vigour, and whole trees may die (CABI 2012).	**Yes (for WA)**
Tectocoris diophthalmus (Thurnberg, 1783) [Scutelleridae] Cotton harlequin bug	Fiji, Tonga, Vanuatu (Cassis 1995).	Yes. Reported on island cabbage in Tonga (Engelberger and Foliaki 1992). They may be found on the foliage (Stout 1982).	Yes. Recorded in NSW, NT, Qld (Cassis 1995) and WA (AICN 2012).			No

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Unaspis citri (Comstock, 1883) [Diaspididae] Citrus snow scale	Cook Islands, Fiji, Samoa, Tonga, Vanuatu (Watson 2012; Waterhouse and Norris 1987).	Yes. Reported on island cabbage in Papua New Guinea (Ecoport 2012). It is a polyphagous scale species attacking a range of plants. Usually on the trunk and main limbs of host plants, but occasionally found on leaves (Watson 2012).	Yes. Recorded in NSW, NT, Qld, SA and Vic. (Watson 2012).	Yes. This species has a broad host range including a number of citrus species (Ben-Dov *et al.* 2012). It is already present in eastern Australia, so is likely to establish if introduced to parts of Western Australia.	Yes. This species is a citrus pest of major economic importance, although it is less of a problem in temperate areas. Heavy infestations of *Unaspis citri* can cause extensive drying and splitting of the bark on the trunk and main limbs of citrus trees (Ben-Dov *et al.* 2012).	**Yes (for WA)**
Order Lepidoptera (butterflies, moths)						
Acrocercops sp. [Gracillariidae] Leaf blister moth	Tonga (Engelberger and Foliaki 1992).	Yes. An unidentified *Acrocercops* species was reported on island cabbage in Tonga (Engelberger and Foliaki 1992). The larvae mine in the leaves (Stout 1982). No further information is available.	More than 65 species of *Acrocercops* have been reported in Australia (Nielsen *et al*. 1996).			No
Anomis flava (Fabricius, 1775) [Noctuidae] Cotton looper	Cook Islands, Fiji, Samoa (Stout 1982), Tonga (Engelberger and Foliaki 1992).	Yes. This species has been reported on island cabbage in Tonga (Engelberger and Foliaki 1992). The larvae eat the leaves (Stout 1982).	Yes. NSW, NT, Qld, SA, Vic., WA (AICN 2012).			No
Anomis lyona (Swinhoe, 1919) [Noctuidae] Looper	Samoa (Kami and Miller 1998).	Yes. Information on this species is not available. However, the larvae of other *Anomis* species are known to be leaf feeders (Stout 1982).	Yes. Recorded in NSW and Qld (Common 1990).	Yes. This species is already present in Australia, although there is no information to suggest it is invasive and likely to spread.	No. There is no information available that suggests that this species is a pest of any economic significance.	No
Chrysodeixis eriosoma (Doubleday, 1843) [Noctuidae] Green garden looper	Cook Islands, Fiji, Samoa, Tonga (Stout 1982).	Yes. This species has been reported on island cabbage in Tonga (Engelberger and Foliaki 1992). The larvae eat the leaves (Stout 1982).	Yes. NSW, NT, Qld, Tas. (CABI 2012) and WA (APPD 2012).			No
Earias vittella (Sherborn, 1902) [Noctuidae] Spiny bollworm	Cook Islands, Fiji, Samoa, Tonga (Stout 1982).	Yes. This species has been reported on island cabbage in Tonga (Engelberger and Foliaki 1992) and Solomon Islands (Walton 1986).	Yes. Qld and WA (APPD 2012).			No

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Haritalodes derogata (Fabricius, 1775) Synonym: *Sylepta derogata* (Fabricius, 1775) [Crambidae] Cotton leaf roller	Fiji, Samoa (Stout 1982).	Yes. The larvae of this species feed on island cabbage leaves, and pupate in a rolled up leaf cases. Eggs are laid on the leaf underside (French 2006).	Yes. Recorded in NSW, Qld (APPD 2012).	Yes. This species has a wide distribution through Asia, Africa and the Pacific. It has yet to establish in Western Australia, but some host plants are grown in parts of that state, so it could potentially establish if introduced.	Yes. This species can be a serious pest of cotton (CABI 2012). It also feeds on cassava, okra, tomato, eggplant and jute (CABI 2012).	**Yes** **(for WA)**
Spodoptera litura (Fabricius, 1775) [Noctuidae] Armyworm	Cook Islands, Fiji, Samoa, Tonga (Stout 1982), Vanuatu (CABI 2012).	Yes. Reported on island cabbage in Papua New Guinea (French 2006) and Tonga (Engelberger and Foliaki 1992). The larvae eat the leaves (Stout 1982).	Yes. Recorded in NSW, NT, Qld, Vic. and WA (CABI 2012).			No
Tiracola plagiata (Walker, 1870) [Noctuidae] Cacao armyworm	Cook Islands, Fiji, Samoa and Tonga (Stout 1982).	Yes. Reported on island cabbage in Tonga (Engelberger and Foliaki 1992). The larvae feed on the foliage (Stout 1982).	Yes. Recorded in NSW, NT, Qld and WA (AICN 2012).			No
NEMATODA: Class (Phylum: Class)						
Order Tylenchida						
Aphelenchoides bicaudatus (Imamura, 1931) Filipjev & Schuurmans Stekhoven, 1941 [Aphelenchoididae]	Fiji, Samoa, Tonga (Orton Williams 1980).	Yes. Recorded on island cabbage in Tonga (Orton Williams 1980).	Yes. Recorded in NSW, Qld, Vic. and WA (McLeod *et al*. 1994).			No

