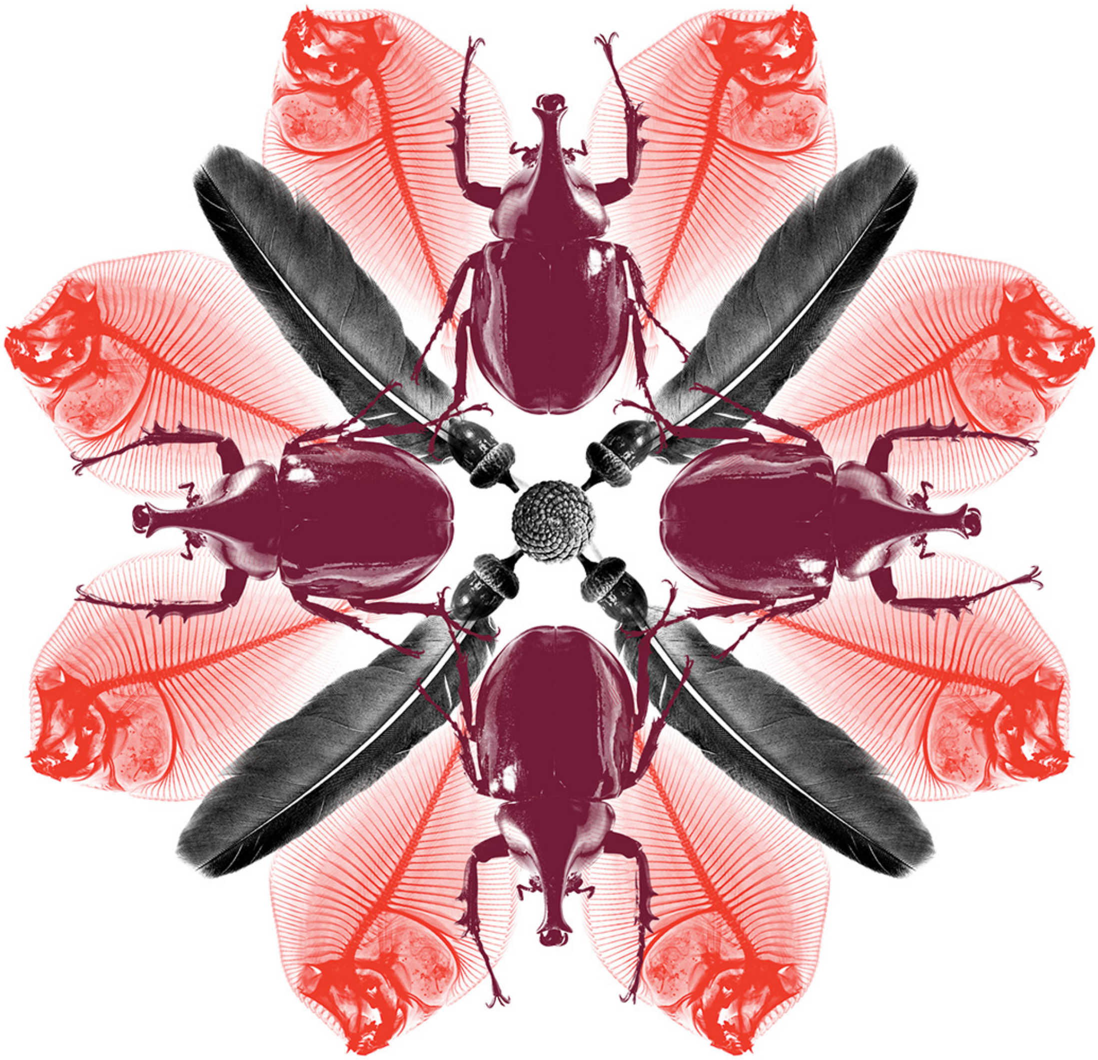
Australian Government

Department of Agriculture, Water and the Environment

Final report for the review of biosecurity import requirements for fresh strawberry fruit from Japan

February 2020



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Contents

Figures

Tables

Maps

Map 1 Map of Australia

Map 2 A guide to Australia's bio-climatic zones

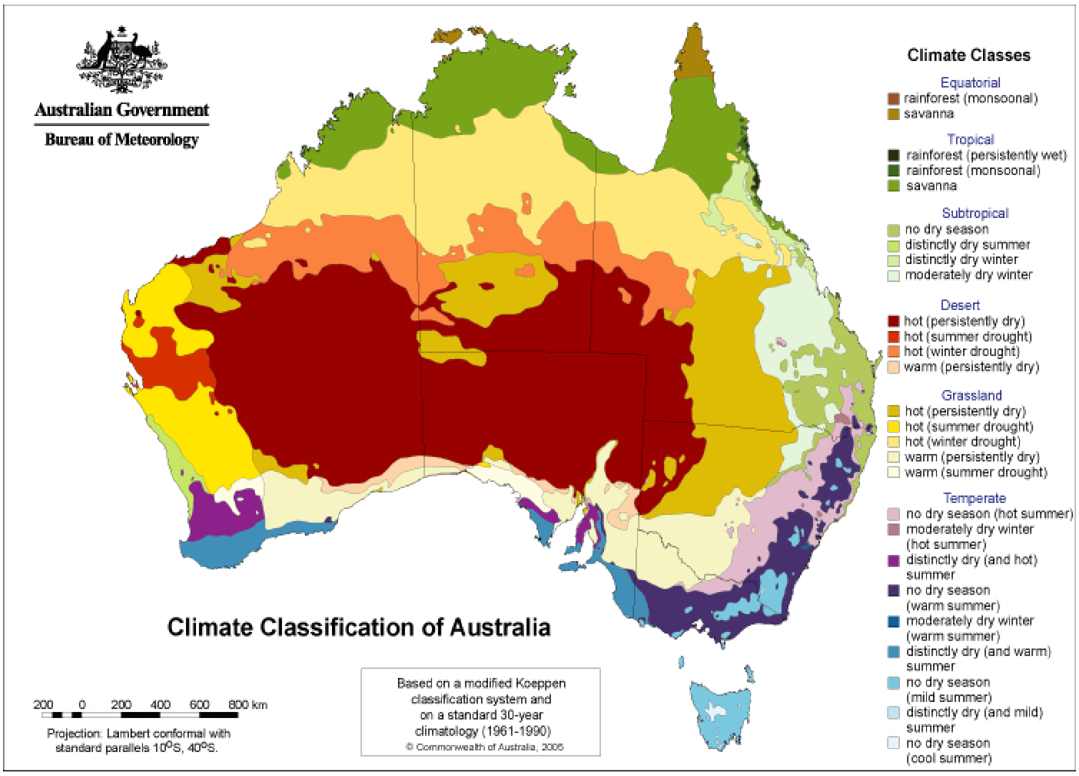
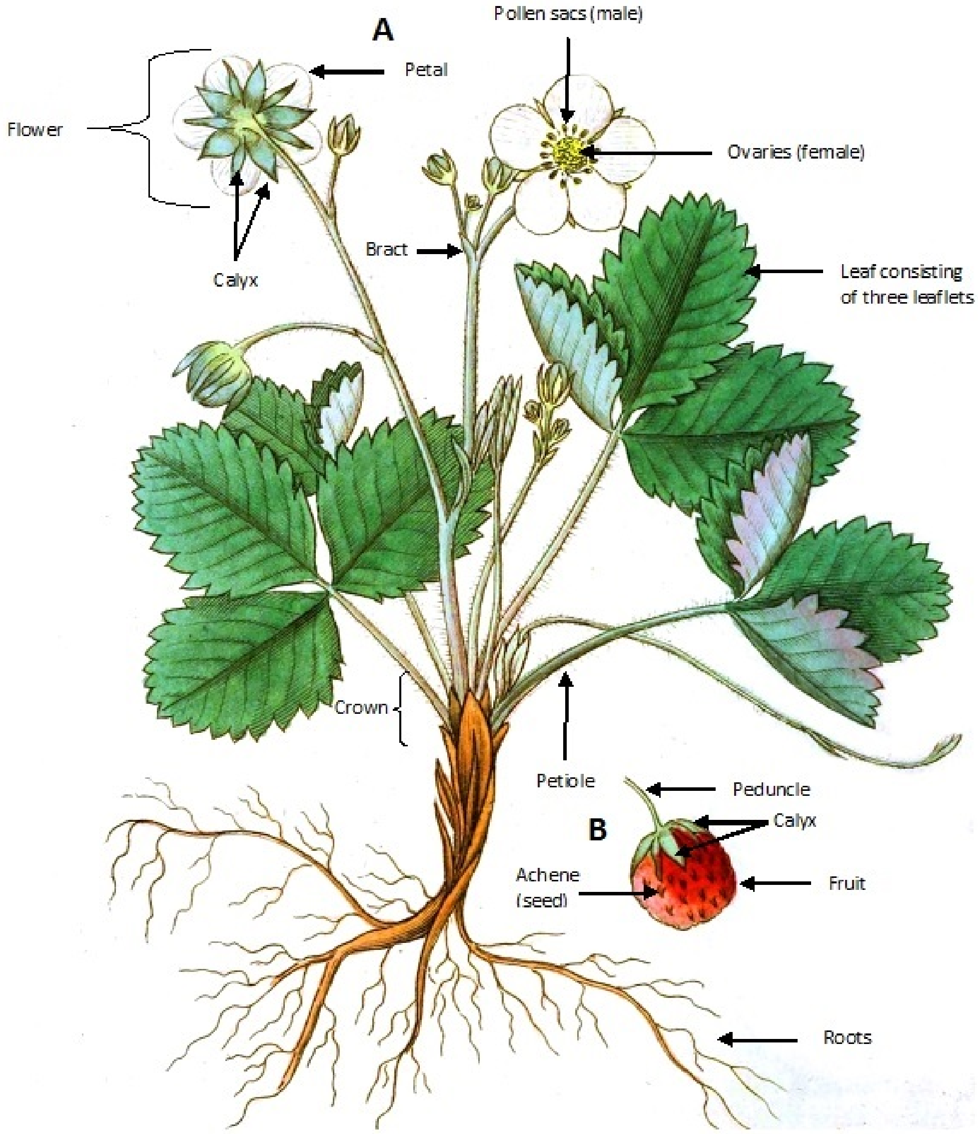


Figure 1 Diagram of strawberries



A shows the main parts of a strawberry runner **B** shows the detail of the strawberry fruit. Source: Modified from Svensk Botanik (Palmstruch et al. 1807)

Acronyms and abbreviations

Term or abbreviation	Definition
ACT	Australian Capital Territory
ALOP	Appropriate level of protection
BA	Biosecurity Advice
BICON	Australia's Biosecurity Import Conditions System
BIRA	Biosecurity Import Risk Analysis
EP	Existing policy
FAO	Food and Agriculture Organization of the United Nations
FSANZ	Food Standards Australia New Zealand
GP	Group policy
IPPC	International Plant Protection Convention
ISPM	International Standard for Phytosanitary Measures
MAFF	Ministry of Agriculture, Fisheries and Forestry
NSW	New South Wales
NPPO	National Plant Protection Organisation
NT	Northern Territory
PCR	Polymerase chain reaction
PRA	Pest risk analysis
Qld	Queensland
RA	Regulated article
RT-PCR	Reverse Transcription Polymerase Chain Reaction
SA	South Australia
SPS Agreement	WTO agreement on the Application of Sanitary and Phytosanitary Measures
Tas	Tasmania
the department	The Department of Agriculture, Water and the Environment
ULDs	Unit Loading Devices
Vic	Victoria
WA	Western Australia
WTO	World Trade Organization
USA	United States of America

Summary

This risk analysis report considers the biosecurity risks for Australia associated with the importation of commercially produced fresh strawberry fruit (strawberries) for human consumption from Japan.

Currently the importation of fresh strawberry fruit for human consumption is permitted into Australia from New Zealand, the State of California, United States of America (USA) and the Republic of Korea, provided it meets Australian biosecurity import conditions.

This final report recommends that the importation of fresh strawberries to Australia from all commercial production areas of Japan be permitted, subject to it meeting a range of biosecurity requirements, as summarised in this report.

This final report contains details of all known pests with the potential to be associated with the importation of strawberry fruit from Japan that may be of biosecurity concern to Australia. It also provides risk assessments for identified quarantine pests, and recommends risk management measures to reduce the biosecurity risk to an acceptable level.

Twelve quarantine pests have been identified in this risk analysis as requiring risk management measures. These pests are:

- *Drosophila* species: drosophilid flies (*Drosophila pulchrella* and *Drosophila subpulchrella*), and spotted wing drosophila (*Drosophila suzukii*)
- Spider mites: hawthorn spider mite (*Amphitetranychus viennensis*), spider mite (*Eotetranychus smithi*), spider mite (*Eotetranychus asiaticus*), spider mite (*Eotetranychus geniculatus*), and Kanzawa spider mite (*Tetranychus kanzawai*)
- Thrips: tobacco thrips (*Frankliniella fusca*), Eurasian flower thrips (*Frankliniella intonsa*), and western flower thrips (*Frankliniella occidentalis*)
- Bacteria: angular leaf spot (*Xanthomonas fragariae*).

These 12 identified species are the same, or of the same pest groups, as those associated with other horticultural commodities that have been previously assessed by the department.

Recommended risk management measures take account of regional differences within Australia. One pest, western flower thrips (*Frankliniella occidentalis*), has been identified as a regional quarantine pest for the Northern Territory, and another arthropod pest, *Tetranychus kanzawai*, has been identified as a regional quarantine pest for Western Australia because interstate quarantine regulations and enforcement are in place for these species. Western flower thrips was also assessed as a regulated article for all of Australia, as it is capable of harbouring and spreading emerging orthotospoviruses that are quarantine pests for Australia, and therefore requires risk management measures for all of Australia.

This final report recommends a range of risk management measures, combined with an operational system, to ensure biosecurity standards are met. The recommended risk management measures will reduce the risks posed by the 12 identified quarantine pests, so as to achieve the appropriate level of protection for Australia. These measures are:

- area freedom (including pest free places of production or pest free production sites, which may require evidence of a seasonal absence) or fruit treatment (such as methyl bromide fumigation or irradiation) for *Drosophila* species
- pre-export visual inspection and, if found, remedial action for spider mites and/or thrips
- area freedom or a systems approach approved by the Department of Agriculture, Water and the Environment for angular leaf spot.

Upon finalisation of this policy, Japan must be able to demonstrate to the Department of Agriculture, Water and the Environment that the processes and procedures are in place to implement the risk management measures. This will ensure safe trade in fresh strawberry fruit from Japan. Import conditions can then be published in the Australian Government's Biosecurity Import Conditions (BICON) database on the department's website, which can be accessed at https://bicon.agriculture.gov.au/BiconWeb4.0.

Written submissions on the draft report were received from seven stakeholders. In addition, a number of issues were raised by stakeholders (in writing and during meetings) through the risk analysis process. The department has made a number of changes to the report following consideration of all the technical comments raised by stakeholders, and subsequent review of the literature. These changes include:

- Amendments to 'Appendix A: Initiation and categorisation for pests of fresh strawberry fruit from Japan' following review of further scientific literature, including to the taxonomic status of two species of spider mite (*Eotetranychus sexmaculatus* and *Eotetranychus asiaticus*) and pathway revision of one spider mite (*Eotetranychus smithi*).
  - The pest status of *Eotetranychus sexmaculatus* in Australia and Japan has been reassessed as 'not present', as it was determined that *E. asiaticus* is not a synonym of *E. sexmaculatus,* and the entry of *E. sexmaculatus* has been removed from the pest categorisation table*.* *E. asiaticus* has been recorded as a pest of strawberry in Japan and a pest risk assessment for this pest was required.
  - Removal of five species from the family Scarabaeidae (e.g. *Anomala viridana*) from the pest categorisation table (Appendix A). After a further review of the literature it was determined that these species had no association with strawberries.
- Amendments to 'Chapter 4: Pest risk assessments for quarantine pests', 'Section 4.3: Spider mites'. Addition of two quarantine pests: *E. asiaticus* and *E. smithi.*
- Addition of 'Appendix B: Issues raised in stakeholder comments', which summarises the key technical issues raised by stakeholders, and how they were considered by the department.
- Minor corrections, rewording and editorial changes for consistency, clarity and web-accessibility.

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 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 risk analysis process is an important part of Australia's biosecurity policies. It enables the Australian Government to formally consider the level of biosecurity risk that may be associated with proposals to import goods into Australia. If the biosecurity risks do not achieve the appropriate level of protection (ALOP) for Australia, risk management measures are recommended to reduce the risks to an acceptable level. If the risks cannot be reduced to an acceptable level, the goods will not be imported into Australia until suitable measures are identified.

Successive Australian governments have maintained a stringent, but not a zero risk, approach to the management of biosecurity risks. This approach is expressed in terms of the ALOP for Australia, which is defined in the *Biosecurity Act 2015* as providing a high level of protection aimed at reducing risk to a very low level, but not to zero.

Australia's risk analyses are undertaken by the Department of Agriculture, Water and the Environment using technical and scientific experts in relevant fields, and involve consultation with stakeholders at various stages during the process.

Risk analyses may take the form of a biosecurity import risk analysis (BIRA) or a review of biosecurity import requirements (such as scientific review of existing policy and import conditions, pest-specific assessments, weed risk assessments, biological control agent assessments or scientific advice).

Further information about Australia's biosecurity framework is provided in the *Biosecurity Import Risk Analysis Guidelines 2016* located on the Department of Agriculture, Water and the Environment's website at http://www.agriculture.gov.au/biosecurity/risk-analysis/guidelines.

1.2 This risk analysis

1.2.1 Background

Japan's Ministry of Agriculture, Fisheries and Forestry (MAFF) formally requested market access to Australia for fresh strawberry fruit (strawberries) for human consumption in a submission received in October 2016. This submission included information on the pests associated with strawberry crops in Japan, including the plant part(s) affected, and the standard commercial production practices for strawberries in Japan.

Australia sought additional information from Japan on a number of pathogens of concern. Information on these pests was received in 2017 and 2018.

On 1 November 2017, the department announced the commencement of this risk analysis, advising that it would be progressed as a review of biosecurity import requirements. This analysis has been conducted in accordance with the *Biosecurity Act 2015*.

In December 2017 and March 2018, officers from the department visited strawberry production areas in Japan. The objectives of these visits were to observe commercial production, pest management and other export practices.

1.2.2 Scope

The scope of this risk analysis is to consider the biosecurity risk that may be associated with the pathway of fresh strawberry fruit (henceforth strawberries) (*Fragaria x ananassa*) grown in Japan using standard commercial production practices and packing procedures, as described in 'Chapter 3: Japan's commercial production practices for strawberries, for import into Australia for human consumption'.

For the purposes of this risk analysis, strawberries are defined as including a small amount of peduncle, the calyx, fruit and achenes (seeds). The major parts of a strawberry plant are shown in Figure 1. This risk analysis assesses commercially produced strawberries, produced under commercial systems in glasshouses or plastic tunnel houses or equivalent, of all cultivars/varieties from all regions of Japan in which they are grown for export.

1.2.3 Existing policy

International policy

Import policy exists for strawberries from New Zealand, the State of California, United States of America (USA) and Korea (Department of Agriculture and Water Resources 2018b). Trade of strawberries from Korea commenced in January 2018, and trade has occurred from New Zealand and the State of California, USA for over 20 years. Risk analyses of other commodities which include assessments of known pests of Japanese strawberries also exist, for instance, the *Final report for the non-regulated analysis of existing policy for table grapes from Japan* (Department of Agriculture 2014) and the *Final import risk analysis report for fresh unshu mandarin fruit from Shizuoka Prefecture, Japan* (Biosecurity Australia 2009). The potential pests of biosecurity concern identified for fresh strawberry fruit from Japan are the same as, or similar to, those identified for commodities for which import conditions already exist.

The import requirements for these commodity pathways can be found on the department's Biosecurity Import Conditions (BICON) system on the department's website at http://bicon.agriculture.gov.au/BiconWeb4.0.

The department has considered all the pests and pest groups previously identified in the existing policies and, where relevant, the information in those assessments has been taken into account in this risk analysis. The department has also reviewed the latest literature to ensure that information in previous assessments is still valid. The biosecurity risk posed by thrips, and the orthotospoviruses they transmit, from all countries was previously assessed in the *Final group pest risk analysis for thrips and orthotospoviruses on fresh fruit, vegetable, cut-flower and foliage imports* (thrips group PRA) (Australian Government Department of Agriculture and Water Resources 2017), which is applicable to strawberries from Japan. The department has determined that the information in those assessments can be adopted for the species under consideration in this risk analysis.

Domestic arrangements

The Australian Government is responsible for regulating the movement of goods such as plants and plant products into and out of Australia. However, the state and territory governments are responsible for plant health controls within their individual jurisdictions. Legislation relating to resource management or plant health may be used by state and territory government agencies to control interstate movement of plants and their products. After plant and plant products have been cleared by Australian Government biosecurity officers, they may be subject to interstate movement regulations. It is the importer's responsibility to identify and ensure compliance with all requirements.

1.2.4 Contaminating pests

In addition to the pests of strawberries from Japan that are assessed in this risk analysis, other organisms may arrive with the imported commodity. These organisms may include pests considered not to be associated with the fruit pathway, pests of other crops, or predators and parasitoids of arthropods. The department considers these organisms to be contaminating pests that could pose sanitary risks (to human or animal life or health) or phytosanitary risks (to plant life or health). These risks are identified and addressed using existing operational procedures that require a 600-unit inspection of all consignments on arrival, or equivalent procedures. The department will investigate if any pest identified through these processes may be of biosecurity concern to Australia, and thus may require remedial action.

1.2.5 Consultation

On 1 November 2017, the department notified stakeholders, in Biosecurity Advice 2017/04, of the commencement of a review of biosecurity import requirements for strawberries from Japan for market access to Australia.

Prior to, and after the announcement of this risk analysis, the department engaged with the Australian strawberry industry regarding the process and technical aspects of this risk analysis.

The department has also consulted with Japan's MAFF and Australian state and territory governments during the preparation of this report.

The draft report was released on 6 June 2019 (Plant Biosecurity Advice 2019/P08) for comment by stakeholders, for a consultation period of 60 days that concluded on 5 August 2019.

The department received seven written submissions on the draft report. All submissions received, and issues raised by domestic stakeholders during the consultation period, were carefully considered and, where relevant, changes were made to the final report. A summary of key technical stakeholder comments and how they were considered is provided in Appendix B.

1.2.6 Next Steps

The final report will be published on the department's website, with a notice advising stakeholders of its release. The department will also notify Japan's MAFF, the registered stakeholders and the WTO Secretariat of the release of the final report. Publication of the final report represents the end of the risk analysis process.

Before any trade in strawberry fruit from Japan commences, the department will verify that Japan can implement the required pest risk management measures, and the system of operational procedures necessary to maintain and verify the phytosanitary status of strawberry fruit for export to Australia (as specified in Chapter 5: Pest risk management of this report). On verification of these requirements, the import conditions for strawberry fruit from Japan will be published in the department's Biosecurity Import Conditions (BICON) system.

2 Method for pest risk analysis

This chapter sets out the method used for the pest risk analysis (PRA) in this report. The Department of Agriculture, Water and the Environment has conducted this PRA in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: *Framework for pest risk analysis* (FAO 2016b) and ISPM 11: *Pest risk analysis for quarantine pests* (FAO 2019b) that have been developed under the SPS Agreement (WTO 1995).

A PRA is ‘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 2019a). A pest is ‘any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products’ (FAO 2019a). This definition is also applied in the *Biosecurity Act 2015*.

Biosecurity risk consists of two major components: the likelihood 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, the department will verify that the consignment received is as described on the commercial documents and 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/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests’ (FAO 2019a).

A glossary of the terms used in the risk analysis is provided at the end of this report.

The PRAs are conducted in the following 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 biosecurity concern and should be considered for risk analysis in relation to the identified PRA area.

Appendix A of this risk analysis report lists the pests with the potential to be associated with the exported commodity produced using commercial production and packing procedures. 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. 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 country’s National Plant Protection Organisation (NPPO) or where the cited literature used a different scientific name.

For this risk analysis, 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 the department in other risk assessments and for which import conditions already exist, this risk analysis considered 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, previous risk assessments were taken into consideration in this risk analysis.

A Group Pest Risk Analysis (Group PRA) has been applied in this risk analysis, as explained in Section 2.2.7.

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 magnitude of the associated potential economic consequences' (FAO 2019a).

The following three, consecutive steps were used in pest risk assessment:

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 (FAO 2019a).

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

- identity of the pest
- 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 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 2019b). The SPS Agreement (WTO 1995) uses the term 'likelihood' rather than 'probability' for these estimates. In qualitative PRAs, the department uses the term 'likelihood' for the descriptors it uses for its estimates of likelihood of entry, establishment and spread. The use of the term 'probability' is limited to the direct quotation of ISPM definitions.

A summary of this process is given here, followed by a description of the qualitative methodology used in this risk analysis.

Likelihood of entry

The likelihood of entry describes the likelihood 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 various stages.

The likelihood 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 Chapter 3. These practices are taken into consideration by the department when estimating the likelihood of entry.

For the purpose of considering the likelihood of entry, the department divides this step into two components:

- **Likelihood of importation**—the likelihood that a pest will arrive in Australia when a given commodity is imported.
- **Likelihood of distribution**— the likelihood 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 to be considered in the likelihood of importation may 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 (for example, 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 (for example, refrigeration) applied to consignments during transport and storage in the country of origin, and during transport to Australia.

Factors to be considered in the likelihood of distribution may include:

- commercial procedures (for example, 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 (for example, for planting, processing or consumption)
- risks from by-products and waste.

Likelihood of establishment

Establishment is defined as the ‘perpetuation for the foreseeable future, of a pest within an area after entry’ (FAO 2019a). In order to estimate the likelihood of establishment of a pest, reliable biological information (for example, lifecycle, host range, epidemiology, survival) 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 likelihood of establishment.

Factors to be considered in the likelihood of establishment in the PRA area may 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.

Likelihood of spread

Spread is defined as ‘the expansion of the geographical distribution of a pest within an area’ (FAO 2019a). The likelihood 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 likelihood 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 likelihood of spread.

Factors to be considered in the likelihood of spread may 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 likelihoods for entry, establishment and spread

Likelihoods are assigned to each step of entry, establishment and spread. Six descriptors are used: high; moderate; low; very low; extremely low; and negligible. 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 and are not used beyond this purpose in qualitative PRAs. These indicative probability ranges provide guidance to the risk analyst and promote consistency between different pest risk assessments.

Table 2-1 Nomenclature of likelihoods

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

Combining likelihoods

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 likelihood of importation is assigned a descriptor of ‘low’ and the likelihood of distribution is assigned a descriptor of ‘moderate’, then they are combined to give a likelihood of ‘low’ for entry. The likelihood for entry is then combined with the likelihood assigned for establishment of ‘high’ to give a likelihood for entry and establishment of ‘low’. The likelihood for entry and establishment is then combined with the likelihood assigned for spread of ‘very low’ to give the overall likelihood for entry, establishment and spread of ‘very low’. This can be summarised as:

importation x distribution = entry [E]	**low x moderate = low**
entry x establishment = [EE]	**low x high = low**
[EE] x spread = [EES]	**low x very low = very low**

Table 2-2 Matrix of rules for combining 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.

The department 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 difference 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.

The use of a one year volume of trade has been taken into account when setting up the matrix that is used to estimate the risk and therefore any policy based on this analysis does not simply apply to one year of trade. Policy decisions that are based on the department'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. If there are substantial changes in the volume and nature of the trade in specific commodities then the department will review the risk analysis and, if necessary, provide updated policy advice.

In assessing the volume of trade in this risk analysis, the department assumed that a substantial volume of trade will occur.

2.2.3 Assessment of potential consequences

The objective of the consequence assessment is to provide a structured and transparent analysis of the potential 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 2019a) and ISPM 11 (FAO 2019b).

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
- domestic trade
- international trade
- non-commercial and environmental.

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) using Table 2-3. 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			
Magnitude	Local	District	Region	Nation
Indiscernible	A	A	A	A
Minor significance	B	C	D	E
Significant	C	D	E	F
Major significance	D	E	F	G

Note: In earlier qualitative PRAs, 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 to F has been 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.

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.

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 assessment of the likelihood of entry, establishment and spread and for potential consequences 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 likelihood of entry, establishment and spread and the overall consequences of pest establishment and spread. Therefore, risk is the combination of likelihood and consequence.

When interpreting the risk estimation matrix, note the descriptors for each axis are similar (for example, 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	Consequences of pest entry, establishment and spread					
	Negligible	Very low	Low	Moderate	High	Extreme
High	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Moderate	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Low	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk	High risk
Very low	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk
Extremely low	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk
Negligible	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk

2.2.5 The appropriate level of protection (ALOP) for Australia

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.

Like many other countries, Australia expresses its ALOP in qualitative terms. The ALOP for Australia, 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 the ALOP for Australia.

2.2.6 Adoption of outcomes from previous assessments

Outcomes of previous risk assessments have been adopted in this assessment for pests for which the risk profile is assessed as comparable to previously assessed situations.

The prospective adoption of previous risk assessment ratings is considered on a case-by-case basis by comparing factors relevant to the current commodity/country pathway with those assessed previously. For assessment of the likelihood of importation, factors considered/compared include the commodity type, the prevalence of the pest and commercial production practices, whereas for assessment of the likelihood of distribution of a pest the factors include the commodity type, the time of year when importation occurs, and the availability and susceptibility of hosts at that time. After comparing these factors and reviewing the latest literature, previously determined ratings may be adopted if the department considers the likelihoods to be comparable to those assigned in the previous assessment(s).

The likelihood of establishment and of spread of a pest species in the PRA area (in this instance, Australia) will be comparable between risk assessments, regardless of the commodity/country pathway through which the pest is imported, as these likelihoods relate specifically to conditions and events that occur in the PRA area, and are independent of the import pathway. Similarly, the estimate of potential consequences associated with a pest species is also independent of the import pathway. Therefore, the likelihoods of establishment and of spread of a pest, and the estimate of potential consequences, are directly comparable between assessments, and may be adopted with confidence.

2.2.7 Application of the Group PRA to this risk analysis

Risk estimates derived from a Group PRA are ‘indicative’ in character. This is because the likelihood of entry (the combined likelihoods of importation and distribution) can be influenced by a range of pathway-specific factors, as explained in Section 2.2.6. Therefore, the indicative likelihood of entry from a Group PRA needs to be verified on a case-by-case basis.

In contrast, and as noted in Section 2.2.6, the risk factors considered in the likelihoods of establishment and spread, and the potential consequences associated with a pest species are not pathway-specific, and are therefore comparable across all import pathways within the scope of the Group PRA. This is because at these latter stages of the risk analysis the pest is assumed to have already found a host within Australia at or beyond its point of entry. Therefore, a Group PRA assessment can be applied as the default outcome for any pest species on a plant import pathway once the previously assigned likelihood of entry has been verified.

In a scenario where the likelihood of entry for a pest species on a commodity is assessed as different to the indicative estimate, the Group PRA-derived likelihoods of establishment and spread and the estimate of consequences can still be used, but the overall risk rating may change.

The group PRA that was applied to this risk analysis is:

- The *Final group pest risk analysis for thrips and orthotospoviruses on fresh fruit, vegetable, cut-flower and foliage imports* (Australian Government Department of Agriculture and Water Resources 2017), which is referred to as the ‘thrips group PRA’.

2.3 Stage 3 Pest risk management

Pest risk management describes the process of identifying and implementing phytosanitary measures to manage risks to achieve the ALOP for Australia, 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 does not achieve the ALOP for Australia, 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 the ALOP for Australia. The effectiveness of any recommended phytosanitary measures (or combination of measures) is evaluated, using the same approach as used to evaluate the unrestricted risk, to ensure the restricted risk for the relevant pest or pests achieves the ALOP for Australia.

ISPM 11 (FAO 2019b) 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 likelihood of entry of the pest.

Examples given of measures commonly applied to traded commodities include:

- options for consignments—for example, 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—for example, 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—for example, pest-free area, pest-free place of production or pest-free production site
- options for other types of pathways—for example, consider natural spread, measures for human travellers and their baggage, cleaning or disinfestations of contaminated machinery
- options within the importing country—for example, 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 level of biosecurity risk does not achieve the ALOP for Australia. These are presented in Chapter 5: Pest risk management of this report.

3 Japan's commercial production practices for strawberries

This chapter provides information on the pre-harvest, harvest and post-harvest practices considered to be standard in Japan for the commercial production of strawberries for export. The export capability of Japan is also outlined.

3.1 Considerations used in estimating unrestricted risk

Japan provided Australia with information on the standard commercial practices used in the production of strawberries in different regions of Japan. This information has been complemented with data from other sources, such as published literature and observations during visits to Japan, all of which have been taken into consideration when estimating the unrestricted risks of pests that may be associated with the import of this commodity.

Officers from the department visited strawberry producing areas in Tochigi and Miyagi Prefectures in December 2017, and Shizuoka Prefecture in March 2018. The objectives of these visits were to observe commercial production, pest management and other export practices. The department's observations, and additional information provided during and after the visits, confirmed the production, harvest, processing and packing procedures described in this chapter as standard commercial production practices for strawberries for export.

In estimating the likelihood of pest introduction to Australia it was assumed that the pre-harvest, harvest and post-harvest production practices for strawberries as described in this chapter are implemented for all regions and for all strawberry cultivars. Where a specific practice described in this chapter has not been used to estimate the unrestricted risk, it is clearly identified and explained in Chapter 4.

3.2 Strawberry production areas

Strawberries are cultivated throughout Japan. However, production is concentrated on the coasts of the islands of Honshu and Kyushu (Sugimoto 2015).

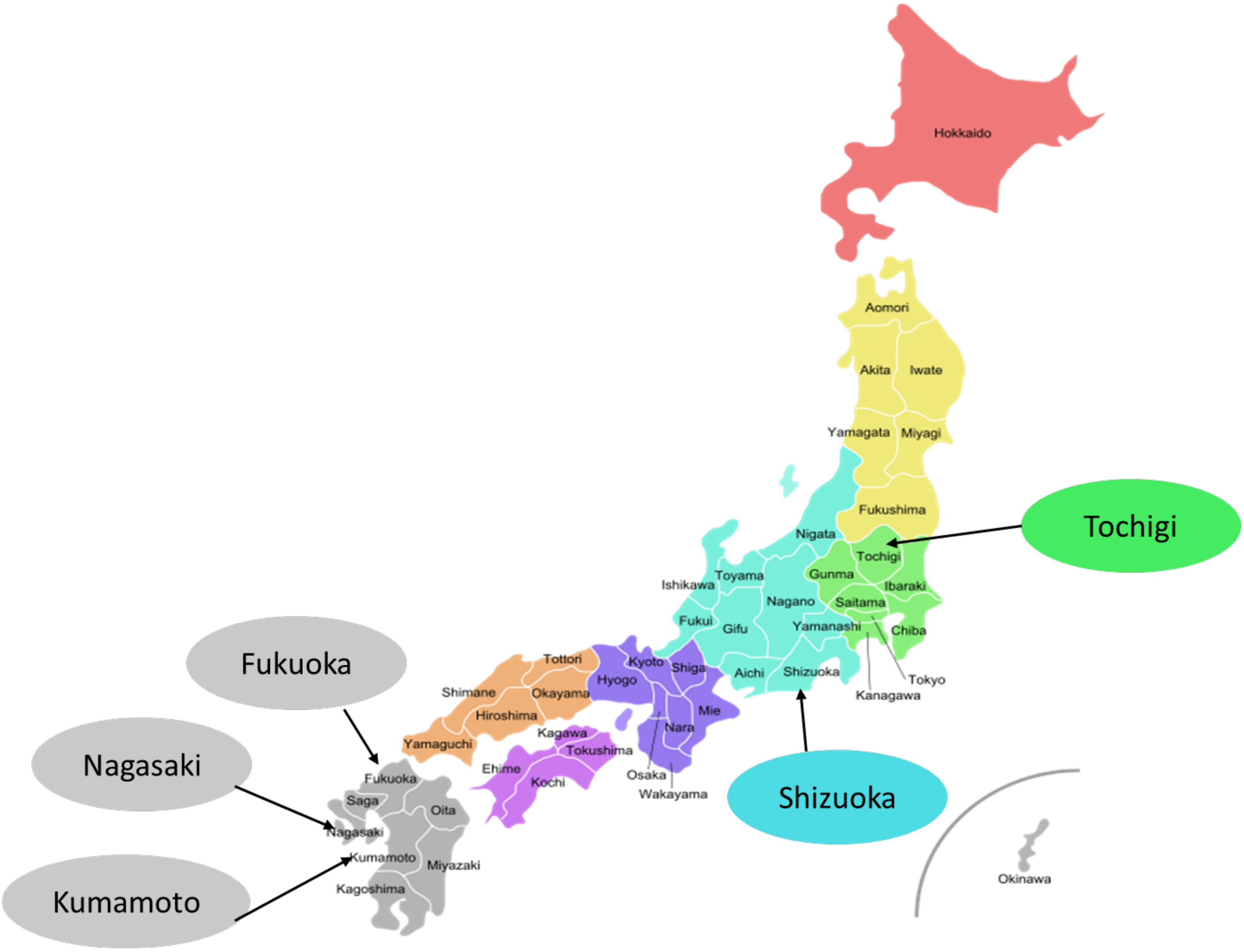
The largest strawberry producing prefectures in 2016 were Tochigi (24,800 tonnes), Fukuoka (16,000 tonnes), Kumamoto (10,900 tonnes), Shizuoka (10,400 tonnes) and Nagasaki (10,200 tonnes) (MAFF 2016). These prefectures are identified in Map 3.

3.3 Climate in production areas

Japan has a variety of climatic zones ranging from subarctic in the north of the country to subtropical in the south. In northern and eastern Japan, summers are warm and winter months are very cold, with some areas often experiencing heavy snow. In western and southern Japan summers are hot and humid, and winters are milder compared to northern Japan (Japan Meteorological Agency 2018).

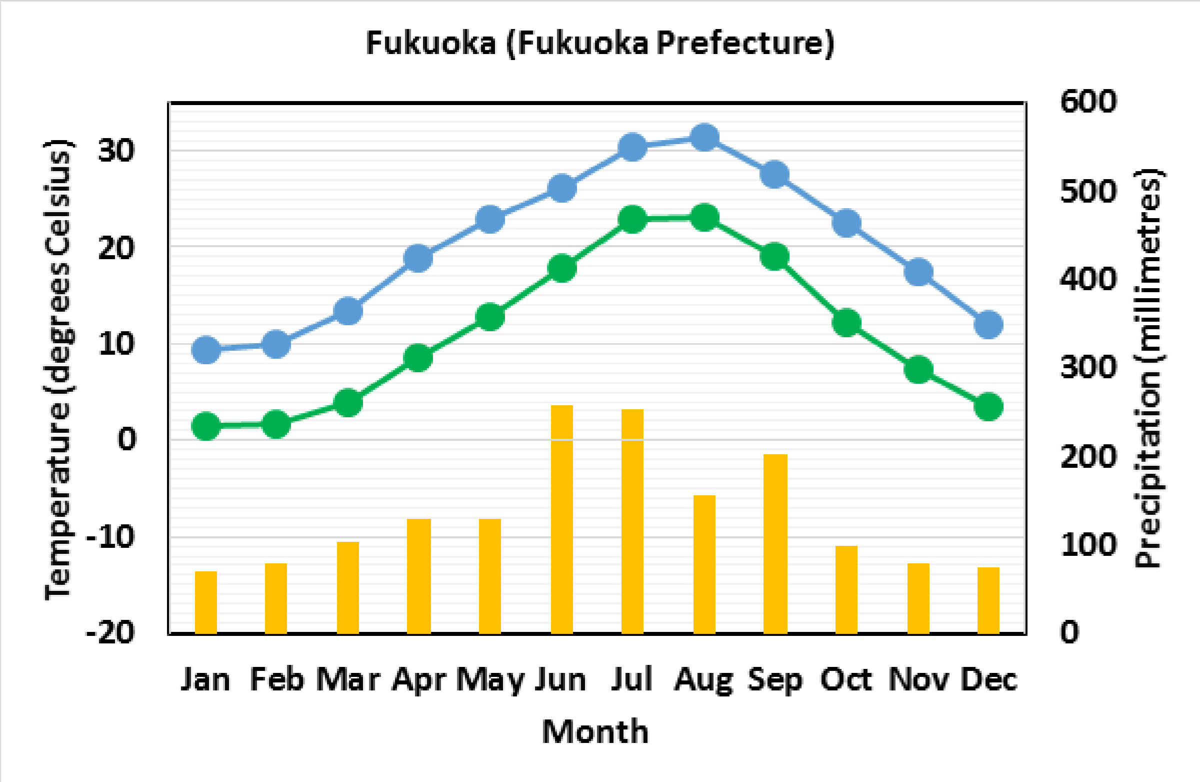
Figure 2 summarises the annual maximum and minimum temperatures, and mean rainfall in cities in Japan in major strawberry producing prefectures.