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
CHROMALVEOLATA (Kingdom)						
Order Pythiales (water moulds)						
Phytophthora nicotianae Breda de Haan Synonyms: *Phytophthora nicotianae* var. *nicotianae* Breda de Haan *Phytophthora nicotianae* var. *parasitica* (Dastur) G.M. Waterh. [Pythiaceae] Black shank	Cook Islands, Fiji (Dingley *et al*. 1981).	No. Island cabbage is reported as a host in Fiji (Dingley *et al*. 1981). Causes root and collar rot, and unlikely to be on leaf, so quarantine measures are not needed for island cabbage leaf (Stout 1982).	Yes. Recorded in Qld (Simmonds 1966), Tas. (Sampson and Walker 1982) and WA (Shivas 1989).			No
DOMAIN FUNGI						
Order Erysiphales						
Podosphaera fuliginea (Schltdl.) U. Braun & S. Takam. Synonym: *Sphaerotheca fuliginea* (Schltdl.) Pollacci [Cystotheceae] Powdery mildew	Cook Islands, Fiji, Samoa, Tonga (Dingley *et al*. 1981) and Vanuatu (McKenzie 1989).	Yes. Reported on island cabbage in China and Taiwan (Farr and Rossman 2012).	Yes. Recorded in NSW (Letham and Priest 1989), Qld (Clare 1964), SA (Cook and Dube 1989) and WA (APPD 2012).			No
Order Hypocreales						
Myrothecium roridum Tode: Fr. [Incertae sedis] Leaf spot	Samoa, Tonga (Dingley *et al*. 1981), Vanuatu (McKenzie 1989).	Yes. Reported on island cabbage leaves in Papua New Guinea (Hyde and Philemon 1994).	Yes. Recorded in NT (Davison *et al*. 2008), Qld (Shivas and Alcorn 1996), SA (Cook and Dube 1989) and WA (APPD 2012).			No
Haematonectria haematococca (Berk. & Broome) Samuels & Rossman Synonym: *Nectria haematococca* Berk. & Broome Anamorph: *Fusarium solani* (Mart.) Sacc. [Nectriaceae] Stem rot	Fiji, Samoa (Dingley *et al*. 1981), Vanuatu (McKenzie 1989).	Yes. Reported on island cabbage in Vanuatu (McKenzie 1989).	Yes. Recorded in NSW (Letham 1995), Qld (Simmonds 1966), SA (Cook and Dube 1989), Tas. (Sampson and Walker 1982) and WA (Shivas 1989).			No

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Order Mycosphaerellales						
Cercospora apii s. lat. Fresen. Emend. PW Crous & U Braun Synonym: *Cercospora malayensis* F. Stevens & Solheim [Mycosphaerellaceae] Brown leaf spot	Fiji, Tonga (Dingley *et al*. 1981), Vanuatu (McKenzie 1989).	Yes. This pathogen causes leaf spots, and has been reported on island cabbage in Japan (Farr and Rossman 2012), although it is more commonly associated with okra in the Pacific.	Yes. Recorded in NSW, NT (Liberato and Stephens 2006), Qld (Simmonds 1966) and WA (Shivas 1989). A number of *Cercospora* species from the Pacific region including *Cercospora malayensis* have been reclassified as belonging to the *Cercospora apii* complex (McTaggart *et al.* 2008).			No
Pseudocercospora abelmoschi (Ellis & Everh.) Deighton [Mycosphaerellaceae] Leaf spot	Fiji, Samoa, Tonga, Vanuatu (Dingley *et al*. 1981; Preston 1998).	Yes. Reported as a pathogen of island cabbage in American Samoa (McKenzie 1996), Fiji, Samoa, Tonga (Dingley *et al*. 1981) and Vanuatu (McKenzie 1989).	Yes. Recorded in NT (APPD 2012) and WA (Shivas 1995).			No
Order Phyllachorales						
Glomerella cingulata (Stoneman) Spauld. & H Schrenk Anamorph: *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. [Glomerellaceae] Anthracnose	Cook Islands, Fiji, Samoa, Tonga (Dingley *et al*. 1981), Vanuatu (McKenzie 1989).	Yes. Reported on island cabbage in American Samoa (McKenzie 1996). It causes disease of foliage, and can be a vigorous pathogen of young, developing tissues causing leaf blights (CABI 2012).	Yes. Recorded in NSW (Letham 1995), Qld (Simmonds 1966; Hyde and Alcorn 1993), SA (Cook and Dube 1989), Tas. (Sampson and Walker 1982), Vic. (Cunnington 2003) and WA (Shivas 1989).	Yes. This pathogen is already widespread in Australia. It can survive as a saprobe. A number of suitable hosts are present in Tasmania including citrus, onions, leeks, garlic, tomato and *Prunus* spp. (CABI 2012).	Yes. This pathogen causes significant damage in tropical crops, and is responsible for major post harvest losses (CABI 2012).	No
Order Pleosporales						
Corynespora cassiicola (Berk. & MA Curtis) CT Wei Anamorph [Corynesporascaceae] Leaf spot	Cook Islands, Fiji, Samoa, Tonga (Dingley *et al.* 1981), Vanuatu (McKenzie 1989).	Yes. Reported on island cabbage in Vanuatu (McKenzie 1989). Lesions appear on the leaves of hosts (Liberato and McTaggart 2007).	Yes. Qld (Shivas and Alcorn 1996), NSW (Letham 1995), NT, Vic. and WA (APPD 2012).	Yes. This fungus is already present in Queensland. Disease caused by *Corynespora cassiicola* has spread rapidly through parts of Africa and Asia. It has been reported on more than 280 plant species (Qi *et al*. 2009), and many of these hosts are present in Australia.	Yes. There are numerous reports of this fungus infecting many economically important crops, including rubber, tobacco, cowpea, eggplant, sesame, tomato, soybean, cucurbits and cotton (Qi *et al*. 2009).	No