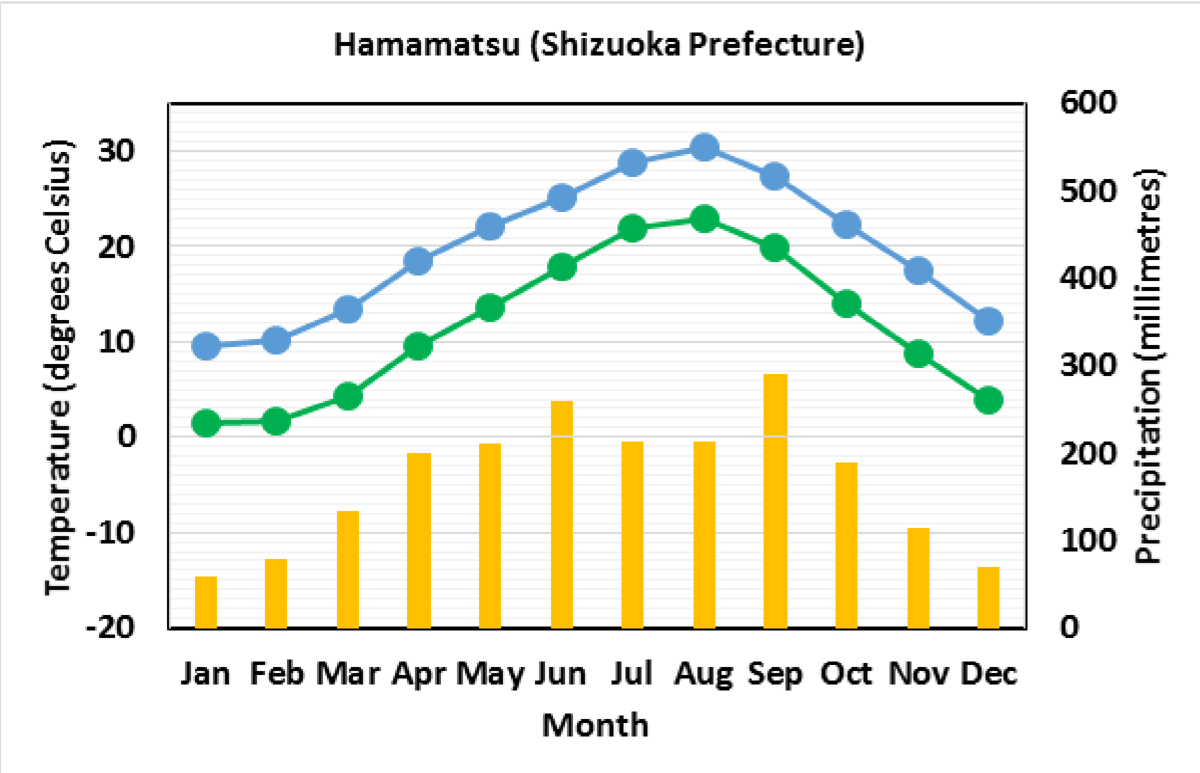
Map 3 Largest strawberry producing prefectures in Japan

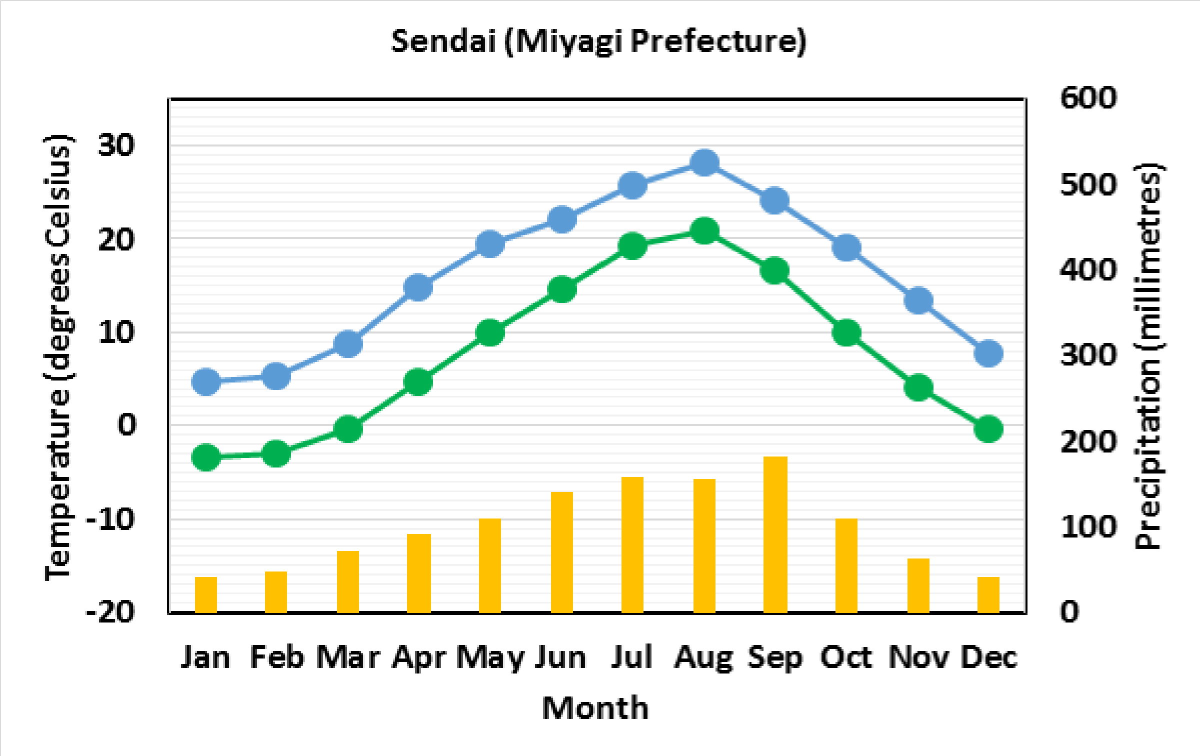


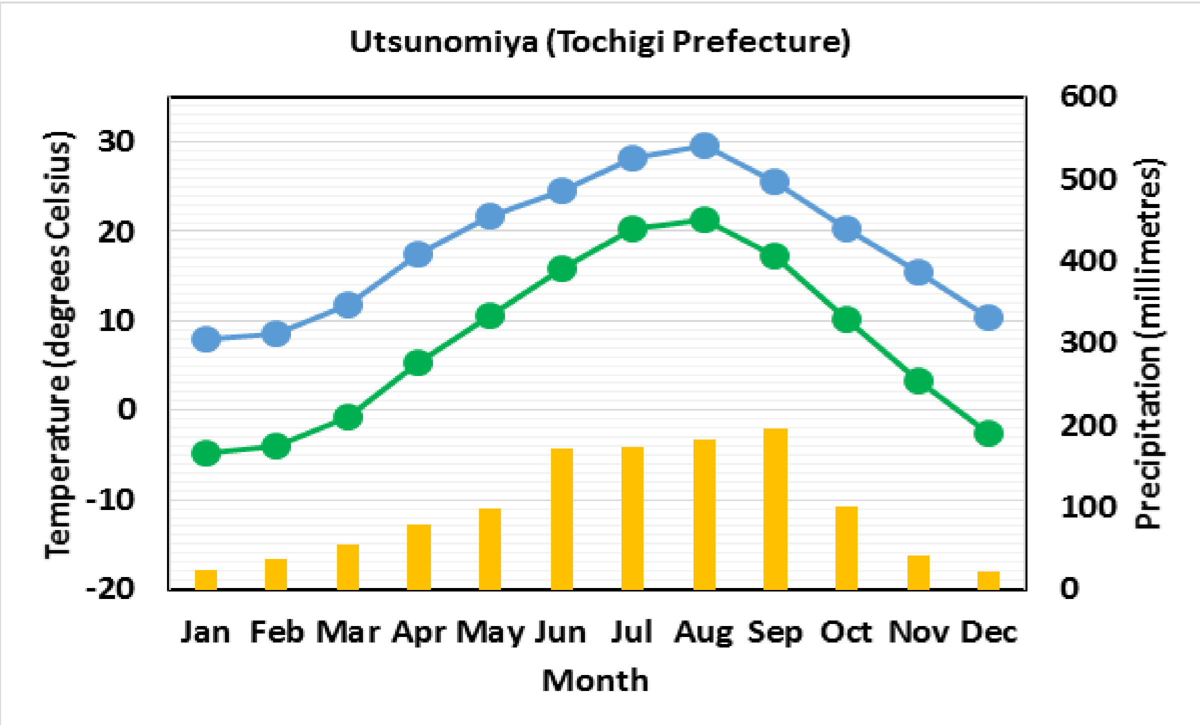
Source: Modified from https://www.kyuhoshi.com/map-of-japan/

Figure 2 Monthly maximum and minimum temperatures and mean rainfall data in strawberry production areas of Japan









Monthly mean maximum (-●-) and minimum (-●-) temperatures (degrees Celsius) and mean monthly rainfall (millimetres) (▬) from climate data sourced from Worldclimate.com 2018 for major strawberry production areas in Japan. Rainfall data was not available for Utsunomiya City; the closest city with rainfall data was used instead, Maebashi City.

3.4 Pre-harvest

3.4.1 Cultivars

Commercial strawberry production began in Japan around 1900 CE. Over the last century different cultivars have been introduced or developed to improve fruit quality and yields.

Modern strawberry cultivar development flourished during the 1990s when private companies and agricultural stations began breeding programs to support local growers (Yoshida 2013).

Many breeding programs are still ongoing, with prefectures competing to develop varieties with unique characteristics or the perfect combination of size, shape, colour and flavour (Sugimoto 2015). There are a large number of varieties currently available; some of the most popular cultivars include Amaou, Beni-hoppe, Saga-honoka and Tochiotome (MAFF 2016; Yoshida 2013). Summarised characteristics of the fruits of these cultivars are as follows:

Amaou: Fruit are large and have a high sugar content; the skin and flesh are red. This variety is known for being moderately robust for storage and transport. It is commonly sold in supermarkets rather than a 'gift' variety (FoodsLink 2017; MAFF 2016).

Beni-hoppe: Fruit are large, bright red, glossy and conical in shape; the flesh is pale red. This variety is gaining popularity in Japan because of its size, colour and flavour (FoodsLink 2017; MAFF 2016). The average size of fruit when grown in soil-less production systems is 35 grams (Liu et al. 2016).

Saga-honoka: Fruit are relatively large, slim and conical in shape. The skin is brilliant and glossy red, the flesh is white (FoodsLink 2017; MAFF 2016).

Tochiotome: Tochiotome is the most common strawberry variety grown in Japan. Fruit are long and conical in shape, large, and sweet. The skin is glossy and bright red, and the flesh is pink (FoodsLink 2017; MAFF 2016). The average size of fruit when grown in soil-less production systems is 21.5 grams (Liu et al. 2016).

Japanese strawberries are softer than American and European varieties (Yoshida 2013), and are harvested when the fruits are at maximum ripeness. In Japan, strawberries are produced for two different markets. Luxury fruits are a major part of Japan's extensive gift-giving culture and practices. Perfect 'gift' strawberries are carefully displayed and sold in speciality stores and command very high prices. 'Eating' strawberries are still expected to meet high quality standards, but are generally sold in small punnets at lower prices.

3.4.2 Cultivation practices

Strawberry runner production

The Prefecture Agricultural Research Stations are responsible for breeding and developing new varieties of strawberries, for conducting research, and for managing the production and testing of 'clean' (that is, pest and disease-free) strawberry runners.

The majority of runners are produced from existing plants (foundation plants). Any strawberry nursery stock imported from other countries is subject to strict quarantine protocols and testing before it is released for propagation.

Foundation plants are grown in isolation in glasshouses, with access restricted to maintain quarantine. Tiny cuttings (0.3mm–0.5mm) are taken from foundation plants and propagated as tissue cultures under sterile conditions. When tissue cultures are large enough, they are transferred to pots and acclimated in another glasshouse, where they are exposed to appropriate temperatures and conditions for growth, and also to allow disease expression. Plants are checked for any signs of infection, as well as quality and yield.

Plants grown by the Prefecture Agricultural Research Stations undergo routine disease testing using polymerase chain reaction (PCR), as summarised in Table 3-1.

Table 3-1 Pathogen testing of strawberry runners produced by Prefecture Agricultural Research Stations

Disease	Test
Virus	
Strawberry mottle virus (SMoV)	RT-PCR
Strawberry mild yellow edge virus (SMYEW)	RT-PCR
Strawberry vein banding virus (SVBV)	RT-PCR
Strawberry crinkle virus (SCV)	RT-PCR
Pathogen	
Colletotrichum gloeosporioides complex	Nested PCR
Fusarium oxysporum f. sp. *fragariae*	Nested PCR
Phytophthora cactorum	Nested PCR
Phytophthora nicotianae	Nested PCR

Clean strawberry runners are supplied to specialised producer groups who multiply the runners. The producer groups are the primary source of strawberry runners for growers and provide all stock for the main varieties of strawberry (only rare or unique varieties are produced outside this system). Testing for *Colletotrichum gloeosporioides* complex is carried out again before plants are sold to growers.

Growers usually replace stock every two to three years, and may multiply runners again on production sites.

It is common practice for growers to expose strawberry plants to cold outdoor conditions in order to induce flower bud differentiation. After flower bud differentiation, plants can be brought inside glasshouses or plastic tunnel houses where warm temperatures initiate flowering and early fruiting, thus avoiding the dormant period that is usual in strawberries grown in outdoor conditions. The practice is referred to as ‘forcing’, and is common in strawberry production systems worldwide.

Strawberry fruit production

In Japan, strawberries are grown under plastic tunnel houses or in glasshouses. Under-cover production allows control of temperature, moisture, and pollination, and effective management of pest and disease pressures. The most important of these factors are generally considered to be temperature and moisture.

Many areas in Japan do not have suitable climates for growing strawberries outdoors, and under-cover production is the only way growers are able to produce strawberry fruits. Planting commonly occurs at the end of August/start of September, and fruiting occurs from November to May.

Overhead watering systems are used for irrigation and temperature control before flowering occurs. When flowering begins, drip irrigation is used to reduce interference with bees used for pollination, and to minimise the risk of fungal and bacterial diseases often linked to the presence of free water.

After bee hives are placed in tunnel houses or glasshouses, applications of insecticides and fungicides are reduced to minimise any negative impacts on the bees. Pollination by bees is the primary method of pollinating strawberry flowers. It is critical to manage bee numbers and activity to ensure maximum pollination, not only for yield but also because flowers that do not receive enough pollen produce deformed fruits, which are not saleable in Japan.

If pesticides or fungicides are required during flowering periods, the bee hives are either removed during spraying, or sprays are applied at night after bees have returned to the hive.

Japan uses two different systems for growing strawberries, namely, plastic tunnel houses and glasshouses. Plastic tunnel houses are the most common system used, but there are a number of sophisticated glasshouse arrangements throughout the country.

Plastic tunnel houses

Tunnel houses typically measure 6 metres by 85 metres (see Figure 3). The clear plastic that covers a metal frame is replaced every two to three years. The entrance often has a polycarbonate front with a door, and the plastic sides of the tunnel houses can be opened (rolled up) to assist with temperature control.

Inside, the soil is treated with a fumigant [Chloropicrin] before the plants are introduced. Soil is mounded to create beds with drainage channels between rows which are approximately 30 centimetres apart. Beds are covered with plastic to prevent the developing fruits coming into contact with the soil.

Temperature is controlled using watering systems and ventilation, by opening the sides of the tunnel house in warm weather, commonly at the end of April and during August to October. Basic heating systems such as electric heaters are used during winter to maintain temperatures suitable for plant growth and fruiting inside the tunnel house.

Figure 3 Plastic tunnel house used for strawberry production

Glasshouses

Glasshouses are permanent structures with concrete flooring. Ventilation windows are covered with fine mesh (about 0.4 millimetres). The entrance to the glasshouse usually has a two door system to minimise the risk of pests entering.

Natural gas and heated water systems are used for heating, and misting with fans combined with ventilation is used for cooling. Any condensation is collected by an overhead system before it reaches the plants below. Glasshouses are usually maintained at 15 to 25 degrees Celsius but can reach a maximum of 30 degrees Celsius and a minimum of 5 degrees Celsius.

Before plants are introduced into glasshouses, soil is removed from the roots and plants are fumigated with 60 per cent carbon dioxide gas (CO_2) for 24 hours to kill any arthropod pests. The plants are then placed into individual pots in soil-less mixes (peat moss-coir mix) that has either been disinfected or sterilised. The pots are placed in raised beds and plastic is used to prevent strawberry fruits coming into contact with the beds.

Raised beds are either fixed to the floor or suspended from the ceiling, and are approximately 50 centimetres to one metre apart. In some facilities artificial lighting is used to supplement natural light (see Figure 4).

Figure 4 Glasshouse with suspended beds for strawberry production

3.4.3 Pest management

Growers manage pests and diseases throughout the production season using various commercial insecticides, fungicides and miticides. Japanese growers also employ integrated pest management procedures in strawberry production using predatory mites, as well as biopesticides (see Table 3-2).

Between September and November, insecticidal sprays are applied at weekly to 10 day intervals. After this time, insecticides are usually applied only as needed, as they can disrupt pollination by bees and integrated pest management activities. Some production sites also use sticky traps to monitor pest pressure within the tunnel house or glasshouse.

Fungicides are routinely applied throughout the season, but are most heavily applied during the fruiting months of December to January.

Growers inspect their strawberry crops for pests at 2-day to weekly intervals. In addition, every production site is visited twice each month by prefecture officials, who monitor the crop for pests. Any plants showing disease symptoms are quickly removed from the production site and destroyed to minimise the spread of diseases.

Each prefecture runs a pest forecasting service, monitoring the presence and abundance of pests across a variety of crops in their region. This information is provided to growers to assist them in identifying pests that are present in their area. Growers also have access to technical support from prefecture staff. If either growers or officials identify any unusual symptoms and/or pests in strawberry crops, samples are sent to the local Prefecture Agricultural Research Station for analysis/identification.

Table 3-2 Example of annual pest management schedule for Japanese strawberries

Time of year	Pest/pathogen	Chemical spray
Mid-September	Aphid (e.g. *Aphis forbesi*)	insecticide
Late-September	Thrips (e.g. *Frankliniella occidentalis*) Cutworm (e.g. *Spodoptera litura*)	insecticide
Early-October	Cutworm (e.g. *Spodoptera litura*) Bollworm (e.g. *Helicoverpa armigera*)	insecticide
Mid-October	Spider mite (e.g. *Tetranychus kanzawai*) Aphid (e.g. *Aphis forbesi*) White flies (e.g. *Trialeurodes packardi*) Anthracnose (e.g. *Colletotrichum gloeosporioides* complex)	insecticide fungicide
Late-October	Spider mite (e.g. *Tetranychus kanzawai*) Anthracnose (e.g. *Colletotrichum gloeosporioides* complex)	miticide fungicide
Early-November	Spider mite (e.g. *Tetranychus kanzawai*) Spider mite (e.g. *Tetranychus kanzawai*)	miticide predatory mite
Mid-November	Spider mite (e.g. *Tetranychus kanzawai*)	predatory mite
Early-December	Anthracnose (e.g. *Colletotrichum gloeosporioides* complex)	biopesticide
Mid-December	Anthracnose (e.g. *Colletotrichum gloeosporioides* complex)	biopesticide
Early-January	Anthracnose (e.g. *Colletotrichum gloeosporioides* complex)	plant growth regulator
Mid-January	Spider mite (e.g. *Tetranychus kanzawai*)	miticide
Early-February	Anthracnose (e.g. *Colletotrichum gloeosporioides* complex)	fungicide
Mid-February	Aphid (e.g. *Aphis forbesi*) White flies (e.g. *Trialeurodes packardi*) Thrips (e.g. *Frankliniella occidentalis*) Spider mite (e.g. *Tetranychus kanzawai*)	insecticide predatory mite
Late-February	Spider mite (e.g. *Tetranychus kanzawai*)	predatory mite
Early-March	Anthracnose (e.g. *Colletotrichum gloeosporioides* complex)	fungicide
Mid-Late-March	Spider mite (e.g. *Tetranychus kanzawai*) Thrips (e.g. *Frankliniella occidentalis*)	miticide biocontrol
Mid-April	Thrips (e.g. *Frankliniella occidentalis*)	biocontrol
Mid-May	Thrips (e.g. *Frankliniella occidentalis*)	insecticide

3.5 Harvesting and handling procedures

In Japan, strawberries are picked at maximum ripeness and fresh fruit typically reaches the consumer within two days.

All picking is done by hand daily or every two days. Picking is conducted during the morning when the temperature, and thus the fruits, are cool.

Strawberries are placed in a single layer into plastic trays lined with foam padding to protect the delicate fruits, and are transported to cool stores. Fruits are inspected at the time of picking; any damaged strawberries are discarded into waste bins which are emptied daily.

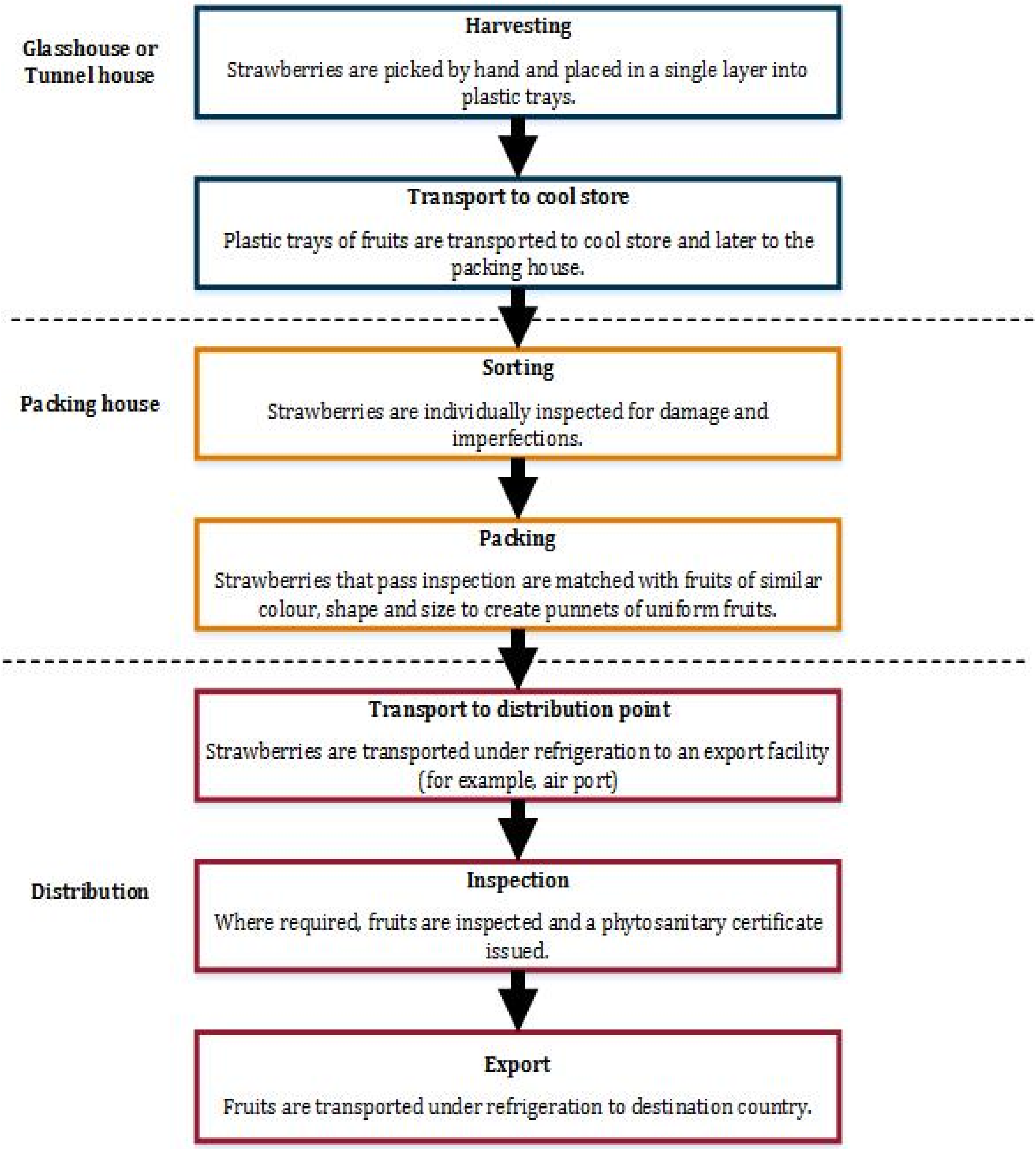
Strawberries are packed the same day they are picked. Trays of fruit are removed from the cool store and brought into a dedicated packing space (see Figure 5). Each fruit is individually inspected for damage and imperfections; damaged strawberries are discarded in waste bins.

Figure 5 Dedicated strawberry inspection and packing space

Strawberries are matched with fruits of a similar colour, shape and size to create high-quality assemblages. Alternatively, 'gift' strawberries are high-end products, usually sold individually or in small assemblages. These fruits are usually placed in specialised packaging to cushion and protect the strawberries.

There are no specific quality standards for strawberry fruits in Japan. Market pressures dictate that only fruits of the highest quality are sold; all imperfect fruits are either redirected for sale domestically (as 'eating' strawberries (see Figure 6) rather than 'gift' strawberries), or are directed to the confectionary industry to be used in desserts or processing.

Figure 6 Summary of operational steps for strawberries grown in Japan for export



3.6 Export capability

In major growing areas, strawberry fruit are typically harvested from November to May. Strawberries are grown in the cool northern regions of Japan through summer (June to August), but these fruits supply the domestic market (Sugimoto 2015). Japan's largest strawberry producing prefectures and their respective crop areas and yields are shown in Table 3-3.

Table 3-3 Strawberry production in Japan's largest producing prefectures in 2016

Prefecture	Yield (tonnes)	Crop Area (hectares)
Tochigi	25,100	586
Fukuoka	15,600	463
Kumamoto	10,200	321
Shizuoka	10,100	308
Nagasaki	9,640	277

Japanese strawberry varieties are soft and must be handled with care (Yoshida 2013). Most farms sell their strawberries branded with the farm name and the variety clearly identified. Variety is an important part of marketing, with prefectures owning the rights to varieties they have developed/bred. There is strong competition to produce new varieties with the perfect combination of sought after qualities such as size, shape, colour and flavour.

Figure 7 Japanese strawberries packaged for retail sale

The majority of strawberries produced in Japan are for domestic consumption. In 2014, Japan exported a total of 205 tonnes of strawberries to markets in Hong Kong (85 per cent), Taiwan (12 per cent), Singapore (1 per cent) and Thailand (1 per cent) (Sugimoto 2015).

4 Pest risk assessments for quarantine pests

Sixteen quarantine pests for Australia, one of which is also considered a regulated article (Table 4-1) associated with commercially produced, export quality strawberries produced in Japan were identified in the pest categorisation process (Appendix A). This chapter assesses the likelihoods of the entry (importation and distribution), establishment and spread of these pests, and the economic (including environmental) consequences these pests may cause if they were to enter, establish and spread in Australia.

Two pests identified in this assessment have been recorded in some regions of Australia but, due to interstate quarantine regulations and their enforcement, are considered pests of regional concern. The acronyms for the states or territories for which the regional pest status is considered, 'NT' (Northern Territory) and 'WA' (Western Australia), are used to identify these pests.

Most of the identified quarantine pests or pest groups considered here have been assessed previously by the department. Where appropriate, the outcomes of the previous assessments for these pests have been adopted for this risk analysis, unless new information is available that suggests the risk would be different. The acronym 'EP' is used to identify species assessed previously and for which import policy already exists. The adoption of outcomes from previous assessments is outlined in Section 2.2.6.

The biosecurity risk posed by thrips and the orthotospoviruses they transmit, from all countries on fresh fruit, vegetable, cut-flower and foliage imports was previously assessed in the *Final group pest risk analysis for thrips and orthotospoviruses on fresh fruit, vegetable, cut-flower and foliage imports* (Australian Government Department of Agriculture and Water Resources 2017). This Group PRA has been applied to this assessment of strawberry fruit from Japan.

The acronym 'GP' is used to identify species assessed previously in a Group PRA and for which the Group PRA was applied. The application of the thrips Group PRA to this risk analysis is outlined in Section 2.2.7. A summary of pest information from the thrips Group PRA is presented in this chapter for convenience.

Assessments of risks associated with these species are presented in this chapter unless otherwise indicated.

Table 4-1 Quarantine pests and regulated thrips associated with fresh strawberries from Japan

Pest	Common name
Drosophila [Diptera: Drosophilidae]	
Drosophila pulchrella	Drosophilid fly
Drosophila subpulchrella	Drosophilid fly
Drosophila suzukii (EP)	Spotted wing drosophila
Thrips [Thysanoptera: Thripidae]	
Frankliniella fusca (GP)	Tobacco thrips
Frankliniella intonsa (GP)	Eurasian flower thrips
Frankliniella occidentalis (GP, NT, RA)	Western flower thrips
Mites [Trombidiformes: Tetranychidae]	
Amphitetranychus viennensis (EP)	Hawthorn spider mite
Eotetranychus asiaticus	Spider mite
Eotetranychus geniculatus	Spider mite
Eotetranychus smithi	Spider mite
Tetranychus kanzawai (EP, WA)	Kanzawa spider mite
Bacteria [Xamthomonadales: Xanthonomadaceae]	
Xanthomonas fragariae (EP)	Angular leaf spot
Phytophthora [Prenosporales: Preonosporaceae]	
Phytophthora fragariaefolia	
Fungi [Glomerellales: Glomerellaceae]	
Colletotrichum aenigma	Anthracnose
Fungi [Helotiales: Sclerotiniaceae]	
Monilia polystroma (EP)	Asiatic brown rot
Monilinia fructigena (EP)	Brown rot

EP: Species has been assessed previously and import policy already exists. **GP:** Species has been assessed previously in a Group PRA and the Group PRA has been applied (Australian Government Department of Agriculture and Water Resources 2017). **NT:** Pest of biosecurity concern for the Northern Territory. **RA:** Regulated article, refer to Section 4.8 for definition of a Regulated article. **WA:** Pest of biosecurity concern for Western Australia.

4.1 Drosophilid flies

Drosophila

The family Drosophilidae includes over 3,950 described species. Within the Drosophilinae subfamily, the largest genus is *Drosophila* with over 1,000 species described. *Drosophila* species are found in all biogeographical regions, and are most abundant in tropical areas (Miller, Marshall & Grimaldi 2017).

Drosophila pulchrella and *D. subpulchrella* are both members of the *D. melanogaster* species group, and *D. suzukii* subgroup (Takamori et al. 2006). These two species are not present in Australia.

These species have been grouped together as they are closely related, with similar biologies and behaviours, such that they are predicted to pose similar risks and to require similar risk mitigation measures. In this assessment, the term drosophilid flies is used to refer to the two species *D. pulchrella* and *D. subpulchrella*. The scientific name is used when information refers to a specific species.

Drosophila pulchrella and *D. subpulchrella* are closely related to *D. suzukii*. The department has previously assessed *Drosophila suzukii*, conducting a pest risk assessment for *D. suzukii* on the pathways commercial grade fruits and cut flowers (Department of Agriculture 2013). *Drosophila suzukii* has also been considered in a number of other commodity-specific risk analyses including strawberries from Korea and table grapes from Japan (Department of Agriculture 2014; Department of Agriculture and Water Resources 2018c).

The likelihoods for establishment and spread of drosophilid flies in Australia from strawberries from Japan are considered similar to those for *D. suzukii* on commercial grade fruits. These likelihoods relate specifically to events that occur in Australia, and are principally independent of the importation pathway. Thus, the existing policy for *D. suzukii* establishment and spread will be adopted for *D. pulchrella* and *D. subpulchrella*.

The likelihood of establishment for *D. suzukii* was based on factors including suitability of the environment in Australia, the presence of multiple host species throughout the PRA area and the time of year, high reproductive potential, and wide geographic range in both native and introduced regions.

The likelihood of spread for *D. suzukii* was based on factors including suitability of the environment, presence of multiple host species throughout the PRA area, potential for spread in domestic commodities, and ability to disperse independently and rapidly.

However, the risk of drosophilid flies being associated with the entry of Japanese strawberries, and the potential consequences of these pests, is considered to be lower than those assessed for *D. suzukii*. Thus entry (importation and distribution), and consequences, are assessed separately here.

All ratings for the likelihoods of entry, establishment and spread, and the rating for the overall consequences are set out in Table 4-5

Drosophila pulchrella and *Drosophila subpulchrella*

Drosophila pulchrella was described in 1949 from China (Tan, Hsu & Sheng 1949). Male *D. pulchrella* are identified as having two spots on the wings, and until 2006 it was believed that flies caught in Japan were a single-spotted variant of *D. pulchrella* (Takamori et al. 2006).

In 2006, Takamori et al. described the new species *D. subpulchrella* based on the collection of flies in China and Japan. The new publication resulted in some of the previous identifications of *D. pulchrella* from Japan being subsequently recognised as *D. subpulchrella* (Beppu 2014).

Takamori et al. (2006) demonstrated that the two species, that are unable to interbreed are reproductively isolated. This trait provides strong evidence that *D. pulchrella* and *D. subpulchrella* are separate species, not variants of one species.

Both *D. pulchrella* and *D. subpulchrella* females have a serrated ovipositor, allowing them to attack ripe fruits (Atallah et al. 2014; Takamori et al. 2006).

In August 2018, Tochigi Prefecture Agricultural and Environmental Training Centre (2018) found *Drosophila* larvae in strawberries in central Japan. The larvae were reared out and subsequently identified as *D. suzukii* and *D. pulchrella*.

Sasaki and Sato (1995a) successfully reared *D. pulchrella* on cherry fruits. In further studies, Sasaki and Sato (1995b) collected *D. pulchrella* in high numbers from naturally infested fruits of raspberries and blackberries, and in lower numbers from blueberry, *Rubus triphyllus*, *Prunus buergeriana* and *Phytolacca americana*.

Atallah et al. (2014) demonstrated that *D. subpulchrella* could lay eggs in raspberries and cherries but was unable to lay eggs in intact Thompson grapes and red grapes. However, eggs were laid in grapes when the skin was removed.

Due to the similar morphologies, and the relatively recent description of *D. subpulchrella*, it is likely that the distribution and hosts of the two species have been confused in the literature. Early descriptions of *D. pulchrella* distribution include reports from China, Japan, Nepal, Taiwan and India (Gupta 1974).

Takamori et al. (2006) reported that *D. pulchrella* is found at high altitudes, 700–2,800 metres above sea level, while *D. subpulchrella* is found at altitudes lower than 900 metres above sea level. A similar pattern of distribution is reported by Girod et al. (2018) who trapped *D. subpulchrella* at lower altitudes in China and Japan (>1,500 metres). However, collections by Mitsui, Beppu and Kimura (2010) are less clear, with *D. subpulchrella* trapped in Japan at sites 1,040–2,000 metres above sea level.

Based on information in the current literature, it appears that *D. subpulchrella* is widely distributed in Japan, and *D. pulchrella* may be absent. However, as noted above, a recent detection of *Drosophila* species in strawberries in Japan was reported as *D. suzukii* and *D. pulchrella* (Tochigi Prefecture Agricultural and Environmental Training Centre 2018).

Drosophila pulchrella and *D. subpulchrella* have four life stages–egg, larva, pupa and adult. The immature life stages of *Drosophila* species are morphologically similar (Ferrar 1987). It is almost impossible to identify immature life stages to species level unless the flies are reared to adulthood or molecular tests are employed.

Eggs are creamy white with 0.5 millimetre long projections. Larvae have the appearance of white maggots and reach approximately 6 millimetres in length. Pupae are red-brown, 4 millimetres long with two branched protrusions at the front edge (Takamori et al. 2006; Tan, Hsu & Sheng 1949; Tochigi Prefecture Agricultural and Environmental Training Centre 2018).

Adults of *D. pulchrella* and *D. subpulchrella* are similar in appearance. Adult flies are dark yellow-brown in colour and almost 3 millimetres long. *D. pulchrella* males have two spots on the wing, whereas *D. subpulchrella* has one. Females of both species lack the wing spot(s).

Yoon, Gagen and Zhu (1990) investigated the longevity of adult *Drosophila* species under laboratory conditions and reported the average lifespan of *D. pulchrella* as 36.1 ± 1.3 days. Within the '*suzukii*' group, there were no significant differences observed in longevity between three of the four species tested, the outlier being *D. rajasekari*.

At 22 degrees Celsius to 30 degrees Celsius *D. pulchrella* develops from egg to adult in approximately 12 days. At 18 degrees Celsius to 22 degrees Celsius it develops faster than *D. suzukii*, and at 25–30 degrees Celsius develops slower than *D. suzukii*. The pre-oviposition period *for D. pulchrella* was 6 ± 1.6 days, three days longer than *D. suzukii* at 25 degrees Celsius. The emergence rate of eggs at 30 degrees Celsius was three per cent (Sasaki & Sato 1996).

Drosophila pulchrella is more suited to cooler temperatures, occurs less frequently and emerges later in the season than *D. suzukii* (Sasaki & Abe 1993; Sasaki & Sato 1996; Tochigi Prefecture Agricultural and Environmental Training Centre 2018).

The risk scenario of concern for *D. pulchrella* and *D. subpulchrella* is the presence of eggs and larvae in strawberries from Japan imported to Australia.

4.1.1 Likelihood of entry

The likelihood of entry is considered in two parts: the likelihood of importation and the likelihood of distribution, which consider the pre-border and post-border issues, respectively.

Likelihood of importation

The likelihood that *Drosophila pulchrella* and *D. subpulchrella* will arrive in Australia with the importation of strawberries from Japan is assessed as: **Low.**

The following information provides supporting evidence for this assessment.

- *Drosophila pulchrella* and *D. subpulchrella* have been reported from Japan (Beppu 2014; Girod et al. 2018; Mitsui, Beppu & Kimura 2010; Takamori et al. 2006; Tochigi Prefecture Agricultural and Environmental Training Centre 2018). The exact distribution of these species in Japan is unclear due to the recent description of *D. subpulchrella*.
- Girod et al. (2018) claims that in some areas of East Asia, *D. pulchrella* and *D. subpulchrella* are as common as *D. suzukii*. However, in Japan trapping studies show that *D. pulchrella* and *D. subpulchrella* are much less prevalent than *D. suzukii*. For example, Beppu (2014) trapped a total of 114,712 *D. suzukii* flies over a single year in the Imperial Gardens, Tokyo, compared to 4,959 *D. subpulchrella*. Katoh and Watada (2011), Mitsui, Beppu and Kimura (2010), Beppu (2006), Beppu (2000), Sasaki and Sato (1995b), and Sasaki and Abe (1993) all report trap catches of *D. suzukii* being higher than *D. pulchrella* or *D. subpulchrella*.
- *Drosophila pulchrella* is reported to be more cold tolerant than *D. suzukii* (Tochigi Prefecture Agricultural and Environmental Training Centre 2018).

- The peak capture of drosophilid flies generally occurs one month after the peak of *D. suzukii* trapping (Beppu 2014; Sasaki & Abe 1993; Sasaki & Sato 1996). The timing of peak trapping is dependent on the location. For example, in Fukushima Prefecture, Sasaki and Sato (1996) reported the peak trapping of *D. pulchrella* in September, while in Tokyo, Beppu (2014) reported peak trapping of *D. subpulchrella* occurring in December. Thus, it is possible these drosophilid flies may be present in Japan during winter production of strawberries.
- Despite trapping of drosophilid flies during winter, the authors Beppu, Kimura and Mitsui suggest that *D. subpulchrella* enters reproductive diapause over winter in Japan. Beppu (2006) reported no sexually mature flies were trapped in Tokyo between November and March. These results were replicated by Mitsui, Beppu and Kimura (2010) who reported peak trapping of *D. subpulchrella* at low altitudes (<1,000 metres above sea level) in December, also finding the population consisted of sexually immature flies.
- *Drosophila suzukii* reproductive diapause observed in winter has been linked to temperature (<10 degrees Celsius) rather than daylight (Hamby et al. 2016). Thus, if the drosophilid flies were to enter a tunnel house or glasshouse, where temperature is controlled between 15 degrees Celsius to 25 degrees Celsius, it is proposed the flies could become sexually mature.
- Both drosophilid flies have serrated ovipositors, similar to *D. suzukii*, that allow them to attack ripe or ripening fruit, laying eggs inside the fruit (Atallah et al. 2014; Sasaki & Abe 1993; Takamori et al. 2006; Tan, Hsu & Sheng 1949; Walsh et al. 2011).
- However, *D. pulchrella* has only once been reported on strawberries (Tochigi Prefecture Agricultural and Environmental Training Centre 2018). Other hosts include cherries, raspberries, blackberries, blueberries, *Rubus triphyllus*, *Prunus buergeriana*, *Phytolacca americana* (Atallah et al. 2014; Sasaki & Sato 1995b). Atallah et al. (2014) also reported that *D. subpulchrella* was unable to pierce the skin of grapes, but that when skin was removed females readily laid eggs in exposed grape tissue.
- Drosophilid eggs hatch quickly; *D. suzukii* eggs typically hatch within one day (Kanzawa 1939). Larval feeding causes collapse of strawberry tissues, followed by rotting (Tochigi Prefecture Agricultural and Environmental Training Centre 2018). Similar to the obvious damage that results from *D. suzukii* attacking soft fruits (Walton et al. 2010), damage to strawberries by *D. pulchrella* is likely to be visually obvious and to render fruit unmarketable.
- Strawberries are subject to pest inspections at intervals from every few days to weekly. An infestation of *D. pulchrella* or *D. subpulchrella* in a tunnel house or glasshouse would be likely to be quickly noticed by growers.
- Japanese strawberries are picked at maximum ripeness and are fragile, requiring delicate handling. The fruits are inspected during picking and packing, with any damaged strawberries discarded into waste bins for disposal through managed waste systems.

Drosophila pulchrella and *D. subpulchrella* are present in Japan, are more cold tolerant compared with the well-known strawberry pest *D. suzukii*, and have a serrated ovipositor allowing them to lay eggs in ripe fruits. They are also less prevalent compared with *D. suzukii*, are not reported to be sexually mature during winter, and only *D. pulchrella* has been reported to attack strawberries. Larval feeding causes obvious damage to fruits, rendering them unmarketable. Fruits are regularly inspected during the growing period, as well as during picking and packing. These factors moderate the likelihood that *D. pulchrella* and *D. subpulchrella* would be associated with strawberries exported to Australia.

For the reasons outlined, the likelihood of importation of eggs and larvae is assessed as ‘Low’.

Likelihood of distribution

The likelihood that *Drosophila pulchrella* and *D. subpulchrella* will be distributed within Australia in a viable state as a result of processing, sale or disposal of strawberry fruit from Japan, and subsequently transfer to a susceptible host is assessed as: **High**.

- Strawberries will be transported to Australia and be distributed to multiple retail points under refrigeration. Due to the perishable nature of strawberry fruits, transit times will be short.
- The developmental threshold for *D. pulchrella* is reported to be 5.8 degrees Celsius (Sasaki & Sato 1996). The cool temperature (generally 2 degrees Celsius for refrigerated transport) will delay the development of any eggs or larvae of drosophilid flies, but may not be lethal.
- At retail points strawberries are likely to be returned to ambient temperature when displayed for sale, enabling any surviving eggs and larvae to continue development.
- Strawberries from Japan are intended for human consumption. The strawberries will be packaged, and are unlikely to be examined or processed until they arrive at retail points.
- However, the feeding by larvae results in obvious symptoms and damage, quickly followed by rotting. This damage may be noticed at retail points and infested fruits discarded into managed waste systems.
- Strawberries infested with eggs or newly-emerged larvae in sound condition may be sold to consumers. It is expected that due to the damage caused by larvae feeding, fruits would quickly become inedible and would likely be discarded into managed waste systems.
- Consumers may discard small quantities of fruit waste in urban, rural and natural localities, or in domestic compost.
- Imported strawberry fruit are likely to arrive between November and March. *Drosophila pulchrella* develops from egg to adult in 12 days at 22 degrees Celsius to 30 degrees Celsius (Sasaki & Sato 1996). This temperature range can be found in many areas of Australia in summer/autumn, particularly on the east coast of Australia (Bureau of Meteorology 2018).
- *Drosophila pulchrella* are negatively affected by high temperatures, with only 3 per cent of eggs hatching at 30 degrees Celsius (Sasaki & Sato 1996). During summer months, some areas of Australia experience maximum temperatures above 30 degrees Celsius for consecutive days (Bureau of Meteorology 2018).
- *Drosophila* species are highly sensitive to low moisture, and require greater than 70 per cent humidity for successful reproduction (Ashburner, Golic & Hawley 2005). *Drosophila suzukii* adults die under normal room conditions in six to 24 hours without a source of moisture (Kellermann et al. 2012). The majority of strawberries are expected to be imported to major metropolitan areas including Sydney and Melbourne. These cities commonly have high levels of humidity (>70 per cent), and during summer have average maximum temperatures below 30 degrees Celsius (Bureau of Meteorology 2018).
- Drosophilid flies that survive on discarded strawberry waste, and develop to adult stage, must find suitable host material. Adults are mobile, being capable of flight. There is no specific data available for *D. pulchrella* or *D. subpulchrella*. However, Kanzawa (1939) reported that *D. suzukii* is capable of flight for several hours, and closely related species of *Drosophila* are known to fly hundreds of metres towards preferred habitat (Coyne, Bryant & Turelli 1987).
- Recorded hosts for *D. pulchrella* and *D. subpulchrella* include cherries, blueberries, raspberries, blackberries, *Rubus triphyllus*, *Prunus buergeriana*, *Phytolacca americana* and strawberry (Sasaki & Sato 1995b, a; Tochigi Prefecture Agricultural and Environmental

Training Centre 2018). Most of these hosts are distributed in commercial and domestic environments within Australia (AVH 2018). Blackberries are declared a weed of national significance, and are widely distributed along the east coast and southern areas of Australia (NSW DPI 2009).

- *Drosophila* species have also been reported to oviposit in fallen or damaged fruits (Atallah et al. 2014; Mitsui, Beppu & Kimura 2010).
- The importation of strawberries from November to March coincides with Australian summer and autumn seasons. Many hosts produce fruits suitable for drosophilid flies during these seasons. In addition, the continuous supply of fruit through the retail sector would ensure host fruits are available throughout the year in residential areas.

Drosophila pulchrella and *D. subpulchrella* eggs and larvae are likely to survive transport and distribution within Australia, complete development to adult stage, and move independently to locate suitable host material.