Pest	Present in Cook Islands, Fiji, Samoa, Tonga or Vanuatu	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
DOMAIN VIRUSES						
Hibiscus chlorotic ringspot virus [Carmovirus: Tombusviridae]	Fiji, Vanuatu (Pearson and Grisoni 2002; Jones *et al*. 1998).	Yes. This virus has been reported in island cabbage in Fiji, Papua New Guinea, Solomon Islands, Vanuatu (Pearson and Grisoni 2002) and Tuvalu (Jones *et al*. 1998).	Yes. Qld and SA (Büchen-Osmond 2002; Jones and Behncken 1980).	No. This virus is disseminated via propagation of infected cuttings, or mechanical transmission through contaminated cutting implements and hands (Jones *et al*. 1998). Island cabbage leaves cannot be propagated once the stems are removed, so there is no pathway for virus transmission.		No

Appendix B Additional quarantine pest data

Quarantine pest	***Aulacophora indica*** (Gmelin, 1790)
Synonyms	*Aulacophora similis* Olivier, 1808
Common name(s)	Pumpkin beetle, cucurbit beetle
Main hosts	Many plants from the Cucurbitaceae family, including *Citrullus lanatus* (watermelon), *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Cucurbita maxima* (pumpkin), *Cucurbita pepo* (ornamental gourd), and *Lagenaria siceraria* (bottle gourd). Also reported from *Vigna sinensis* ssp. *sesquipedalis* (asparagus bean), *Vicia faba* (broad bean), *Lablab purpureus* (hyacinth bean), *Zea mays* (maize), *Oryza sativa* (rice), *Spinacia oleracea* (spinach), *Ipomoea batatas* (sweet potato) and *Triticum* spp. (wheat) (CABI 2012).
Distribution	EUROPE: Russia, Siberia ASIA: Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Hong Kong, India, Indonesia, Japan, Korea Republic, Laos, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand, Vietnam OCEANIA: American Samoa, Federated States of Micronesia, Fiji, Guam, New Caledonia, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu, Territory of Wallis and Futuna (CABI 2012).

Quarantine pest	***Adoretus versutus*** Harold, 1869
Synonyms	*Adoretus vestitus* Boheman, 1858 *Adoretus vitiensis* Nonfried, 1891 *Adoretus insularis* Fairmaire, 1897 *Adoretus bangalorensis* Brenske, 1900
Common name(s)	Rose beetle, Indian rose beetle, Fijian cane root grub
Main hosts	*Abelmoschus manihot* (island cabbage), *Acacia* spp., *Anacardium occidentale* (cashew), *Bauhinia* spp. (orchid tree), *Citrus maxima* (pomelo), *Colocasia esculenta* (taro), *Dioscorea* spp. (yams), *Lagerstroemia indica* (crepe myrtle), *Litchi chinensis* (lychee), *Pachyrhizus erosus* (jicama), *Phaseolus* spp. (beans), *Rosa* spp. (rose), *Saccharum officinarum* (sugarcane), *Terminalia catappa* (tropical almond), *Theobroma cacao* (cocoa), *Vitis* spp. (grape), *Zingiber officinale* (ginger), *Zinnia elegans* (common zinnia) (Aberlenc *et al.* 2004).
Distribution	American Samoa, Bangladesh, Cook Islands, Fiji, India, Indonesia, Madagascar, Malaysia, Mauritius, New Caledonia, Pakistan, Reunion, Saint Helena, Samoa, Seychelles, Sri Lanka, Tonga, Vanuatu, Territory of Wallis and Futuna Islands (Aberlenc *et al.* 2004; CABI 2012; Waterhouse and Norris 1987).