For the reasons outlined, the likelihood of the distribution of *D. pulchrella* and *D. subpulchrella* is assessed as 'High'.

Overall likelihood of entry

The overall likelihood of entry is determined by combining the likelihood of importation with the likelihood of distribution using the matrix of rules shown in Table 2-2.

The likelihood that *Drosophila pulchrella* and *D. subpulchrella* will enter Australia as a result of trade in strawberry fruit from Japan and be distributed in a viable state to a susceptible host is assessed as: **Low.**

4.1.2 Likelihoods of establishment and spread

The likelihoods of establishment and of spread for *Drosophila pulchrella* and *D. subpulchrella* are similar to those assessed in the pest risk analysis for *D. suzukii* on the fresh fruit pathway (Department of Agriculture 2013). The ratings from previous assessments are:

Likelihood of establishment: High

Likelihood of spread: High

4.1.3 Overall likelihood of entry, establishment and spread

The overall likelihood of entry, establishment and spread is determined by combining the likelihoods of entry, of establishment and spread using the matrix of rules shown in Table 2-2.

The overall likelihood that *Drosophila pulchrella* and *D. subpulchrella* will enter Australia as a result of trade in strawberry fruit from Japan, be distributed in a viable state to a susceptible host, establish in Australia and subsequently spread within Australia is assessed as: **Low**.

4.1.4 Consequences

The potential consequences of the establishment of *Drosophila pulchrella* and/or *D. subpulchrella* in Australia have been estimated according to the methods described in Table 2-3.

Based on the decision rules described in Table 2-4, that is, where the potential consequences of a pest with respect to one or more criteria are 'E', the overall consequences are estimated to be **Moderate**.

Criterion	Estimate and rationale
Direct	
Plant life or health	E – Significant at the regional level *Drosophila pulchrella* and *D. subpulchrella* have been reported to attack a range of important commercial crops including strawberry, cherry, blueberry, raspberry and blackberry (Atallah et al. 2014; Sasaki & Sato 1995b; Tochigi Prefecture Agricultural and Environmental Training Centre 2018). In Australia these industries are valued at: • *Rubus* berries: in 2016–2017, 5,946 tonnes was produced. The value of production was $166.5 million • strawberries: in 2016–2017, 91,083 tonnes was produced. The value of production was $506.5 million • cherry: in 2016–2017, 11,012 tonnes was produced. The value of production was $120.7 million • blueberry: in 2016–2017, 9,553 tonnes was produced. The value of production was $193.6 million (Horticulture Innovation Australia 2018b). While there are limited reports of commercial damage by these species, neither *D. pulchrella* or *D. subpulchrella* has been found outside the native range of Asia (Gupta 1974; Takamori et al. 2006). Both species have short life cycles with the ability for multiple generations per year, and survive unfavourable conditions during winter and summer in their native distribution (Beppu 2014; Mitsui, Beppu & Kimura 2010; Takamori et al. 2006). Similar to *D. suzukii*, both species have a serrated ovipositor enabling them to attack ripening fruits (Atallah et al. 2014; Sasaki & Abe 1993; Takamori et al. 2006; Tan, Hsu & Sheng 1949; Walsh et al. 2011). In Japan, the major hosts of *D. pulchrella* and *D. subpulchrella* are *Rubus* and cherry (Atallah et al. 2014; Mitsui, Beppu & Kimura 2010; Sasaki & Sato 1995b). Even on major hosts in their native range, these flies are usually found in low numbers, and almost always associated with *D. suzukii* (Girod et al. 2018). Girod et al. (2018) notes these species have the potential to become invasive pests and their introduction to new environments is be to avoided at all costs. (Atallah et al. 2014) suggests that *D. subpulchrella* may pose a threat to raspberry and cherry industries however, also cautions that with little known of the ecology of *D. subpulchrella*, it is difficult to determine its invasive potential. The relatively low abundance of *D. pulchrella* and *D. subpulchrella* and the narrower host range, suggests these drosophilid flies will have a lower impact than *D. suzukii* in Australia. It is possible the presence of *D. pulchrella* and *D. subpulchrella* could threaten the economic viability of commercial production of some soft fruit industries in Australia, although this is uncertain. Production from other host plants in the environment, including garden plants, would be affected, as infested fruit is not suitable for consumption. Considering all the information, a rating of significant at the regional level is determined to be appropriate.

Criterion	Estimate and rationale
Other aspects of the environment	B – Minor significance at the local level There may be some impact on insect or animal species that feed on host plants due to reduced availability of fruits through larval competition or highly damaged fruits.
Indirect	
Eradication, control	E – Major significance at the district level There are no insecticides registered for the control of *Drosophila* species (APVMA 2019). However, there are several insecticides registered in Australia for use on host plants that have been shown to be effective in the United States of America (OSU 2010c). There are no pheromone-specific traps for these species. Any trapping would be food based; this technique has limited use in controlling populations of flies and would be used to determine presence and distribution in specific areas. Affected growers would be required to use a number of techniques to manage/control the flies in their orchards/production sites, with no single measure offering full protection. These techniques might include monitoring pest pressures, implementing orchard hygiene practices, applying insecticides, and possibly introducing physical measures such as netting to exclude flies. All of these techniques would increase production costs for growers. Eradication of drosophilid flies would require the removal of large numbers of native, amenity, weedy and commercial host fruits within the vicinity of outbreaks, and/or the broad-scale application of insecticides to control adult and juvenile life stages. Due to the large number of host plants affected, and the likely human-assisted and natural spread, the costs of any eradication campaign are likely to be substantial. The high reproductive capacity and dispersal abilities of these pests would make early detection vital if eradication was to be successful. As an example, *Drosophila suzukii* has recently been found in multiple countries and eradication efforts have been unsuccessful. The impact of these factors is expected to be moderated by the narrower host range of *D. pulchrella* and *D. subpulchrella*, compared to that of *D. suzukii*.
Domestic trade	E – Major significance at the district level The presence of drosophilid flies in production areas would likely result in restrictions on the domestic movement of host commodities. Post-harvest treatments would likely be required to facilitate interstate movement of host commodities.
International trade	E – Major significance at the district level The presence of drosophilid flies in production areas would limit access to some overseas markets and complicate market access negotiations. Fruit flies are the highest priority issue for Australian growers exporting horticultural produce to overseas markets.
Environmental and non-commercial	B – Minor significance at the local level Broad-scale applications of insecticides to target *D. pulchrella* and *D. subpulchrella* would be likely to have some impacts on native species of insects. The increased use of insecticides might also have off-target impacts on other native species, for example, negative impacts on

Criterion	Estimate and rationale
	native water systems through runoff, noting however, that large amounts of chemical insecticides are already used in Australian agricultural production systems.

4.1.5 Unrestricted risk estimate

Unrestricted risk is the result of combining the likelihoods of entry, establishment and spread with the outcome of overall consequences. Likelihoods and consequences are combined using the risk estimation matrix shown in Table 2-5.

Unrestricted risk estimate for *Drosophila pulchrella and D. subpulchrella*	
Overall likelihood of entry, establishment and spread	Low
Consequences	Moderate
Unrestricted risk	Low

As indicated, the unrestricted risk estimates for *Drosophila pulchrella* and *D. subpulchrella* have been assessed as ‘Low’, which does not achieve the ALOP for Australia. Therefore, specific risk management measures are required for these pests.

4.2 Spotted wing drosophila

Drosophila suzukii **(EP)**

The quarantine risks posed by *Drosophila suzukii* from all countries and for all commodities, including strawberries, were previously assessed in the final pest risk analysis (PRA) report for *D. suzukii* (Department of Agriculture 2013). Therefore, there is no need to reassess this pest here. A summary of pest information and the previous risk assessment for strawberries from the final PRA report for *D. suzukii* is provided below.

In addition, the department has reviewed the latest literature (for example (Asplen et al. 2015; Joshi et al. 2017; Plantamp et al. 2016; Toxopeus et al. 2016)), and has found no new information that would significantly change the risk ratings for importation, distribution, establishment, spread and consequences as set out in the final PRA report for *D. suzukii*. The likelihood of *D. suzukii* being associated with host fruit will change depending on the time of year and the region from which the fruit is sourced (see Sections 3.4.2 and 3.4.3 of the Final PRA report for *Drosophila suzukii* and below for further discussion).

Drosophila suzukii is native to temperate parts of Asia (Rota-Stabelli, Blaxter & Anfora 2013) and is present in Japan, including on the four main islands (Department of Agriculture 2013). It has also invaded North America and Europe where its distribution has spread dramatically in recent years (Asplen et al. 2015; Calabria et al. 2012; Cini, Ioriatti & Anfora 2012). It has also been detected in South America (Asplen et al. 2015).

Drosophila suzukii preferentially oviposit on ripening fruit but will also oviposit on unripe and overripe fruit (Brewer et al. 2012; CABI 2019; Kanzawa 1939; Lee et al. 2011). Larval feeding causes collapse of the fruit around the area of oviposition, and high attack rates can lead to collapse of the entire fruit (Department of Agriculture 2013). Larvae feeding on very acidic fruit fail to complete development (Kanzawa 1935). In both the native and introduced ranges, *D. suzukii* has been recorded as causing commercial damage to a wide range of fruits including cherries, blueberries, red bayberries, apricots, plums, strawberries and various caneberries (Lee et al. 2011).

Drosophila suzukii is a multi-voltine pest that can develop from egg to adult in eight to 12 days under suitable warm conditions (for example constant 25–28 degrees Celsius) (Brewer et al. 2011; Kanzawa 1939; Tochen et al. 2014). This rapid development allows the pest to produce up to 13 generations per year (Kanzawa 1939). *Drosophila suzukii* development is temperature sensitive, and development to adult ceases at constant temperatures of about 8 degrees Celsius to 12 degrees Celsius (Tochen et al. 2014; Tonina et al. 2016). At temperatures just above this threshold, development times are significantly increased, to over 70 days (Tochen et al. 2014; Tonina et al. 2016).

During autumn, newly-emerged adults do not sexually mature, and enter a winter reproductive diapause (Asplen et al. 2015; Kanzawa 1939; Mitsui, Beppu & Kimura 2010; Rossi-Stacconi et al. 2016; Shearer, Long & Stoven 2016; Toda 1979; Wallingford, Lee & Loeb 2016; Zhai et al. 2016). Adults collected in central and southern Japan during late autumn to winter do not have developed ovaries and are sexually immature (Mitsui, Beppu & Kimura 2010; Toda 1979). A detailed study in the Imperial Gardens in Tokyo showed peak sexual maturity occurs from April to October (mid-spring to mid-autumn) (Beppu 2006). From November to March (late autumn to early spring), the number of adults collected with mature ovaries rapidly declined until all adults were sexually immature by February (Beppu 2006). The continued decline in sexual maturity at the Tokyo site indicates winter temperatures are unfavourable for *D. suzukii* to maintain reproductive capacity during winter.

The factors that induce reproductive diapause in *D. suzukii* are temperature and day length (Rossi-Stacconi et al. 2016; Wallingford, Lee & Loeb 2016; Zhai et al. 2016). Temperature is the dominant factor, and even at very short day lengths, suitably warm temperatures in laboratory conditions allow ovary development and oviposition (Zhai et al. 2016). Adults that are in diapause take longer to resume oviposition compared to summer-reared flies when returned to temperatures suitable for adult activity (Wallingford, Lee & Loeb 2016). Low temperature and decreasing day length are also known to induce a winter morph of *D. suzukii* that is considered to have higher winter survival (Shearer, Long & Stoven 2016; Wallingford, Lee & Loeb 2016).

The survival of *D. suzukii* is significantly reduced during winter. Immature life stages do not survive protracted winters, and the adult is considered the life stage that over-winters (Dalton et al. 2011; Kaçar et al. 2016; Kanzawa 1939; Sasaki & Sato 1995b). Field experiments have shown that adult mortality approaches, or reaches, 100 per cent by early spring (Dalton et al. 2011; Kaçar et al. 2016). Lack of access to suitably protected sites, water and food accelerate mortality (Kaçar et al. 2016; Wallingford et al. 2018). In the absence of food, over-wintering adults do not survive two weeks under experimental field conditions in California (Kaçar et al. 2016). Numerous studies have also shown that *D. suzukii* abundance is very low post-winter (even once favourable temperatures return), and that this period is a significant restriction ('bottle-neck') for the population (Asplen et al. 2015; Grassi et al. 2018; Kanzawa 1939; Rossi-Stacconi et al. 2016; Shearer, Long & Stoven 2016; Wallingford, Lee & Loeb 2016). For example, work in Europe has shown that the severity of winter negatively affects the population of *D. suzukii* in the following summer (Rossi-Stacconi et al. 2016).

The largest recorded number of adult *D. suzukii* trapped in Japan occurred in the Imperial Palace Gardens in Tokyo (Beppu 2000, 2006, 2014) where thousands of adults were trapped/collected after the reproductive season in November and December (Beppu 2000, 2006, 2014). The higher *D. suzukii* adult activity in winter at this site is consistent with large numbers of *Drosophila* adults among a broad range of species trapped at this location (Beppu 2000, 2006, 2014). This is likely to reflect an abundance of the flies due to the diverse range of plant hosts available in the gardens. In addition, locally favourable micro-climates due to urban structures in the gardens, and the general warming effect of the Tokyo metropolitan area moderating winter temperatures, are likely to allow *D. suzukii* adult activity to continue for longer at this particular site.

It has been reported in Europe that winter survival between years varies and that *D. suzukii* activity and over-wintering survival is positively linked to temperature (Rossi-Stacconi et al. 2016). In the central valley of California (where winters are mild) the majority of sampled sites do not detect *D. suzukii* through winter and early spring. However, at some locations where host trees can be within one metre of a building, or crops are nearby, adults can be trapped throughout the winter (Harris et al. 2014).

The activity of *D. suzukii* adults is very low over winter until spring in temperate regions. For example, in 1995 Sasaki and Sato did not collect any adults in Fukushima Prefecture from December to April for two years. In 2016, Sasaki trapped a very small number of adults in a blueberry orchard during winter including a single female in January and a male and female in March. In other southern locations (Aichi and Kagawa Prefectures) very low numbers of adults were collected, but not at others (Kochi Prefecture) (Toda 1979). Similarly, very low or nil adult activity over winter in temperate regions has been reported from mainland Asia (Zhai et al. 2016), Europe (Rossi-Stacconi et al. 2016) and North America (Dalton et al. 2011; Harris et al. 2014; Thistlewood et al. 2018).

The dominant and positive influence of temperature on *D. suzukii* activity supports considerations that reproduction could occur in regions with mild to warm winters, such as sub-tropical areas. For example, *D. suzukii* is reported to be active in the State of Florida, United States of America (USA) with sexually mature adults trapped throughout the winter period (Renkema et al. 2018). Nevertheless, although this pest has been present in the State of Florida for about 10 years, there is still no significant damage observed to commercial strawberries grown through winter (November to March) (Renkema et al. 2018). Similarly, low levels of oviposition have been recorded over winter in the central valley of California (Kaçar et al. 2016). Trap catches through the Florida winter period also remain low, commonly being 95 per cent to 98 per cent less than numbers of adults trapped during summer in temperate regions of the USA (Renkema et al. 2018).

Monitoring programs in the northwest of the United States show trap catches in strawberry fields over summer are high, and that strawberries are a preferred host for *D. suzukii* (OSU 2010a, b; Peerbolt 2010). In the eastern United States, high larval infestations in strawberries in North Carolina have been reported (Burrack 2010). Damage to commercial strawberries has also been recorded in Europe (EPPO 2010), with 60 to 100 per cent damage in infested areas (Grassi, Giongo & Palmieri 2011; Grassi & Pallaoro 2012; Süss & Costanzi 2010). Early in the season, when *D. suzukii* populations are lower and insecticide applications more frequent, infestation levels range from 2 per cent to 10 per cent (Grassi, Giongo & Palmieri 2011; Grassi & Pallaoro 2012).

In contrast to the numerous reports of *D. suzukii* attacking strawberry in the introduced range, there is only one report of this pest attacking commercial strawberries in August in Japan since the 1930s (Kanzawa 1939; Tochigi Prefecture Agricultural and Environmental Training Centre 2018). MAFF has provided information on pest surveillance activities in Japan. Japan has 47 Prefectures, and each Prefecture monitors about 100 pests monthly to support commercial growers in making decisions about pest management. Nationally, there are about 11,000 sites monitored across a wide range of crops and this monitoring program has been in place for many decades. For commercial winter strawberry production, 400 sites are monitored monthly (during the production season of November to May) and there has been no detection of *D. suzukii* for over 40 years.

In summary, winter conditions in Japan impose a significant stress on *D. suzukii* that results in very high levels of mortality, significantly limits adult flight activity, and induces reproductive diapause in the small number of surviving adults. Furthermore, information provided by MAFF indicates the complete absence of *D. suzukii* from commercial strawberry production sites in Japan.

The risk scenario of concern for *D. suzukii* is the presence of larvae and eggs in strawberries from Japan imported to Australia.

All ratings for the likelihoods of entry, establishment and spread, and the rating for the overall consequences are set out in Table 4-5

4.2.1 Unrestricted risk estimate

Based on the final PRA report for *D. suzukii* (Department of Agriculture 2013), the unrestricted risk estimate for *D. suzukii* for strawberries from Japan is ‘High’ and therefore does not achieve the ALOP for Australia. Therefore, specific risk management measures are required for this pest.

4.3 Spider mites

Amphitetranychus viennensis (EP), *Eotetranychus smithi, Eotetranychus asiaticus, Eotetranychus geniculatus*, *Tetranychus kanzawai* (EP, WA)

Spider mites are common pests on a wide range of horticultural commodities. They generally occur on leaves but are also found on fruits when infestation levels are high (NAPPO 2014). Spider mites have been intercepted on strawberries from the United States, as well as other horticultural commodities (unpublished data DAWR)(NAPPO 2014).

Amphitetranychus viennensis, *Eotetranychus smithi, Eotetranychus asiaticus*, *Eotetranychus geniculatus* and *Tetranychus kanzawai* have been grouped together on the basis that their biologies and behaviours are considered to be very similar, such that they are predicted to pose similar risks and to require similar risk mitigation measures.

Amphitetranychus viennensis, *Eotetranychus smithi, Eotetranychus asiaticus* and *Eotetranychus geniculatus* are not present in Australia. *Tetranychus kanzawai* is not present in the state of Western Australia and is a pest of biosecurity concern for that state.

Various spider mite species, including two of the species assessed here, have been assessed previously in existing risk analyses. The department has previously assessed *T. kanzawai* on horticultural commodities including for table grapes from Japan (Department of Agriculture 2014), Korea (Biosecurity Australia 2011b) and China (Biosecurity Australia 2011a), and most recently strawberries from Korea (Department of Agriculture and Water Resources 2018c). *Amphitetranychus viennensis* was previously assessed on apples from China (Biosecurity Australia 2010). In these existing risk analyses, the unrestricted risk estimates for spider mites were uniformly assessed as not achieving ALOP for Australia. Therefore, specific risk management measures are required for these pests on these pathways, and in this report are extended to imported strawberries from Japan.

Eotetranychus smithi, *Eotetranychus asiaticus* and *Eotetranychus geniculatus* have not been previously assessed by the department. *Eotetranychus smithi* is known from China, Japan, South Korea, Madagascar, the Philippines, Taiwan and the United States of America (USA) (Vacante 2016). Host plants of *E. smithi* include 25 species in six families, which include important economic crops such as cotton, apple, grape and peach (Migeon & Dorkeld 2019; Vacante 2016). *Eotetranychus asiaticus* is known from Japan, China, Korea and Taiwan (Ehara 1999). Host plants of economic importance of *E. asiaticus* include citrus, tea, persimmon and grapes (Ehara 1999; USDA 1995). *Eotetranychus geniculatus* it is only known from Japan and China, and there is limited information available about this species. However, Zhang (2003) and Vacante (2016) described the behaviour and biology of two other well-known species of the genus *Eotetranychus*, *E. lewisi* and *E. sexmaculatus*, and in both instances these are considered similar to the behaviour and biology of the other spider mites of different genera considered in this assessment. It is therefore considered appropriate to include *E. smithi*, *E. asiaticus* and *E. geniculatus* in this joint assessment.

Most species of spider mites have a wide host range that includes agricultural and horticultural crops. *Amphitetranychus viennensis* and *T. kanzawai* are important pests in Japan on fruit trees, woody ornamentals and greenhouse grapes (Ehara 1999; Kafil, Allahyari & Saboori 2007; Takafuji et al. 2000; Zhang 2003). *Eotetranychus smithi* has been reported on grape, pear and strawberry in Japan (Ehara 1999), *E. asiaticus* has been reported on citrus, tea, persimmon in

Japan and grapes in Taiwan (Ehara 1999; USDA 1995) and *E. geniculatus* has been reported on grape and strawberry in Japan (Ehara 1999). The hosts of these species are economically important crops in Australia. Therefore, these species are considered likely to have similar potential consequences.

Spider mites usually inhabit the underside of leaves where they spin a covering of fine silk webbing. They feed by piercing plant cells and consuming their contents (Zhang 2008; Zhang 2003). Damaged leaves develop yellowish/brownish spots due to the removal of moisture, and large infestations may result in stunted growth of plants, reduced fruit quality, and eventually, plant death (Alford 2007; NAPPO 2014; Zhang 2008; Zhang 2003).

The life cycle of spider mites consists of five stages—egg, larva, protonymph, deutonymph and adult. The largest of these life stages are adult females, which typically measure 0.3 millimetres to 0.5 millimetres in length and are commonly red, brown, green or yellow in colour. Immature stages resemble adults, but are smaller (Alford 2007; NAPPO 2014; Zhang 2008; Zhang 2003).

Development from egg to adult takes one to two weeks depending on temperature, host, humidity and other environmental conditions (Zhang 2008; Zhang 2003). Due to their short development time, several generations can occur each year. In most species, females overwinter in protected sites. However, in glasshouses spider mites can reproduce throughout the year (Zhang 2003).

Spider mites can spread aerially, and through the movement of infested materials including plants and contaminated equipment and clothing. They can also disperse by crawling between plants, particularly under high infestation levels (NAPPO 2014; Zhang 2003).