Quarantine pest	***Amblypelta cocophaga*** China, 1934
Synonyms	
Common name(s)	Coconut bug
Main hosts	*Carica papaya* (papaya), *Ceiba pentandra* (kapok), *Citrus sinensis* (orange), *Cocos nucifera* (coconut), *Cucumis melo* (melon), *Delonix regia* (flamboyant), *Eucalyptus deglupta* (kamarere), *Macaranga tanarius* (blush macaranga), *Macaranga aleuritoides* (bas), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Merremia pacifica* (veliyawa), *Merremia peltata* (big leaf), *Passiflora quadrangularis* (giant granadilla), *Pipterus argenteus* (native mulberry), *Prunus persica* (peach), *Psophocarpus tetragonolobus* (winged bean), *Rubus molluccanus* (wild raspberry), *Saccharum officinarum* (sugarcane), *Theobroma cacao* (cocoa) (Bigger 1985; CABI 2012).
Distribution	Fiji, Papua New Guinea, Singapore, Solomon Islands (CABI 2012).

Quarantine pest	***Brachylybas variegatus*** (Le Guillou, 1841)
Synonyms	
Common name(s)	Brown coreid bug
Main hosts	Colocasia esculenta (taro), *Cucurbita maxima* (pumpkin), *Lycopersicon esculentum* (tomato), *Passiflora quadrangularis* (giant granadilla) (Lever 1947)
Distribution	Fiji (Lever 1947), Tonga (Ecoport 2012)

Quarantine pest	***Bemisia tabaci*** (Gennadius, 1889) 'Nauru' biotype
Synonyms	
Common name(s)	Whitefly
Main hosts	*Abelmoschus esculentus* (okra), *Achyranthes obtusifolia* (devil's horsewhip), *Achyranthes bidentata* (ox knee), *Achyranthes rubrofusca*, *Ageratum houstonianum* (blue billygoat weed), *Bidens pilosa* (cobbler's pegs), *Boehmeria nivea* (ramie), *Brassica oleracea* (broccoli and cabbage), *Cleome viscose* (Asian spiderflower), *Colocasia esculenta* (taro), *Conyaza bonariensis* (flaxleaf fleabane), *Crassoocephalum crepidioides* (thickhead), *Cucumis sativus* (cucumber), *Cucurbita* sp. (pumpkin), *Cucurbita moschata* (butternut pumpkin), *Dicliptera chinensis* (Chinese foldwing), *Eclipta prostrata* (false daisy), *Emilia sonchifolia* (lilac tasselflower), *Euphorbia cyathophora* (fireplant), *Euphorbia glomerifera*, *Euphorbia hirta* (asthma plant), *Euphorbia heterophylla* (fireplant), *Euphorbia pulcherrima* (poinsettia), *Hibiscus sabdariffa* (roselle), *Humulus scandens* (hop), *Ipomoea acuminata* (blue morning glory), *Ipomoea batatas* (sweet potato), *Lantana camara* (lantana), *Leonurus heterophyllus* (Chinese motherwort), *Lycopersicon esculentum* (tomato), *Manihot esculenta* (cassava), *Merremia umbellata* (hogvine), *Phyllanthus amarus* (stonebreaker), *Physalis angulata* (cutleaf groundcherry), *Siegesbeckia orientalis*, *Solanum melongena* (eggplant), *Sonchus oleraceus* (sow thistle), *Vernonia cinerea* (little ironweed), *Xanthium strumarium* (cocklebur), *Xanthosoma sagittifolium* (tannia) (De Barro *et al*. 1998; Hsieh *et al*. 2005).
Distribution	American Samoa, China, Federated States of Micronesia (Pohnpei), Fiji, Guam, Indonesia, Kiribati, Marshall Islands, Nauru, Niue, Northern Mariana Islands, Palau, Taiwan, Tonga, Tuvalu (De Barro *et al*. 1998; Hsieh *et al*. 2006).

Quarantine pest	***Coccus capparidis*** (Green, 1904)
Synonyms	*Lecanium capparidis* Green, 1904
Common name(s)	Tortoise scale, capparis soft scale
Main hosts	This scale has been reported on hosts from at least 21 plant families. Hosts include *Abelmoschus manihot* (island cabbage), *Acrostichum aureum* (mangrove fern), *Alyxia olivaeformis* (maile), *Artocarpus altilis* (breadfruit), *Asclepias curassavica* (bloodflower), *Bidens pilosa* (cobbler's pegs), *Canna indica* (Indian shot), *Capparis moonii* (Indian caper), *Citrus aurantium* (bitter orange), *Citrus paradisi* (grapefruit), *Citrus sinensis* (orange), *Clermontia* spp., *Codiaeum* spp., *Cordia subcordata* (kou), *Croton* spp., *Dendrobium* spp., *Diospyros virginiana* (persimmon), *Guettarda speciosa* (beach gardenia), *Lantana camara* (lantana), *Meryta macrophylla* (fagufagu), *Mirabilis jalapa* (four o'clock), *Morinda citrifolia* (noni), *Murraya paniculata* (mock orange), *Musa paradisiacal* (plantain), *Myoporum acuminatum* (waterbush), *Nerium oleander* (oleander), *Panax* spp., *Paphiopedilum villosum* (orchid), *Plumeria rubra* (frangipani), *Polyscias balfouriana* (aralia), *Premna* spp., *Stachytarpheta* spp., *Xanthosoma* spp. (Ben-Dov *et al*. 2012)
Distribution	Bahamas, Egypt, Hawaii, Honduras, India, Israel, Kiribati; Sri Lanka, Tonga; United States of America (Florida), Western Samoa (Ben-Dov *et al.* 2012).