Further to the previous assessments noted, the department has reviewed the latest literature (for example (Choi et al. 2018; Ghazy et al. 2016; Murase & Fujita 2017; Peng et al. 2016; Seeman, Beard & Zhang 2017)) and found no new information that would significantly change the risk ratings for the importation, distribution, establishment, spread and consequences as already established for *A. viennensis* and *T. kanzawai* in existing policies.

The likelihoods of entry, establishment and spread of *A. viennensis*, *E. smithi*, *E. asiaticus, E. geniculatus* and *T. kanzawai* on strawberries from Japan are assessed as being similar to the previous assessment for *T. kanzawai* on strawberries from Korea.

Thus, the likelihood of importation is assessed as ‘Moderate’. This is based on factors including the association of mites with strawberry fruit under high infestation levels, the visually-obvious damage and silk webbing produced by mites, and the hand-picking and packing of strawberries that could all be expected to reduce the potentially high association of these mites with fruit. The likelihood of distribution is also assessed as ‘Moderate’. This is based on factors including the potential for survival of mites during transport and distribution, their wide host range and host availability in the PRA area; these factors are moderated by recognition of the primary method of dispersal of mites, by crawling over short distances.

All ratings for the likelihoods of entry, establishment and spread, and the rating for the overall consequences are set out in Table 4-5.

4.3.1 Unrestricted risk estimate

The unrestricted risk estimate for spider mites from the strawberries from Japan pathway is assessed as ‘Low’, which is similar to the outcomes of previous assessments, and does not achieve the ALOP for Australia. Therefore, specific risk management measures are required.

4.4 Angular leaf spot

Xanthomonas fragariae (EP)

Angular leaf spot is a disease of strawberries caused by the gram-negative bacterium *Xanthomonas fragariae* (Parkinson et al. 2007). *Xanthomonas fragariae* was first detected in the State of Minnesota, United States of America (USA) in 1960 (Kennedy & King 1962), and has become an important pest of strawberries in the USA. It has since been reported in many other strawberry-growing areas around the world (FAO 2016a).

In Australia, *X. fragariae* has been found in Gosford, New South Wales in 1975, the Adelaide Hills, South Australia in 1994 and in Bundaberg, Queensland in 2010. These outbreaks have since been eradicated, and Australia is now considered to be free of *X. fragariae* (Australian Government Department of Agriculture 2012; Gillings, Fahy & Bradley 1998; IPPC 2015; McGechan & Fahy 1976; Young et al. 2011).

Xanthomonas fragariae was assessed in the risk analysis for strawberries from Korea (Department of Agriculture and Water Resources 2018c). In that risk analysis the unrestricted risk estimate for angular leaf spot was assessed as not achieving the ALOP for Australia. Therefore, specific risk management measures are required for angular leaf spot on that pathway, and in this report are extended to imported strawberries from Japan.

Strawberries are the only natural host of this bacterium. Experimental data indicate that susceptibility to *X. fragariae* varies among different strawberry cultivars (Bestfleisch et al. 2015; Maas et al. 2000), with fully resistant genotypes not yet identified.

Infection of leaves of wild and cultivated strawberry plants causes water-soaked lesions to form on the lower surface of the leaf (Gubler et al. 1999; Kwon et al. 2010; Peres 2014; Stöger et al. 2008). The lesions are initially small and irregular in shape; under high moisture conditions they may enlarge, becoming angular in shape and forming reddish-brown spots. These may develop into necrotic tissue and exude bacteria in an ooze (Heidenreich & Turechek 2016; Hildebrand, Schroth & Wilhelm 1967; Peres 2014).

The calyx may become infected, with symptoms identical to those on leaves (Heidenreich & Turechek 2016; Peres 2014). During severe infections the whole calyx may dry up and darken (Wang, McTavish & Turechek 2018). Lesions on the calyx and flowers can also secrete bacterial ooze (Gubler et al. 1999; Peres 2014). In the crown, water-soaked lesions may be localised or confined to one section (Hildebrand, Schroth & Wilhelm 1967).

In addition to host specificity attributes, many *Xanthomonas* species and pathovars also show tissue specificity, invading either intercellular spaces of mesophyll tissue (mesophilic pathogens) and/or xylem elements of vascular tissue (vascular pathogens) (Ryan et al. 2011).

Xanthomonas fragariae has been found in vascular tissues of all parts of strawberry plants, including the crown, leaves, roots, petioles, stolons, daughter plants and calyx (Anco & Ellis 2011; Bestfleisch et al. 2015; Heidenreich & Turechek 2016; Louws, Harrison & Garrett 2014). *Xanthomonas fragariae* is not directly associated with fruits (Gubler et al. 1999). Recent information suggests the movement of the bacterium in vascular tissue to uninfected plant parts may be a passive process (Wang, McTavish & Turechek 2018).

The spread of *X. fragariae* occurs through infected propagative material, and in water, for example, by overhead irrigation, rain splash and windblown droplets (Hildebrand, Schroth & Wilhelm 1967; Wang, McTavish & Turechek 2018). Seed transmission has not been demonstrated.

The department has reviewed the latest literature about *X. fragariae* (for example (FAO 2016a; Gétaz et al. 2018; Wang, McTavish & Turechek 2018)). New information identified on the colonisation and movement of *X. fragariae* in strawberry plants does not change the risk ratings for the importation, distribution, establishment, spread and consequences as set out for *X. fragariae* in existing policy.

The department has assessed the factors affecting the likelihood of entry, establishment and spread of *X. fragariae* on strawberries from Japan as being similar to the previous assessment for *X. fragariae* on strawberries from Korea.

The likelihood of importation is therefore assessed here as 'Moderate'. This assessment is based on factors that include recognition that *X. fragariae* may remain asymptomatic in plants and may be associated with the calyx, and that the disease is rare in Japan in production systems under cover (glasshouse/tunnel house). The likelihood of distribution is assessed as 'Low'. This assessment is based on factors including the natural host range being limited to strawberries, and environmental transmission being limited to water splash over short distances.

All ratings for the likelihoods of entry, establishment and spread, and the rating for the overall consequences are set out in Table 4-5

4.4.1 Unrestricted risk estimate

The unrestricted risk estimate for *X. fragariae* from the strawberries from Japan pathway is assessed as 'Low', which is similar to the outcome of the previous assessment for strawberries from Korea, and does not achieve the ALOP for Australia. Therefore, specific risk management measures are required.

4.5 Phytophthora

Phytophthora biology

Phytophthora are oomycetes, water-loving fungi-like microorganisms that require a moist environment to actively grow and reproduce (Erwin & Ribeiro 1996). The genus contains a large number of species, the majority of which are plant pathogens, and is currently divided into 10 different clades (taxonomic groups) (Kroon et al. 2012; Roy & Grünwald 2014).

Phytophthora species produce five different life stages: mycelium, oospores, chlamydospores, sporangia and zoospores (Erwin & Ribeiro 1996).

Mycelium grows inside the host, infecting plant tissues and acquiring nutrients from dead or dying cells (Hardham 2007). Oospores are sexually-produced spores generated from mycelium that are released into the soil when infected plant tissues break down. Oospores have thick cell walls, are resistant to desiccation, and are able to remain dormant in soil for extended periods (Erwin & Ribeiro 1996; Hardham 2007).

Chlamydospores are asexual spores also formed in host tissues from mycelium, generally when conditions for growth are unfavourable. Both oospores and chlamydospores are an important survival mechanism for *Phytophthora* (Erwin & Ribeiro 1996).

Sporangia and zoospores are asexual and are only produced under ideal conditions (for example, in the presence of free water or very high humidity, and optimum temperature). When mature, sporangia can germinate directly forming hyphae, or indirectly, forming zoospores (Erwin & Ribeiro 1996; Hardham 2007).

Zoospores are the only motile spore produced by *Phytophthora* and are considered to be the major type of infectious propagule. They disperse through water in soil and are attracted to chemicals released by roots. They lack cell walls and are highly sensitive to dehydration (Erwin & Ribeiro 1996; Hardham 2007).

The movement of infected planting material and soil is the major pathway for long-distance dispersal of *Phytophthora* species (Erwin & Ribeiro 1996; Ristaino & Gumpertz 2000).

Some species of *Phytophthora* such as *P. sojae* are highly host specific; other species, such as *P. cinnamoni* and *P. nicotianae*, are effective and widespread generalists with a wide host range (Rahman et al. 2014; Roy & Grünwald 2014).

Phytophthora fragariaefolia

Phytophthora fragariaefolia was discovered in strawberries in Hokkaido, Japan in 2005 (Shirai et al. 2006), but only formally described in 2014 (Rahman et al. 2014). It has been assigned to *Phytophthora* clade 7 which includes agricultural threats such as *P. sojae*, *P. melonis* and *P. cinnamomi* (Rahman et al. 2014; Yang, Tyler & Hong 2017). Most species in clade 7 are pathogenic on plant roots (Kroon et al. 2012).

Phytophthora fragariaefolia has only been reported from Japan (Rahman et al. 2014) and Poland (Tkaczyk, Nowakowska & Oszako 2016). It is not known to occur in Australia.

In Poland, *P. fragariaefolia* was recovered from soil in contact with the roots of ash trees (*Fraxinus excelsior*) suffering die-back caused by the fungus *Hymenoscyphus fraxineus* (Tkaczyk, Nowakowska & Oszako 2016). However, wild strawberries (*Fragaria* sp.) are present in the Białowieża forest where the isolation was made (Pabian & Jaroszewicz 2009).

The known natural host range of *P. fragariaefolia* is currently limited to strawberries (*Fragaria* x *ananassa*). Under laboratory conditions, roses were found to be capable of supporting infection, although the pathogen was less virulent than on strawberries (Rahman et al. 2014).

The scenario of concern is that strawberry fruits may be contaminated with spores of *P. fragariaefolia* from soil or infected plant material, and that *P. fragariaefolia* may be unintentionally introduced into Australia.

All ratings for the likelihoods of entry, establishment and spread, and the rating for the overall consequences are set out in Table 4-5

4.5.1 Likelihood of entry

The likelihood of entry is considered in two parts: the likelihood of importation and the likelihood of distribution, which consider pre-border and post-border issues, respectively.

Likelihood of importation

The likelihood that spores of *Phytophthora fragariaefolia* will arrive in Australia with the importation of strawberries from Japan is assessed as: **Very Low**.

The following information provides supporting evidence for this assessment.

- *Phytophthora fragariaefolia* was isolated in Hokkaido, Japan in 2005 causing wilt and rot of strawberry plants (Rahman et al. 2014; Shirai et al. 2006). It has not been reported from any other area of Japan. The majority of strawberry production in Japan occurs outside Hokkaido.
- Strawberry production is closely managed throughout Japan. Strawberry runner production is managed by Japan's Prefecture Agricultural Research Stations. Tissue cultures from which mother stock is produced are routinely tested for viruses and diseases (see Chapter 3). Clean runners are produced and sold to specialised producer groups who multiply stock for sale to growers. Growers plant runners in outdoor fields for further multiplication.
- Runners may come into contact with *P. fragariaefolia* when they are planted outside for multiplication. Under favourable conditions *P. fragariaefolia* could be present as sporangia and zoospores that could infect plants; if conditions were unfavourable the pest may exist as inactive oospores and/or chlamydospores.
- In tunnel house production, soil is fumigated before runners are transplanted for fruit production. However, it is unlikely this practice would destroy any resistant *Phytophthora* oospores and chlamydospores present in the soil (Erwin & Ribeiro 1996). In glasshouse production, the growing medium (commonly a peat-coir mix) is sterilised or disinfected before being used for planting. The runners have soil removed and are fumigated with carbon dioxide gas (60 per cent for 24 hours) before planting in the glasshouse. The removal of soil will reduce the risk of oospores and chlamydospores, but may not affect sporangia and mycelium present inside a plant.
- Commercial production of strawberries in tunnel houses employs the use of plastic sheeting to prevent fruits from coming into contact with soil. In glasshouses, soil-less mixes are generally used as a growing medium (a combination of peat and coir). In addition, the use in glasshouses of raised beds for cultivation and plastic sheeting prevents fruit from coming into contact with the growing medium.

- Plants are grown in tunnel houses and in glasshouses from August. The temperature can vary from a maximum of 30 degrees Celsius to a minimum of 5 degrees Celsius. Routine watering is often supplied by overhead irrigation systems before flowering occurs, to assist in minimising high temperatures, and by dripper irrigation systems after flowering.
- Availability of water and suitability of temperature are key factors for *Phytophthora* disease, but water availability is the more important (Erwin & Ribeiro 1996). *Phytophthora fragariaefolia* has a relatively high optimum growth temperature of 25 degrees Celsius to 28 degrees Celsius, but growth has been observed between 5 degrees Celsius and 33 degrees Celsius (Rahman et al. 2014).
- Infection occurs through roots, and as the mycelium progresses into the crown of the plant the disease symptoms become obvious. Under ideal conditions in laboratory trials, strawberry plants infected with *P. fragariaefolia* expressed disease symptoms within 4 days (Rahman et al. 2014).
- With no known latency phase in the plant and rapid expression of disease symptoms, it is unlikely infected plants would produce commercial quality fruits.
- When conditions are favourable, *Phytophthora* can rapidly induce disease outbreaks in field situations, particularly in monocultures such as strawberry production (Erwin & Ribeiro 1996), as was the situation observed in strawberry beds in Hokkaido, Japan (Shirai et al. 2006). Symptoms of *P. fragariaefolia* infection observed in strawberry plants include wilting, browning of leaves, petioles and runner tips, browning inside crown and roots, tissue death and eventually plant death (Rahman et al. 2014; Shirai et al. 2006). An outbreak of *P. fragariaefolia* in a commercial production system would thus be expected to result in obvious symptoms.
- Throughout the production season, regular monitoring for pests and diseases is conducted, with plants inspected by growers every few days to weekly. Prefecture officials also visit each production site twice per month to observe plants and advise growers of any specific pest pressures in their region.
- Any plants displaying symptoms of disease are removed from the production facility and destroyed. However, this practice is unlikely to eliminate the spread of *P. fragariaefolia* to other plants as the disease can spread through the soil and potentially the irrigation water in recycled systems.
- There is no evidence that *P. fragariaefolia* is directly associated with strawberry fruits. *Phytophthora* is not a systemic disease, and *P. fragariaefolia* does not produce aerially dispersed spores, as is the case with some other species of *Phytophthora* (Department of Agriculture and Water Resources 2015; Rahman et al. 2014).
- Strawberry fruits are harvested every day or second day. Each fruit is handpicked and placed in a lined tray. Fruits are inspected both during harvest and packing. Any strawberries with deformities or signs of disease are discarded into bins which are emptied daily. In addition, any material other than strawberry would be removed. However, if any strawberries were incidentally contaminated with spores they would be unlikely to be identified, and would be included in the export line.
- Strawberry fruits are held in cool storage at around six degrees Celsius prior to packing, and during pre-shipment and shipment. Japan's current practice is to pick strawberries at maximum ripeness and transport them to consumers within two days. This time period will likely be longer for transport to and within Australia.
- Sporangia and zoospores are highly sensitive to desiccation (Erwin & Ribeiro 1996). It is unlikely that sporangia and zoospores would survive storage and transport in a viable state. However, the more resistant chlamydospores and oospores are expected to be capable of surviving cold temperatures and dry conditions.

Phytophthora fragariaefolia has only been reported from diseased strawberry plants in Hokkaido, Japan. It has not been detected in the major strawberry production areas of Japan. The conditions for growing strawberries in both tunnel houses and glasshouses are ideal for *P. fragariaefolia* disease expression; infected plants quickly display symptoms of browning and rotting of roots, crown and petioles. Plants are subject to regular pest monitoring both by the grower and Prefecture officials, and infected plants are expected to be easily detected. There is no information to indicate that strawberry fruit are infected. Use of plastic sheeting to prevent strawberries coming into contact with soil/growing medium limits the chance of contamination from soil. Packing practices remove second grade fruits and any extraneous material.

For the reasons outlined, the likelihood of importation of spores of *P. fragariaefolia* is assessed as 'Very Low'.

Likelihood of distribution

The likelihood that *Phytophthora fragariaefolia* will be distributed within Australia in a viable state as a result of processing, sale or disposal of strawberry fruit from Japan, and subsequently transfer to a susceptible part of a host is assessed as: **Very Low**.

- *Phytophthora fragariaefolia* is not known to be associated with strawberry fruits. The scenario of concern is that fruits have come into incidental contact with spores potentially present in soil. As discussed in the likelihood of importation, strawberries from Japan are likely to have a very low level of *P. fragariaefolia* contamination.
- Upon arrival, strawberries will be maintained and transported in cool store to multiple retail points throughout Australia.
- Strawberries will be packaged, and are unlikely to be examined or processed until they arrive at retail points. Even if they were examined, *Phytophthora* spores are microscopic and would not be visible without significant magnification. Therefore, any contaminated strawberries would likely be sold to domestic consumers.
- Strawberries from Japan are intended for human consumption and most fruit will be consumed. Any waste will likely be discarded into managed waste systems and disposed of in municipal tips, posing little risk of exposure to a suitable host.
- Consumers may discard small quantities of fruit waste in urban, rural and natural localities, or in domestic compost.
- Oospores and chlamydospores are known to remain dormant in soil for extended periods (Erwin & Ribeiro 1996), and are the spore types most likely to survive transport and distribution with strawberries from Japan. These are resting spores which require optimal conditions before they will germinate. Oospores of *Phytophthora fragariae* var. *fragariae* have an optimum germination temperature of 15 degrees Celsius; as temperature increases the germination rate declines (Duncan 1985). Imported strawberry fruit is likely to arrive between November and March, when summer temperatures may inhibit oospore germination.
- Oospores germinate to produce either mycelium or sporangia, and chlamydospores germinate to produce sporangia (Erwin & Ribeiro 1996). Mature sporangia release motile zoospores which are capable of dispersing short distances through water in soil pores (35-50 centimetres, depending on the soil type), or potentially longer distances if released into a watercourse (Erwin & Ribeiro 1996; Judelson & Blanco 2005).

- Zoospores are attracted to plant roots, regardless of whether the roots are of a host plant (Judelson & Blanco 2005). Zoospores attracted to non-hosts would not result in establishment of an infection.
- Strawberries are the only known host of *P. fragariaefolia*. Strawberries are grown domestically in all states and territories in Australia; the majority of commercial production occurs in Queensland, Victoria and Western Australia (Department of Agriculture and Water Resources 2018a). Occasionally *Fragaria* spp. can be found in unmanaged environments in Australia (ALA 2019; Groves 2002), but this is rare.
- It is considered unlikely that *P. fragariaefolia* zoospores would come into contact with a susceptible host.

Imported strawberries are intended for human consumption and will be distributed to multiple retail points throughout Australia. Small quantities of fruit and fruit waste may be discarded in urban, rural and natural localities. *Phytophthora fragariaefolia* is not known to be associated with strawberry fruit, however it is possible that very low levels of incidental contamination with spores could occur. Oospores and chlamydospores are able to survive in soils until favourable conditions initiate germination. However, spore survival is limited by predation and competition, and dispersal in soils is likely to be limited to short distances. The only known natural host of *P. fragariaefolia* is strawberries.

For the reasons outlined, the likelihood of distribution of *P. fragariaefolia* is assessed as 'Very Low'.

Overall likelihood of entry

The overall likelihood of entry is determined by combining the likelihood of importation with the likelihood of distribution using the matrix of rules shown in Table 2-2.

The likelihood that *Phytophthora fragariaefolia* will enter Australia as a result of trade in strawberry fruit from Japan and be distributed in a viable state to a susceptible host is assessed as: **Extremely Low**.

4.5.2 Likelihood of establishment

The likelihood that *Phytophthora fragariaefolia* will establish within Australia based on a comparison of factors in the source and destination areas that affect pest survival and reproduction is assessed as: **Moderate**.

- Strawberries, the only known host of *P. fragariaefolia*, are grown domestically in all states and territories in Australia; the majority of commercial production occurs in Queensland, Victoria and Western Australia (Department of Agriculture and Water Resources 2018a). Occasionally *Fragaria* spp. can be found in unmanaged environments in Australia (ALA 2019; Groves 2002), but this is rare.
- *In-vitro, P. fragariaefolia* was found to require a temperature of 20 degrees Celsius and daily water changes to produce sporangia. Mycelium had an optimal growth temperature of 25 degrees Celsius to 28 degrees Celsius, with growth observed between 5 degrees Celsius and 33 degrees Celsius (Rahman et al. 2014). Excessive irrigation or rainfall is the most important factor that increases severity and spread of *Phytophthora* diseases (Erwin & Ribeiro 1996). These conditions can be found in some areas of Australia including strawberry production sites.

- All oomycetes have a short generation time and great reproductive capacity (Erwin & Ribeiro 1996). In addition, *P. fragariaefolia* is homothallic (self-fertile) (Rahman et al. 2014), and thus able to produce sexual oospores from within diseased plant tissues.
- *Phytophthora* zoospores disperse by swimming in water through soil pores or on the soil surface; they can also be dispersed passively in flowing water such as irrigation water or rainwater. *Phytophthora* can also be distributed by the movement of infected planting material and soil (Erwin & Ribeiro 1996; Link, Powelson & Johnson 2012).
- *Phytophthora* oospores and chlamydospores can survive in soil for extended periods during unfavourable conditions. However, they are also subject to predation and competition from other microorganisms. An increase in bacterial or fungal populations in soil has been observed to supress *Phytophthora* (Erwin & Ribeiro 1996).
- Zoospores, the major infective propagules, are attracted to chemicals released by plant roots, however this behaviour is not host specific, and may result in zoospores encountering a non-host plant (Hardham 2007; Judelson & Blanco 2005).
- Strawberry runners are produced under accreditation schemes in Victoria and Queensland to ensure disease-free mother stock is supplied to both commercial growers and nurseries (Plant Health Australia 2009; Strawberries Australia 2016).
- Commercial production of strawberries in Australia includes soil disinfestation using chemicals or solarisation (Department of Primary Industries and Regional Development 2016; Strawberries Australia 2016). However, these practices are unlikely to be completely effective against oospores that are protected by a thick cell wall (Erwin & Ribeiro 1996).