Quarantine pest	***Pseudaulacaspis pentagona*** (Targioni Tozzetti, 1886)
Synonyms	*Diapis pentagona* Targioni Tozzetti, 1886; *Aulacaspis pentagona* (Targioni Tozzetti) Cockerell, 1902
Common name(s)	White peach scale, mulberry scale, West Indian scale, white plum scale
Main hosts	This pest is highly polyphagous and feeds on a variety of wild and cultivated woody plants, ornamentals and weeds. It has been reported on hosts from 115 genera in 55 plant families, although it cannot complete development on some of those hosts, so they may not be true hosts. Some important hosts include deciduous fruit trees such as apple, almond, cherry, mulberry, peach and plum, as well as other plants like soybeans, olives, mango, island cabbage, passionfruit, grapevine and cotton (Ben-Dov *et al*. 2012; Watson 2012).
Distribution	Antigua and Barbuda, Argentina, Australia, Austria, Bahamas, Barbados, Bermuda, Brazil, Bulgaria, Canada, Canary Islands, Cayman Islands, Chile, China, Colombia, Comoros, Costa Rica, Croatia, Cuba, Dominica, Dominican Republic, Egypt, France, French Guiana, Federated States of Micronesia, Fiji, Georgia, Germany, Ghana, Greece, Grenada, Guadeloupe, Guam, Guyana, Hawaii, Honduras, Hungary, India, Indonesia, Iran, Italy, Jamaica, Japan, Macedonia, Madagascar, Malawi, Malaysia, Malta, Mauritius, Martinique, Mexico, Montserrat, Netherlands, New Caledonia, Norfolk Island, Palau, Panama, Papua New Guinea, Peru, Puerto Rico, Reunion, Russia, St Croix, St Kitts and Nevis, St Lucia, St Vincent and Grenadines, Samoa, Seychelles, Singapore, Solomon Islands, South Africa, South Korea, Spain, Sri Lanka, Switzerland, Taiwan, Tanzania, Tonga, Trinidad and Tobago, Turkey, Ukraine, United Kingdom, United States of America, Uruguay, Vanuatu, Vietnam, Zanzibar, Zimbabwe (Ben-Dov *et al*. 2012).

Quarantine pest	***Unaspis citri*** (Comstock, 1883)
Synonyms	*Chionaspis citri* Comstock; *Dinaspis veitchi* Green & Liang
Common name(s)	Citrus snow scale, white louse scale
Main hosts	This pest attacks plant species belonging to 12 genera in 9 plant families. The main hosts of economic importance are *Citrus* spp., but it also attacks a wide range of other fruit crops and ornamentals including banana, capsicum, coconut, guava, *Hibiscus* spp., jackfruit, kumquat, pineapple, *Poncirus trifoliata* (trifoliate orange) and *Tillandsia usneoides* (Spanish moss) (EPPO 2012c).
Distribution	Antigua and Barbuda, Argentina, Australia, Barbados, Benin, Bermuda, Bolivia, Brazil, British Virgin Islands, Cameroon, Chile, China, Colombia, Congo, Cook Islands, Cuba, Dominica, Dominican Republic, El Salvador, Ecuador, Fiji, Gabon, Grenada, Guadeloupe, Guinea, Guyana, Haiti, Honduras, Indonesia, Ivory Coast, Jamaica, Kiribati, Malaysia, Mauritius, Mexico, Montserrat, New Caledonia, New Zealand, Niger, Nigeria, Niue, Panama, Papua New Guinea, Paraguay, Peru, Puerto Rico, St Kitts and Nevis, St Lucia, St Vincent and Grenadines, Samoa, Senegal, Sierra Leone, Singapore, Solomon Islands, Togo, Tonga, Trinidad and Tobago, United States of America, Uruguay, Vanuatu, Venezuela, Vietnam, Territory of Wallis and Futuna, Zaire (EPPO 2012c).