Phytophthora fragariaefolia oospores are able to survive in soil for long periods of time, and favourable conditions for disease occur in some areas of Australia where strawberries are grown. However, oospores residing in soil are subject to predation and competition from other microorganisms. Zoospores, the major infective propagules, move short distances through soil pores in the presence of free water, and passively over longer distances in flowing water. However, *P. fragariaefolia* is attracted to all plant roots, regardless of whether the plant is a suitable host. Strawberry is the only known host for *P. fragariaefolia*.

For the reasons outlined, the likelihood of *P. fragariaefolia* establishing in Australia is assessed as ‘Moderate’.

4.5.3 Likelihood of spread

The likelihood that *Phytophthora fragariaefolia* will spread within Australia, based on a comparison of factors in the source and destination areas that affect the expansion of the geographic distribution of the pest is assessed as: **Moderate**.

- *Phytophthora fragariaefolia* is most likely to spread locally through infective spores present in soil, irrigation water and infected plant material. Long distance dispersal of *Phytophthora* species occurs through the movement of infected plant tissue or soil (Erwin & Ribeiro 1996).
- In *Phytophthora*, zoospores are considered to be the major infectious propagules. Zoospores are motile by way of two flagella (tails) and actively swim short distances through water in soil pores (35–50 centimetres, depending on the soil type). They may also be passively dispersed over longer distances through flowing water such as irrigation water or rainwater (Erwin & Ribeiro 1996; Link, Powelson & Johnson 2012).
- Optimal (temperature and moisture) conditions for *P. fragariaefolia* occur naturally in some areas of Australia, including strawberry production areas of the Sunshine Coast,

Queensland. The maximum temperature range for October–April falls in the optimal range for *P. fragariaefolia* (25 to 28 degrees Celsius) and monthly rainfall is high between December and May (well over 100 millimetres) (Bureau of Meteorology 2018). However, optimal conditions may also be generated in other production systems where temperatures are sufficiently high and irrigation supplies the necessary moisture to support germination of spores and disease development.

- While optimal conditions occur in some areas of Australia, there are also large unfavourable areas across Australia characterised by high temperatures and low rainfall, which will limit the natural spread of *P. fragariaefolia*.
- Similar to other *Phytophthora* species, *P. fragariaefolia* produces oospores and chlamydospores that can survive in soil for extended periods (Rahman et al. 2014). The pest may be spread through contaminated soil, for example on machinery. However, most farms and production sites have good biosecurity practices and use a range of measures to manage on-farm biosecurity (Plant Health Australia 2009).
- The only known natural host of *P. fragariaefolia* is strawberries (Rahman et al. 2014). Strawberries are grown in all states and territories in Australia, and commercially in New South Wales, Queensland, Victoria, and Western Australia (Department of Agriculture and Water Resources 2018a). Occasionally *Fragaria* spp. can be found in unmanaged environments in Australia (ALA 2019; Groves 2002), but this is rare.
- When conditions are favourable, *Phytophthora* inoculum rapidly increases, particularly in monocultures such as strawberry production (Erwin & Ribeiro 1996). Symptoms of *P. fragariaefolia* infection in strawberry plants are expressed quickly (Rahman et al. 2014), and are likely to be detected in sites for commercial production of both runners and fruit.
- In Australia, strawberry planting material is produced from disease-tested stock by the Queensland Strawberry Runner Accreditation Scheme and the Victorian Certified Runner Scheme (Plant Health Australia 2009; Strawberries Australia 2016). If *P. fragariaefolia* was detected in Australia, it is likely that testing for this pathogen would be included in the certification schemes.
- Small volumes of planting material may also be distributed through non-commercial growers exchanging runners, and the sale of plants through local markets, potentially aiding the spread of *P. fragariaefolia* in urban settings.

Phytophthora fragariaefolia can spread over short distances via movement of zoospores through soil when conditions are favourable. It may also be spread over long distances by the movement of infected plant material and potentially the movement of contaminated soil on machinery. However, the risk is limited by naturally unfavourable areas in the Australian environment, the rapid development and associated high detectability of symptoms in infected plants, and the production of planting material through certified schemes.

For the reasons outlined, the likelihood of *P. fragariaefolia* spreading in Australia is assessed as 'Moderate'.

4.5.4 Overall likelihood of entry, establishment and spread

The overall likelihood of entry, establishment and spread is determined by combining the likelihoods of entry, of establishment and spread using the matrix of rules shown in Table 2-2.

The overall likelihood that *Phytophthora fragariaefolia* will enter Australia as a result of trade in strawberry fruit from Japan, be distributed in a viable state to a susceptible host, establish in Australia and subsequently spread within Australia is assessed as: **Extremely Low**.

4.5.5 Consequences

The potential consequences of the establishment of *Phytophthora fragariaefolia* in Australia has been estimated according to the methods described in Table 2-3.

Based on the decision rules described in Table 2-4, that is, where the potential consequences of a pest with respect to one or more criteria are 'D', the overall consequences are estimated to be **Low**.

Criterion	Estimate and rationale
Direct	
Plant life or health	D – Significant at the district level *Phytophthora fragariaefolia* was isolated from diseased strawberry plants in Hokkaido, Japan (Shirai et al. 2006). It has not been reported from other regions in Japan or in strawberry production elsewhere in the world. No economic losses are reported for this species. However, *Phytophthora* are known to be serious plant pathogens and other species have been reported to cause significant economic losses (Erwin & Ribeiro 1996; Roy & Grünwald 2014). *Phytophthora fragariaefolia* infects only strawberries (Rahman et al. 2014). In 2016–17, Australia produced more than 91,000 tonnes of strawberries valued at AU$506.5 million (Horticulture Innovation Australia 2018a). *Phytophthora cactorum* and *P. nicotianae* have been reported in strawberry production in Australia (Gerrettson-Cornell 1994; Golzar, Phillips & Mack 2007). Current growing practices therefore include the use of certified runners and raised soil beds in field to improve drainage, and minimise the impacts of *Phytophthora* crown rot. Appropriate climatic conditions exist in some strawberry growing regions in Australia but not all. As strawberry plants are frequently irrigated, temperature may be the limiting factor in disease development (optimum 25 to 28 degrees Celsius).
Other aspects of the environment	A –Indiscernible at the local level There are currently no known direct consequences of *P. fragariaefolia* on other aspects of the natural environment. *Phytophthora fragariaefolia* was isolated from soil associated with diseased ash trees in Poland. However, the cause of the decline of trees was attributed to the pathogen *Hymenoscyphus fraxineus* (Tkaczyk, Nowakowska & Oszako 2016). Wild strawberries are known to occur in the same location (Pabian & Jaroszewicz 2009) and are the likely source of *P. fragariaefolia* found in Poland.
Indirect	
Eradication, control	D – Significant at the district level Eradication of soil-borne *Phytophthora* is particularly difficult as thick-walled oospores can remain viable in the soil for many years. Under ideal conditions oospores will germinate, and the disease cycle rapidly produces large amounts of inoculum (Erwin & Ribeiro 1996). Any eradication effort would likely require the destruction of infected or potentially infected plant material and a

Criterion	Estimate and rationale
	period of host-free planting, noting that *P. fragariaefolia* is limited to a single host–strawberry (Rahman et al. 2014). The use of disease-free planting material is the primary control method for soil-borne pathogens including *Phytophthora* (Erwin & Ribeiro 1996). The Queensland Strawberry Runner Accreditation Scheme and the Victorian Certified Runner Scheme produce clean strawberry runners for the Australian industry (Plant Health Australia 2009; Strawberries Australia 2016). There are a number of fungicides registered for use on horticultural commodities for *Phytophthora* (APVMA 2018). The cultural practices already applied in Australia to manage *P. cactorum* and *P. nicotianae* in strawberries, such as use of mounded soil beds for maximum drainage, treatment of soil before planting, and controlled irrigation, would also be used to control *P. fragariaefolia*.
Domestic trade	D – Significant at the district level The presence of *P. fragariaefolia* in commercial production areas is likely to result in interstate trade restrictions on strawberry runners and require industry adjustment at the district level.
International trade	D – Significant at the district level The presence of *P. fragariaefolia* is likely to impact trade in strawberry runners. Australia exports strawberry runners/tissue cultures to a small number of countries: Spain, Cook Islands, New Caledonia, Turkey and USA. Currently none of these countries regulate for *P. fragariaefolia*, however several regulate for the similar pathogen *P. fragariae* var. *fragariae* (Department of Agriculture and Water Resources 2018d). The existing schemes in Queensland and Victoria responsible for producing disease-free strawberry runners would be able to implement testing to provide assurance to international trading partners that strawberry runners produced for export are free of *P. fragariaefolia*.
Environmental and non-commercial	A – Indiscernible at the local level Australia does not have any native species of strawberry. Occasionally, *Fragaria* spp. can be encountered in unmanaged environments (ALA 2019; Groves 2002), but this is rare. Fungicides are commonly applied in agriculture throughout Australia to control many diseases. Any additional usage is unlikely to result in an increase in the current level of impact.

4.5.6 Unrestricted risk estimate

Unrestricted risk is the result of combining the likelihoods of entry, establishment and spread with the outcome of overall consequences. Likelihoods and consequences are combined using the risk estimation matrix shown in Table 2-5.

Unrestricted risk estimate for *Phytophthora fragariaefolia*	
Overall likelihood of entry, establishment and spread	Extremely low
Consequences	Low
Unrestricted risk	Negligible

As indicated, the unrestricted risk estimate for *Phytophthora fragariaefolia* has been assessed as 'Negligible', which achieves the ALOP for Australia. Therefore, specific risk management measures are not required for this pest.

4.6 Anthracnose

Colletotrichum biology

Anthracnose is the common name used for diseases caused by closely related species of the genus *Colletotrichum* including *C. aenigma*. Fruit rot and crown rot are the most economically important anthracnose diseases for strawberry production (Maas 1998). Other anthracnose diseases include runner and petiole infections, leaf spot, flower blight and canker of stems, shoots and twigs (Coates, Cooke & Forsberg 2016; Howard et al. 1992; Maas 1998). Anthracnose diseases affect strawberry production worldwide (Maas 1998; Martínez-Culebras et al. 2000).

Many *Colletotrichum* species are cryptic (that is morphologically indistinguishable). A number of species that cause anthracnose disease on strawberry belong to the *Colletotrichum gloeosporioides* species complex. Species in this complex include *C. fructicola, C. siamense, C. theobromicola* (synonym: *C. fragariae*) and *C. gloeosporioides* (Weir, Johnston & Damm 2012).

Symptoms of strawberry anthracnose crown rot include wilting of young leaves and reddish brown rot inside the crown (Smith 2008). When infection is extensive the whole plant wilts and dies (Smith 2008). Fruit rot causes water-soaked spots on ripening fruit, which turn into firm black round lesions (Smith 2008). Pink to orange conidial masses cover the centre of lesions under humid conditions (Smith 2008). Lesions will eventually cover the whole fruit.

Colletotrichum species are dispersed primarily through asexual conidiospores. *Colletotrichum* produces conidiospores in large numbers on diseased plant tissue, including dead and decomposing leaf litter at the base of plants (Coates, Cooke & Forsberg 2016). *Colletotrichum* can also produce ascospores through sexual reproduction (Coates, Cooke & Forsberg 2016).

Colletotrichum spore spread is assisted by rain splash, which is the primary method by which *Colletotrichum* conidia are spread from plant to plant (Smith 2008). The spread of anthracnose fruit rot of strawberry is highly dependent on ground cover or surface topography (Madden, Wilson & Ellis 1993). *Colletotrichum* conidia can also be disseminated by wind-blown rain droplets (Cacciola et al. 2012) and through infected nursery stock (Maas 1998).

Colletotrichum aenigma

Colletotrichum aenigma belongs to the *C. gloeosporioides* species complex, and has recently been reported as being associated with strawberry anthracnose disease in Japan (Gan et al. 2016). *Colletotrichum aenigma* is not known to occur in Australia.

Colletotrichum aenigma was only recently described as a species (Weir, Johnston & Damm 2012), and little information is available describing its disease symptoms on strawberry. However, as *C. aenigma* shares common biological and pathogenic characteristics with other species in the genus *Colletotrichum,* particularly the *C. gloeosporioides* species complex, it is likely to behave similarly on strawberry to other *Colletotrichum* species.

In this assessment, the descriptor *Colletotrichum* spp. is used to refer to diseases caused by species from the genus *Colletotrichum*, while *Colletotrichum aenigma* is used to refer to the specific species being assessed.

Colletotrichum aenigma has been isolated from a number of hosts including strawberry, citrus, chili, avocado, dragon fruit, Asian pear, grapevine, tea, olives and apple (Diao et al. 2017; Meetum, Leksomboon & Kanjanamaneesathian 2015; Schena et al. 2014; Wang et al. 2015; Wang et al. 2016; Weir, Johnston & Damm 2012; Yan et al. 2015). It is generally found in country or regional surveys in conjunction with a number of other *Colletotrichum* species, at much lower levels than other dominant species (Diao et al. 2017; Han et al. 2016; Yan et al. 2015).

Pathogenicity testing by Baroncelli et al. (2015) determined that *C. aenigma* isolates could infect strawberry fruit and cause anthracnose disease symptoms. *Colletotrichum aenigma* pathogenicity varied depending on the strawberry plant part affected. *Colletotrichum aenigma* isolates from diseased strawberry plants showed strong pathogenicity on strawberry leaves but a weaker pathogenicity on petioles (Han et al. 2016). Strawberry leaves infected by *C. aenigma* develop prominent and sunken dark brown to black necrotic lesions (Han et al. 2016).

The scenario of concern for *C. aenigma* is that there may be potential for symptomless infected strawberry fruit to be imported into Australia.

All ratings for the likelihoods of entry, establishment and spread, and the rating for the overall consequences are set out in Table 4-5

4.6.1 Likelihood of entry

The likelihood of entry is considered in two parts, the likelihood of importation and the likelihood of distribution, which consider pre-border and post-border issues, respectively.

Likelihood of importation

The likelihood that *Colletotrichum aenigma* will arrive in Australia with the importation of strawberries from Japan is assessed as: **Low**.

The following information provides supporting evidence for this assessment.

- Strawberry plants in Japan are reported to be susceptible to anthracnose infection caused by *C. aenigma* (Gan et al. 2016).
- Anthracnose has also been reported by growers as a common disease of strawberry fruit in Japan. There are several *Colletotrichum* spp. in the *C. gloeosporioides* species complex that infect strawberries in Japan (Gan et al. 2016).
- *Colletotrichum aenigma* and other cryptic species in the *C. gloeosporioides* species complex are likely to cause similar anthracnose disease symptoms on strawberry.
- In Japan, *C. aenigma* was isolated from strawberry production sites during regional surveys at much lower levels than the dominant species *C. fructicola*, and was only recorded sporadically across a number of years (Gan et al. 2016). Similarly, in surveys of strawberries across a number of regions in China, *C. murrayae* was the dominant species recovered, while *C. aenigma* accounted for a small number of total isolates and only occurred in one of the 13 locations sampled (Han et al. 2016).
- Infected transplants and contaminated soil on transplants are the primary sources of anthracnose inoculum (Maas 1998). Therefore, propagating disease-free runners is the primary means of controlling strawberry anthracnose infection (Smith 2008).

- In Japan, strawberry runner production is controlled by the Prefecture Agricultural Research Stations which produce disease-free runners for producer groups. The research stations conduct virus and disease testing of strawberry seedlings.
- Strawberry tissue culture and runner stock infected with anthracnose are likely to be identified and removed before being transplanted in nurseries and sold to producers.
- After being tested for anthracnose and other diseases, strawberry runners are further multiplied by producer groups and farmers. Multiplication can occur outdoors; runner stock may be exposed to anthracnose during this process.
- Contaminated soil is also a source of anthracnose inoculum (Maas 1998). In Japan, soil inside plastic tunnel houses is treated with a fumigant (Chloropicrin) before plants are introduced. Inside glasshouses, plants are generally grown in soil-less mixes (peat-coir mix) that have been disinfected or sterilised. This ensures that strawberry transplants are not grown in soil or a growing medium that may potentially be contaminated with *Colletotrichum* spp.
- Inside plastic tunnel houses or glasshouses, strawberries are usually grown at 15 degrees Celsius to 25 degrees Celsius, with a maximum temperature of 30 degrees Celsius and a minimum temperature of 5 degrees Celsius. *Colletotrichum aenigma* mycelium can grow at temperatures between 10 degrees Celsius to and 36 degrees Celsius, with an optimum temperature of 28 degrees Celsius (Han et al. 2016). Disease development of *Colletotrichum* spp. is favoured by warm, wet weather, and optimal temperature is around 27 degrees Celsius (Howard et al. 1992; Maas 1998; Madeiras 2016). Any plants displaying symptoms of disease are removed from the production facility and destroyed.Optimal temperatures for sporulation of *Colletotrichum* spp. vary. King et al. (1997) found sporulation could occur within the temperature range of 5 degrees Celsius to 35 degrees Celsius for the four species of *Colletotrichum* spp. infecting strawberry. Optimal temperature for maximum sporulation was around 25 degrees Celsius (King et al. 1997).
- Secondary infection may occur through dispersal of spores from infected plants onto strawberry flowers or fruit. The typical temperatures for growing strawberries in Japan are within the optimum temperature range for initiating maximum sporulation of *Colletotrichum* spp. However, the removal of plants with any symptoms of disease is likely to remove the source of inoculum before it can spread to other plants or fruit.
- Strawberry fruits can be infected by *Colletotrichum* spp. conidia, which germinate to form infection structures (appressoria) that penetrate the host cuticle and epidermis (Perfect et al. 1999; Wharton & Schilder 2008). It has been reported that plants can also be directly infected by *Colletotrichum* spp. conidia, which can enter through stomata or wounds without appressoria (Coates, Cooke & Forsberg 2016; Zulfiqar & Brlansky 1996). However, it is likely that any strawberries with wounds or splitting would be removed during routine monitoring of fruits, and during picking and packing procedures.
- Japanese growers also routinely apply fungicides, in the tunnel houses and glasshouses during the growing period, to control anthracnose infections (refer to Chapter 3, Table 3-2).
- Anthracnose disease is less severe when water is supplied to plants using drip irrigation than overhead irrigation (Maas 1998). Irrigation systems for strawberry in Japan include both overhead and drip systems. Overhead sprinklers are used in late summer/early autumn to help manage high temperatures. During fruiting, drip irrigation is used to minimise free water to manage disease.
- In addition to fungicide application, routine pest monitoring also occurs at intervals of every two days to weekly. Prefecture officials also inspect production sites regularly to observe plants and advise growers of any specific pest pressures in their region.

- Lesions caused by anthracnose disease on developing and mature strawberry fruit are firm, slightly sunken and covered with pink or orange conidial spore masses (Jayawardena et al. 2016a; Smith 2008). Any plants with disease symptoms are removed from the production site and destroyed.
- To reduce the build-up of fruit rot caused by anthracnose, fruits should be harvested frequently and any rotten fruit removed (Smith 2008). In Japan, strawberry picking is done by hand and occurs every day or second day. Fruit is individually inspected for damage and imperfections. Damaged fruits are discarded into waste bins which are emptied daily. Frequent picking and individual examination of strawberries is likely to detect fruit with disease symptoms.
- Many *Colletotrichum* spp. have a quiescent (latent) period in unripe fruit before anthracnose fruit rot disease symptoms begin to develop (Coates, Cooke & Forsberg 2016; De Silva et al. 2017). The necrotrophic life cycle of *Colletotrichum* spp. is triggered by host physiology and environmental conditions, and generally occurs during fruit ripening as *Colletotrichum* spp. resumes colonising fruit tissue (Binyamini & Schiffmann-Nadel 1972; Coates, Cooke & Forsberg 2016; De Silva et al. 2017; Prusky & Lichter 2007).
- Strawberry fruit in Japan are handpicked at maximum ripeness. Therefore, quiescence (latency) is likely to have already been broken, such that symptoms would be detected during harvest or later at the packing house.
- Strawberries with obvious symptoms of disease will be removed during packing procedures. Strawberries that are asymptomatic could, however, escape detection and may be packed and exported.

Colletotrichum aenigma has only been reported at low frequency and sporadically over time in strawberry plants in Japan. Pathogen testing, cultural practices, including fungicidal treatments and regular inspections in the glasshouses/plastic tunnel houses, are likely to minimise the occurrence of *C. aenigma* infecting plants and fruit.

Strawberry runners may be infected when moisture levels and temperatures are suitable during field multiplication. When brought into the glasshouse/plastic tunnel house, temperatures will be conducive for disease expression and therefore symptomatic plants would be removed.

Colletotrichum spp. have been reported as having a quiescent (latent) period, and may remain dormant inside infected symptomless strawberry fruit. Symptomless fruit may be overlooked by inspections during harvesting and packing, which may result in infected fruit being harvested, stored, transported and sold. However, as strawberry fruit in Japan are handpicked at maximum ripeness, quiescence (latency) is likely to have already been broken, such that symptoms would be detected during harvest or inspection.

For the reasons outlined, the likelihood of importation of *C. aenigma* on strawberries from Japan is assessed as 'Low'.

Likelihood of distribution

The likelihood that *Colletotrichum aenigma* will be distributed within Australia in a viable state as a result of the processing, sale or disposal of strawberry from Japan and subsequently transfer to a susceptible part of a host is assessed as: **Low.**

The following information provides supporting evidence for this assessment.

- *Colletotrichum* spp. can be distributed over long distances through transport of asymptomatic hosts (De Silva et al. 2017). Distribution of imported strawberries from Japan would be for retail sale, and is likely to be Australia-wide.