Quarantine pest	***Planococcus minor*** (Maskell, 1897)
Synonyms	*Planococcus pacificus* Cox, 1981; *Pseudococcus calceolaria* var. *minor* Maskell, 1897
Common name(s)	Pacific mealybug, passionvine mealybug
Main hosts	This pest is highly polyphagous and feeds on a variety of wild and cultivated plants. There are more than 250 reported host plants in nearly 80 families. Important agricultural crops affected include banana, citrus, cocoa, coffee, corn, grape, mango, potato and soybean (Venette and Davis 2004).
Distribution	American Samoa, Argentina, Bangladesh, Bermuda, Brazil, Burma, Colombia, Cook Islands, Costa Rica, Cuba, Dominica, Fiji, French Polynesia, Galapagos Islands, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Jamaica, Kiribati, Madagascar, Malaysia, Mexico, New Caledonia, Niue, Papua New Guinea, the Philippines, Saint Lucia, Samoa, Singapore, Solomon Islands, Suriname, Taiwan, Thailand, Tokelau, Tonga, Trinidad, Uruguay, Vanuatu (Venette and Davis 2004)

Quarantine pest	***Haritalodes derogata*** (Fabricius, 1775)
Synonyms	*Sylepta derogata* (Fabricius, 1775); *Syllepte derogata* (Fabricius, 1775)
Common name(s)	Cotton leaf roller
Main hosts	*Abelmoschus esculenta* (okra), *Abelmoschus manihot* (island cabbage), *Ceiba pentandra* (kapok), *Corchorus* spp. (jute), *Gossypium* spp. (cotton), *Hibiscus* spp. (rosemallows), *Lycopersicon esculentum* (tomato), *Manihot esculenta* (cassava), *Ochroma pyramidale* (balsa), *Solanum melongena* (eggplant) (Anioke 1989; Arora *et al*. 2009; CABI 2012; Silvie 1990)
Distribution	Angola, Australia, Bangladesh, Benin, Burkina Faso, Buundi, Cameroon, Chad, Congo, Ethiopia, Federated States of Micronesia, Fiji, Ghana, India, Indonesia, Ivory Coast, Japan, Kenya, Korea, Laos, Malawi, Malaysia, Maldives, Mali, Myanmar, Niger, Nigeria, Pakistan, Papua New Guinea, the Philippines, Rwanda, Samoa, Senegal, Seychelles, Sierra Leone, Singapore, Solomon Islands, Somalia, South Africa, Sri Lanka, Sudan, Tanzania, Thailand, Togo, Uganda, Vietnam, Zambia (CABI 2012)

Appendix C Biosecurity framework

Australia's biosecurity policies

The objective of Australia's biosecurity policies and risk management measures is the prevention or control of the entry, establishment or spread of pests and diseases that could cause significant harm to people, animals, plants and other aspects of the environment.

Australia has diverse native flora and fauna and a large agricultural sector, and is relatively free from the more significant pests and diseases present in other countries. Therefore, successive Australian Governments have maintained a conservative, but not a zero-risk, approach to the management of biosecurity risks. This approach is consistent with the World Trade Organization's (WTO's) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement).

The SPS Agreement defines the concept of an 'appropriate level of protection' (ALOP) as the level of protection deemed appropriate by a WTO Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory. Among a number of obligations, a WTO Member should take into account the objective of minimising negative trade effects in setting its ALOP.

Like many other countries, Australia expresses its ALOP in qualitative terms. Australia's ALOP, which reflects community expectations through Australian Government policy, is currently expressed as providing a high level of sanitary and phytosanitary protection, aimed at reducing risk to a very low level, but not to zero.

Consistent with the SPS Agreement, in conducting risk analyses Australia takes into account as relevant economic factors:

- the potential damage in terms of loss of production or sales in the event of the entry, establishment or spread of a pest or disease in the territory of Australia
- the costs of control or eradication of a pest or disease and
- the relative cost-effectiveness of alternative approaches to limiting risks.

Roles and responsibilities within Australia's quarantine system

Australia protects its human[4], animal and plant life or health through a comprehensive quarantine system that covers the quarantine continuum, from pre-border to border and post-border activities.

Pre-border, Australia participates in international standard-setting bodies, undertakes risk analyses, develops offshore quarantine arrangements where appropriate, and engages with our neighbours to counter the spread of exotic pests and diseases.

At the border, Australia screens vessels (including aircraft), people and goods entering the country to detect potential threats to Australian human, animal and plant health.

[4] The Australian Government Department of Health and Ageing is responsible for human health aspects of quarantine.

The Australian Government also undertakes targeted measures at the immediate post-border level within Australia. This includes national co-ordination of emergency responses to pest and disease incursions. The movement of goods of quarantine concern within Australia's border is the responsibility of relevant state and territory authorities, which undertake inter- and intra-state quarantine operations that reflect regional differences in pest and disease status, as a part of their wider plant and animal health responsibilities.

Roles and responsibilities within the Department

The Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) is responsible for the Australian Government's animal and plant biosecurity policy development and the establishment of risk management measures. The Secretary of the Department is appointed as the Director of Animal and Plant Quarantine under the *Quarantine Act 1908* (the Act).

DAFF takes the lead in biosecurity and quarantine policy development and the establishment and implementation of risk management measures across the biosecurity continuum, and:

- conducts risk analyses, including IRAs, and develops recommendations for biosecurity policy as well as providing quarantine policy advice to the Director of Animal and Plant Quarantine
- develops operational procedures, makes a range of quarantine decisions under the Act (including import permit decisions under delegation from the Director of Animal and Plant Quarantine) and delivers quarantine services
- coordinates pest and disease preparedness, emergency responses and liaison on inter- and intra-state quarantine arrangements for the Australian Government, in conjunction with Australia's state and territory governments.

Roles and responsibilities of other government agencies

State and territory governments play a vital role in the quarantine continuum. The BSG works in partnership with state and territory governments to address regional differences in pest and disease status and risk within Australia, and develops appropriate sanitary and phytosanitary measures to account for those differences. Australia's partnership approach to quarantine is supported by a formal Memorandum of Understanding that provides for consultation between the Australian Government and the state and territory governments.

Depending on the nature of the good being imported or proposed for importation, DAFF may consult other Australian Government authorities or agencies in developing its recommendations and providing advice.

As well as a Director of Animal and Plant Quarantine, the Act provides for a Director of Human Quarantine. The Australian Government Department of Health and Ageing is responsible for human health aspects of quarantine and Australia's Chief Medical Officer within that Department holds the position of Director of Human Quarantine. DAFF may, where appropriate, consult with that Department on relevant matters that may have implications for human health.

The Act also requires the Director of Animal and Plant Quarantine, before making certain decisions, to request advice from the Environment Minister and to take the advice into account when making those decisions. The Australian Government Department of the

Sustainability, Environment, Water, Population and Communities (DSEWPC) is responsible under the *Environment Protection and Biodiversity Conservation Act 1999* for assessing the environmental impact associated with proposals to import live species. Anyone proposing to import such material should contact DSEWPC directly for further information.

When undertaking risk analyses, DAFF consults with DSEWPC about environmental issues and may use or refer to DSEWPC's assessment.

Australian quarantine legislation

The Australian quarantine system is supported by Commonwealth, state and territory quarantine laws. Under the Australian Constitution, the Commonwealth Government does not have exclusive power to make laws in relation to quarantine, and as a result, Commonwealth and state quarantine laws can co-exist.

Commonwealth quarantine laws are contained in the *Quarantine Act 1908* and subordinate legislation including the Quarantine Regulations 2000, the Quarantine Proclamation 1998, the Quarantine (Cocos Islands) Proclamation 2004 and the Quarantine (Christmas Island) Proclamation 2004.

The quarantine proclamations identify goods, which cannot be imported, into Australia, the Cocos Islands and or Christmas Island unless the Director of Animal and Plant Quarantine or delegate grants an import permit or unless they comply with other conditions specified in the proclamations. Section 70 of the Quarantine Proclamation 1998, section 34 of the Quarantine (Cocos Islands) Proclamation 2004 and section 34 of the Quarantine (Christmas Island) Proclamation 2004 specify the things a Director of Animal and Plant Quarantine must take into account when deciding whether to grant a permit.

In particular, a Director of Animal and Plant Quarantine (or delegate):

- must consider the level of quarantine risk if the permit were granted, and
- must consider whether, if the permit were granted, the imposition of conditions would be necessary to limit the level of quarantine risk to one that is acceptably low, and
- for a permit to import a seed of a plant that was produced by genetic manipulation – must take into account any risk assessment prepared, and any decision made, in relation to the seed under the Gene Technology Act, and
- may take into account anything else that he or she knows is relevant.

The level of quarantine risk is defined in section 5D of the *Quarantine Act 1908*. The definition is as follows:

> reference in this Act to a *level of quarantine risk* is a reference to:
>
> (a) the probability of:
>
> (i) a disease or pest being introduced, established or spread in Australia, the Cocos Islands or Christmas Island; and
>
> (ii) the disease or pest causing harm to human beings, animals, plants, other aspects of the environment, or economic activities; and
>
> (b) the probable extent of the harm.

The Quarantine Regulations 2000 were amended in 2007 to regulate keys steps of the import risk analysis process. The Regulations:

- define both a standard and an expanded IRA,
- identify certain steps, which must be included in each type of IRA,
- specify time limits for certain steps and overall timeframes for the completion of IRAs (up to 24 months for a standard IRA and up to 30 months for an expanded IRA),
- specify publication requirements,
- make provision for termination of an IRA, and
- allow for a partially completed risk analysis to be completed as an IRA under the Regulations.

The Regulations are available at www.comlaw.gov.au.

International agreements and standards

The process set out in the *Import Risk Analysis Handbook 2011* is consistent with Australia's international obligations under the SPS Agreement. It also takes into account relevant international standards on risk assessment developed under the International Plant Protection Convention (IPPC) and by the World Organisation for Animal Health (OIE).

Australia bases its national risk management measures on international standards where they exist and when they achieve Australia's ALOP. Otherwise, Australia exercises its right under the SPS Agreement to apply science-based sanitary and phytosanitary measures that are not more trade restrictive than required to achieve Australia's ALOP.

Notification obligations

Under the transparency provisions of the SPS Agreement, WTO Members are required, among other things, to notify other members of proposed sanitary or phytosanitary regulations, or changes to existing regulations, that are not substantially the same as the content of an international standard and that may have a significant effect on trade of other WTO Members.

Risk analysis

Within Australia's quarantine framework, the Australian Government uses risk analyses to assist it in considering the level of quarantine risk that may be associated with the importation or proposed importation of animals, plants or other goods.

In conducting a risk analysis, DAFF:

- identifies the pests and diseases of quarantine concern that may be carried by the good
- assesses the likelihood that an identified pest or disease or pest would enter, establish or spread
- assesses the probable extent of the harm that would result.

If the assessed level of quarantine risk exceeds Australia's ALOP, DAFF will consider whether there are any risk management measures that will reduce quarantine risk to achieve the ALOP. If there are no risk management measures that reduce the risk to that level, trade will not be allowed.

Risk analyses may be carried out by DAFF's specialists, but may also involve relevant experts from state and territory agencies, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), universities and industry to access the technical expertise needed for a particular analysis.

Risk analyses are conducted across a spectrum of scientific complexity and available scientific information. An IRA is a type of risk analysis with key steps regulated under the Quarantine Regulations 2000. DAFF's assessment of risk may also take the form of a non-regulated analysis of existing policy or technical advice. Further information on the types of risk analysis is provided in the *Import Risk Analysis Handbook 2011*.

Glossary

Term or abbreviation	Definition
Additional declaration	A statement that is required by an importing country to be entered on a phytosanitary certificate and which provides specific additional information on a consignment in relation to regulated pests (FAO 2012).
Appropriate level of protection (ALOP)	The level of protection deemed appropriate by the Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory (WTO 1995).
Area	An officially defined country, part of a country or all or parts of several countries (FAO 2012).
Area of low pest prevalence	An area, whether all of a country, part of a country, or all parts of several countries, as identified by the competent authorities, in which a specific pest occurs at low levels and which is subject to effective surveillance, control or eradication measures (FAO 2012).
Certificate	An official document which attests to the phytosanitary status of any consignment affected by phytosanitary regulations (FAO 2012).
Consignment	A quantity of plants, plant products and/or other articles being moved from one country to another and covered, when required, by a single phytosanitary certificate (a consignment may be composed of one or more commodities or lots) (FAO 2012).
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO 2012).
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
Endangered area	An area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss (FAO 2012).
Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO 2012).
Establishment	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2012).
Fresh	Living; not dried, deep-frozen or otherwise conserved (FAO 2012).
Host range	Species capable, under natural conditions, of sustaining a specific pest or other organism (FAO 2012).
Import permit	Official document authorising importation of a commodity in accordance with specified phytosanitary import requirements (FAO 2012).
Import risk analysis	An administrative process through which quarantine policy is developed or reviewed, incorporating risk assessment, risk management and risk communication.
Infestation (of a commodity)	Presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection (FAO 2012).
Inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present and/or to determine compliance with phytosanitary regulations (FAO 2012).
Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced, or used (FAO 2012).
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2012).
International Standard for Phytosanitary Measures (ISPM)	An international standard adopted by the Conference of the Food and Agriculture Organization, the Interim Commission on phytosanitary measures or the Commission on phytosanitary measures, established under the IPCC (FAO 2012).
Introduction	The entry of a pest resulting in its establishment (FAO 2012).
Lot	A number of units of a single commodity, identifiable by its homogeneity of composition, origin etc., forming part of a consignment (FAO 2012).
National Plant Protection Organization (NPPO)	Official service established by a government to discharge the functions specified by the IPPC (FAO 2012).
Official control	The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests (FAO 2012).
Pathway	Any means that allows the entry or spread of a pest (FAO 2012).
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2012).

Term or abbreviation	Definition
Pest categorisation	The process for determining whether a pest has or has not the characteristics of a quarantine pest or those of a regulated non-quarantine pest (FAO 2012).
Pest free area (PFA)	An area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained (FAO 2012).
Pest free place of production	Place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period (FAO 2012).
Pest free production site	A defined portion of a place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period and that is managed as a separate unit in the same way as a pest free place of production (FAO 2012).
Pest risk analysis (PRA)	The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (FAO 2012).
Pest risk assessment (for quarantine pests)	Evaluation of the probability of the introduction and spread of a pest and of the associated potential economic consequences (FAO 2012).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2012).
Phytosanitary certificate	Certificate patterned after the model certificates of the IPPC (FAO 2012).
Phytosanitary measure	Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO 2012).
Phytosanitary regulation	Official rule to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests, including establishment of procedures for phytosanitary certification (FAO 2012).
Polyphagous	Feeding on a relatively large number of hosts from different genera.
PRA area	Area in relation to which a pest risk analysis is conducted (FAO 2012).
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO 2012).
Regulated article	Any plant, plant product, storage place, packing, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved (FAO 2012).
Restricted risk	Risk estimate with phytosanitary measure(s) applied.
Spread	Expansion of the geographical distribution of a pest within an area (FAO 2012).
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures (WTO 1995).
Stakeholders	Government agencies, individuals, community or industry groups or organizations, whether in Australia or overseas, including the proponent/applicant for a specific proposal, who have an interest in the policy issues.
Systems approach(es)	The integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against regulated pests (FAO 2012).
Unrestricted risk	Unrestricted risk estimates apply in the absence of risk mitigation measures.

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