- As strawberries will be packaged in punnets, packed strawberries may not be processed or handled again until they arrive at retailers. If anthracnose remains latent in packed strawberries, it is unlikely to be detected during transportation and distribution.
- Imported strawberries are intended for human consumption. Fruit with no symptoms will most likely be consumed, and fruit showing signs of disease will be discarded.
- Most fruit waste will be discarded into managed waste systems and will be disposed of in municipal tips, and would therefore pose little risk of exposure to a suitable host.
- Consumers may discard small quantities of strawberry fruit waste in urban, rural and natural localities. Small amounts of fruit waste may be discarded in domestic compost.
- There is some potential for consumer waste to be discarded near potential host plants, including commercially grown, household or wild host plants. If present in fruit waste, the pathogen would then need to be transferred to the host plants.
- Japan's strawberry export season is typically from November to May (MAFF 2017), which coincides with Australia's summer/autumn period. Strawberry fruits are highly perishable and very susceptible to water loss (Shin et al. 2008). Exposed to the environment over summer the fruit waste would quickly desiccate leaving minimal plant matter. Rapid desiccation would limit the ability of *C. aenigma* to develop spores and infect hosts. Predation and competition by other microorganisms would also limit *C. aenigma's* survival.
- In addition to strawberry, *C. aenigma* has been isolated from a diverse range of hosts including avocado, citrus, chili, dragon fruit, Asian pear, grapevine, tea, olives and apple (Meetum, Leksomboon & Kanjanamaneesathian 2015; Schena et al. 2014; Sharma, Maymon & Freeman 2017; Wang et al. 2015; Wang et al. 2016; Weir, Johnston & Damm 2012; Yan et al. 2015). Many of these plants are grown commercially and domestically, and have a wide distribution across Australia.
- *Colletotrichum* spp. produce conidiospores in large quantities on the tissues of infected living and non-living hosts, including fruit, through asexual reproduction (Coates, Cooke & Forsberg 2016; Maas 1998).
- Warm, humid and wet conditions favour infection, disease development, sporulation and spread of *Colletotrichum* spp. (Coates, Cooke & Forsberg 2016). Nearly 100 per cent relative humidity is needed for germination of *Colletotrichum* spp. spores (Maas 1998). Areas with favourable climatic conditions for *Colletotrichum* spp. can be found in some parts of Australia, including major commercial production regions of host commodities.
- There are varied reports of survival of *Colletotrichum* spp. in soil. Eastburn and Gubler (1990) took samples monthly from a strawberry nursery in northern California where plants that were heavily infected with anthracnose were tilled into the field. *Colletotrichum acutatum* was detected in the soil for nine months, but was not detected in the eleventh month (Eastburn & Gubler 1990).
- In the State of Florida, USA, strawberry crowns were taken from highly infected fields, and buried in a plot that had been cropped with strawberries the previous season, under conventional practices including methyl bromide fumigation (pre-trial) (Ureña-Padilla, Mitchell & Legard 2001). Samples were taken routinely up to 140 days and *C. gloeosporioides* was not detected after 98 days (Ureña-Padilla, Mitchell & Legard 2001).
- Preliminary studies in Queensland and the Granite Belt in Australia reported that *Colletotrichum* spp. could survive while buried in soil for 80 days during summer, and for 120 days during winter (DEEDI 2009, 2010).
- These reports show that *Colletotrichum* spp. on vegetative plant material does not survive for ten months in the soil, even in heavily infested fields. Survival is likely to be significantly

less on highly perishable strawberry fruit waste. However, the pathogen may survive for short periods in waste, in the absence of a suitable host or favourable climatic conditions.

- *Colletotrichum aenigma* that survives on waste would need to sporulate, and spores would need to disperse to a suitable host.
- Dispersal of *Colletotrichum* spores from infected to healthy hosts primarily occurs by rain splash (Smith 2008). *Colletotrichum* spp. spores can also be disseminated through wind-blown rain droplets to cause secondary infection (Cacciola et al. 2012). These modes of dispersal will only distribute spores very short distances from infected waste to new hosts in Australia.
- While optimal conditions occur in some areas of Australia for the germination and dispersal of *C. aenigma*, there are also many areas across Australia which experience very dry and hot conditions in summer, which will severely limit spore production and dispersal.

Imported strawberries are intended for human consumption and would likely be distributed Australia-wide. Quiescent (latent) anthracnose infection in packed strawberries is unlikely to be detected during transportation and distribution. Fruit showing no symptoms is likely to be consumed. Small quantities of fruit waste could be discarded in urban, rural and natural localities where hosts may be present. Survival of *C. aenigma* in fruit waste would be limited by desiccation of fruit, and predation and competition by other microorganisms. *Colletotrichum* spp. can produce spores on the tissues of living and non-living hosts. *Colletotrichum aenigma* has been isolated from a diverse range of plants which are grown commercially and domestically, and are widely distributed across Australia. However, *C. aenigma's* distribution is likely to be limited, as specific conditions for disease development are needed to produce spores, and spores are only able to disperse very short distances.

For the reasons outlined, the likelihood of distribution of *C. aenigma* on strawberries from Japan is assessed as 'Low'.

Overall likelihood of entry

The overall likelihood of entry is determined by combining the likelihood of importation with the likelihood of distribution using the matrix of rules shown in Table 2-2.

The likelihood that *Colletotrichum aenigma* will enter Australia as a result of trade in strawberries from Japan and be distributed in a viable state to a susceptible host is assessed as: **Very Low.**

4.6.2 Likelihood of establishment

The likelihood that *Colletotrichum aenigma* will establish within Australia based on a comparison of factors in the source and destination areas that affect pest survival and reproduction is assessed as: **Moderate.**

The following information provides supporting evidence for this assessment.

- *Colletotrichum aenigma* has been isolated from a number of host species including strawberry, avocado, citrus, chili, dragon fruit, Asian pear, grapevine, tea plant, olives and apples (Han et al. 2016; Meetum, Leksomboon & Kanjanamaneesathian 2015; Schena et al. 2014; Sharma, Maymon & Freeman 2017; Wang et al. 2015; Wang et al. 2016; Weir, Johnston & Damm 2012; Yan et al. 2015). These plants are grown commercially and domestically, and are distributed across Australia.

- *Colletotrichum* spp. produces conidiospores in large quantities on the tissues of infected living and non-living hosts through asexual reproduction (Coates, Cooke & Forsberg 2016).
- There are varied reports of survival of *Colletotrichum* spp. in soil. *Colletotrichum* spp. has been reported to survive in heavily infected buried plants for three to nine months in Florida and California respectively (Eastburn & Gubler 1990; Ureña-Padilla, Mitchell & Legard 2001). Preliminary studies in Queensland and the Granite Belt in Australia reported that *Colletotrichum* spp. could survive while buried in soil for 80 days during summer and for 120 days during winter (DEEDI 2009, 2010).
- These reports show that *Colletotrichum* spp. on vegetative plant material does not survive for ten months in the soil, even in heavily infested fields. Survival is likely to be significantly less on highly perishable strawberry fruit waste. However, the pathogen may survive for short periods in waste, in the absence of a suitable host or favourable climatic conditions.
- *Colletotrichum aenigma* that survives in soil will need to disperse to a suitable host.
- Warm, humid and wet conditions favour infection, disease development, sporulation and spread of *Colletotrichum* spp. (Coates, Cooke & Forsberg 2016). Japan's strawberry export season is typically from November to May (MAFF 2017), which coincides with Australia's summer/autumn period, when temperatures would be suitable for infection.
- *Colletotrichum aenigma* can grow at temperatures between 10 degrees Celsius and 36 degrees Celsius with an optimum temperature 28 degrees Celsius (Han et al. 2016). Optimal temperatures for sporulation of *Colletotrichum* spp. vary. King et al. (1997) found sporulation could occur within the temperature ranges of 5 degrees Celsius to 35 degrees Celsius for the four species of *Colletotrichum* spp. infecting strawberry studied. Optimal temperature for maximum sporulation was around 25 degrees Celsius (King et al. 1997).
- Areas with average mean temperatures of 25 degrees Celsius to 30 degrees Celsius can be found in some areas of Australia in summer/autumn. These areas could provide suitable conditions for infection of hosts by *C. aenigma* if accompanied by extended periods of rainfall/irrigation.
- Several *Colletotrichum* spp. are already present in Australia (Shivas et al. 2016), indicating that there may be suitable environmental and climatic conditions for the establishment of *C. aenigma* in Australia.
- *Colletotrichum aenigma* has been reported in a number of countries over a variety of climatic zones including China, Japan, Thailand, Italy and Israel (Gan et al. 2016; Han et al. 2016; Meetum, Leksomboon & Kanjanamaneesathian 2015; Schena et al. 2014; Sharma, Maymon & Freeman 2017). However, it has generally been reported at low frequency of occurrence in regional surveys, and with limited distribution (Han et al. 2016; Wang et al. 2016).

Colletotrichum aenigma has a diverse host range which are grown commercially and domestically, and are distributed across Australia. Favourable conditions for disease development occur in some areas of Australia. Although *C. aenigma* has been reported in a number of countries over a variety of climatic zones it is generally reported at low levels in regional surveys, with limited distribution.

For the reasons outlined, the likelihood of establishment of *C. aenigma* on strawberries from Japan is assessed as 'Moderate'.

4.6.3 Likelihood of spread

The likelihood that *Colletotrichum aenigma* will spread within Australia, based on a comparison of factors in the source and destination areas that affect the expansion of the geographic distribution of the pest is assessed as: **Moderate.**

The following information provides supporting evidence for this assessment.

- *Colletotrichum aenigma* has been isolated from a number of host species including strawberry, avocado, citrus, chili, dragon fruit, Asian pear, grapevine, tea, olives and apples (Diao et al. 2017; Han et al. 2016; Meetum, Leksomboon & Kanjanamaneesathian 2015; Schena et al. 2014; Sharma, Maymon & Freeman 2017; Wang et al. 2015; Wang et al. 2016; Weir, Johnston & Damm 2012; Yan et al. 2015). These plants are grown commercially and domestically, and are distributed across Australia.
- Several *Colletotrichum* spp. are already present in Australia (Shivas et al. 2016), indicating that there may be suitable environmental and climatic conditions for the survival of *C. aenigma* in Australia.
- Specific conditions that are favourable for the spread of *Colletotrichum* spp. such as a warm and humid climate, temperatures of 25 degrees Celsius to 30 degrees Celsius, and prolonged periods of wetness (Coates, Cooke & Forsberg 2016; Han et al. 2016; King et al. 1997; Maas 1998) can be found in some parts of Australia in summer, and span different geographical regions.
- While optimal conditions occur in some areas of Australia, there are also large areas across Australia which experience very dry and hot conditions in summer which will limit the spread of *C. aenigma*.
- *Colletotrichum* spp. produce conidiospores in large quantities on the tissues of infected living and non-living hosts through asexual reproduction under favourable conditions (Coates, Cooke & Forsberg 2016).
- *Colletotrichum* spp. spores are dispersed primarily by rain splash (Smith 2008), but can also be disseminated through wind-blown rain droplets to cause secondary infection (Cacciola et al. 2012). These modes of dispersal are limited to distributing spores over short distances, so potential for infection of hosts located at further distances is unlikely.
- *Colletotrichum* spp. can survive for a limited period in the soil (DEEDI 2009, 2010; Eastburn & Gubler 1990; Ureña-Padilla, Mitchell & Legard 2001). It may be spread through contaminated soil, for example on machinery. However, most farms and production sites have good biosecurity practices and use a range of measures to manage on farm biosecurity (Australian Olive Association 2018; Plant Health Australia 2009, 2010, 2011, 2013a, 2014).
- As *Colletotrichum* spp. can sporulate and infect leaves, stems and fruit of hosts the distribution of *Colletotrichum* spp. over long distances may occur through transport of infected symptomless hosts including fruit and commercial and domestic planting material (De Silva et al. 2017).
- The long distance movement of *Colletotrichum* spp. in strawberries is predominantly through infected planting material (Smith 2008). Strawberry runners and nursery stock of commercial hosts are likely to be produced under best practice procedures and inspected and tested for pests and diseases. Strawberry planting material produced from pathogen-tested stock is available from the Queensland Strawberry Runner Accreditation Scheme and the Victorian Certified Runner Scheme (DAFWA 2016; Strawberries Australia 2016).

The presence of other *Colletotrichum* spp. in Australia indicates that there are likely to be suitable environmental and climatic conditions for the spread of *C. aenigma* in Australia. The potential for spread of the fungus with infected fruit and plant material is moderated by its short-distance capacity for dispersal of spores and its requirement for specific conditions for disease development and sporulation.

For the reasons outlined, the likelihood of spread of *C. aenigma* on strawberries from Japan is assessed as 'Moderate'.

4.6.4 Overall likelihood of entry, establishment and spread

The overall likelihood of entry, establishment and spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of rules shown in Table 2-2.

The overall likelihood that *Colletotrichum aenigma* will enter Australia as a result of trade in strawberry fruit from Japan, be distributed in a viable state to a susceptible host, establish in Australia and subsequently spread within Australia is assessed as: **Very Low.**

4.6.5 Consequences

The potential consequences of the establishment of *Colletotrichum aenigma* in Australia have been estimated according to the methods described in Table 2-3.

Based on the decision rules described in Table 2-4, that is, where the potential consequences of a pest with respect to one or more criteria are 'D', the overall consequences are estimated to be **Low**.

Criterion	Estimate and rationale
Direct	
Plant life or health	D—Significant at the district level *Colletotrichum* spp. include a number of economically important postharvest pathogens worldwide (De Silva et al. 2017; Dean et al. 2012; Gan et al. 2016). *Colletotrichum aenigma* has only recently been recognised as a species, so little information is available on its potential to cause economic damage. To date it has been found on a number of commodities, in country or regional surveys, in conjunction with economically important species including *C. gloeosporioides* and *C. fructicola* (Diao et al. 2017; Gan et al. 2016; Han et al. 2016). In general it is found with a number of other *Colletotrichum* species at much lower levels than other dominant species (Diao et al. 2017; Han et al. 2016; Wang et al. 2016; Yan et al. 2015). This suggests that *C. aenigma* may be less consequential than other *Colletotrichum* spp. already present in Australia. *Colletotrichum aenigma* has been isolated from a number of host plants including strawberry, citrus, chili, avocado, dragon fruit, Asian pear, grapevine, tea, olives and apple (Diao et al. 2017; Meetum, Leksomboon & Kanjanamaneesathian 2015; Schena et al. 2014; Sharma, Maymon & Freeman 2017; Wang et al. 2015; Wang et al. 2016; Weir, Johnston & Damm 2012; Yan et al. 2015). These plants are grown commercially and domestically, and are distributed across Australia. The volume and value of some of these commodities are listed below: • strawberries: in 2016–2017, 91,083 tonnes was produced. The value of production was $506.5 million • citrus: in 2016–2017, 708,121 tonnes was produced. The value of production was $724.2 million • avocados: in 2016–2017, 65,992 tonnes was produced. The value of production was $374.5 million • table grapes: in 2016–2017, 171,637 tonnes was produced. The value of production was $534.4 million (Horticulture Innovation Australia 2018a). *Colletotrichum* spp. are reported in Australia as infecting and causing damage on a number of host species including strawberries, olives, citrus, apples, avocados and grapevine. Fungicides are used to limit the impact of the pathogens (Allen 2004; Citrus Australia 2011; DEEDI 2010; Dodds & Browne 2018; NSW DPI 2018; Sergeeva & Spooner-Heart 2009; Shivas et al. 2016). There are no known records of the pathogen being able to infect native species.
Other aspects of the environment	A— Indiscernible at the local level There are currently no known direct consequences of *C. aenigma* for the natural environment.
Indirect	
Eradication, control	D—Significant at the district level The primary source for the spread of *Colletotrichum* spp. is infected planting material (Smith 2008). Eradication would include removal of plants and a period of host-free planting. There are a number of *Colletotrichum* spp. present in Australia (Shivas et al. 2016). The use of fungicides and cultural practices already used to manage other *Colletotrichum* species in Australia would also likely be used to control *C. aenigma*.

Criterion	Estimate and rationale
Domestic trade	D—Significant at the district level The presence of anthracnose disease caused by *C. aenigma* in commercial production areas may result in temporary interstate trade restrictions on strawberries and other economically important host crops.
International trade	C—Minor significance at the district level The presence of *C. aenigma* in commercial production areas would have an impact on the trade of host commodities to countries where *C. aenigma* is not present. However, *C. aenigma* is already recorded in many major export markets (for example Asia).
Non-commercial and environmental	B—Minor significance at the local level Any additional usage of fungicidal sprays to manage anthracnose disease caused by *C. aenigma* on other plant hosts may affect the environment, with minor impact at local level.

4.6.6 Unrestricted risk estimate

Unrestricted risk is the result of combining the likelihoods of entry, establishment and spread with the outcome of overall consequences. Likelihoods and consequences are combined using the risk estimation matrix shown in Table 2-5.

Unrestricted risk estimate for *Colletotrichum aenigma*	
Overall likelihood of entry, establishment and spread	Very low
Consequences	Low
Unrestricted risk	Negligible

As indicated, the unrestricted risk estimate for *Colletotrichum aenigma* has been assessed as 'Negligible', which achieves the ALOP for Australia. Therefore, no specific risk management measures are required for this pest.

4.7 Brown rot

Monilinia fructigena (EP) and *Monilia polystroma* (EP)

Brown rot is a fungal disease of stone and pome fruit caused by a number of closely related species of the genus *Monilinia*. The anamorph (asexual stage) of the fungus is the genus *Monilia*. The genus belongs to the family Sclerotiniaceae and it can cause severe losses and damage to stone fruit (Zhu, Chen & Guo 2011). However, it has also been reported on other hosts including grapes and strawberries (Byrde & Willets 1977; Cline & Farr 2006).

They have been grouped together because of their related biologies and taxonomies, and they are predicted to pose similar risks and to require similar risk mitigation measures.

Both *M. fructigena* and *M. polystroma* were assessed in the risk analysis for strawberries from Korea (Department of Agriculture and Water Resources 2018c), nectarines from China (Department of Agriculture and Water Resources 2016) and table grapes from Japan (Department of Agriculture 2014). *Monilinia fructigena* was also assessed in the risk analysis for apples and table grapes from China (Biosecurity Australia 2010, 2011a).

The unrestricted risks for *M. fructigena* and *M. polystroma* are different on different pathways. For example, brown rots were assessed as having an unrestricted risk of 'Moderate' on nectarines from China, and thus required risk mitigation measures, while the unrestricted risk on strawberries from Korea was assessed as 'Very Low', achieving ALOP. The differences in unrestricted risk are attributed mainly to the different rates of association of brown rots with major and minor hosts, and non-host commodities.

Brown rot is primarily a disease of stone and pome fruit. Infection of fruit can occur at any time throughout fruit development. Symptoms develop rapidly, and are commonly evident as areas of firm, brown decay. Within days the entire fruit is rotten and the surface covered with conidial tufts of spores or mycelium (Chalkley 2016).

Brown rot fungi can also cause latent infection in fruits, which may not be evident until ripening or post-harvest. However, while *M. fructigena* and *M. polystroma* can infect strawberries, *Fragaria* species are not reported as a major host (CABI 2019; Chalkley 2016). No records have been found for *M. fructigena* or *M. polystroma* infecting strawberries in Japan.

The department has reviewed the latest literature (for example (Vasić et al. 2016; Vasić et al. 2018)), and found no new information that would significantly change the risk ratings for the importation, distribution, establishment, spread and consequences as set out for *M. fructigena* and *M. polystroma* in existing policies.

The department has assessed the factors affecting the likelihoods of entry, establishment and spread of *M. fructigena* and *M. polystroma* on strawberries from Japan as being similar to the previous assessment for *M. fructigena* and *M. polystroma* on strawberries from Korea.

The likelihood of importation is therefore assessed here as 'Very Low'. This assessment is based on factors including recognition that strawberry is not a major host of *M. fructigena* or *M. polystroma*, and that these fungi have not been found on strawberries in Japan. The likelihood of distribution is assessed as 'High'. This assessment is based on factors including potential for survival of *M. fructigena* and *M. polystroma* during transport and distribution, their wide host ranges and availability of hosts in the PRA area, and capacity for dispersal of infective spores by air currents and water splash.

All ratings for the likelihoods of entry, establishment and spread, and the rating for the overall consequences are set out in Table 4-5

4.7.1 Unrestricted risk estimate

The unrestricted risk estimates for *Monilinia fructigena* and *Monilia polystroma* from the strawberries from Japan pathway are assessed as 'Very Low' and are similar to the estimates in the previous assessment for strawberries from Korea, and meet Australia's ALOP. Therefore, no specific risk management measures are required for *Monilinia fructigena* and *Monilia polystroma*.

4.8 Thrips

Frankliniella fusca (GP), *Frankliniella intonsa* (GP) and *Frankliniella occidentalis* (GP, NT, RA)

Three thrips species, that are either quarantine pests and/or regulated articles for Australia were identified on the strawberries from Japan pathway, these being *Frankliniella fusca*, *F. intonsa* and *F. occidentalis* (Table 4-2).

Frankliniella occidentalis is not present in the Northern Territory and is a pest of regional concern for that territory.

Table 4-2 Quarantine and regulated thrips species for strawberries from Japan

Pest	In thrips Group PRA	Quarantine pest	Regulated thrips	On strawberry pathway	Moderate likelihood of entry for thrips verified
Frankliniella fusca (GP)	Yes	Yes	No	Yes	Yes
Frankliniella intonsa (GP)	Yes	Yes	No	Yes	Yes
Frankliniella occidentalis (GP, NT, RA)	Yes	Yes (NT)	Yes	Yes	Yes

GP: Species has been assessed previously in a Group PRA and the Group PRA has been applied. **NT:** Pest of biosecurity concern for the Northern Territory. **RA:** Regulated article, see below for definition of a Regulated article.

The indicative likelihood of entry for all thrips is assessed in the thrips Group PRA as Moderate. *Frankliniella fusca*, *F. intonsa* and *F. occidentalis* are reported from Japan and are associated with strawberry fruit (CABI 2019; MAFF 2016; Matos & Obrycki 2004; Nakao et al. 2011; Plantwise 2019). Standard packing house procedures and transportation are not expected to eliminate these thrips from the pathway. After assessment of the pathway-specific factors (see Section 2.2.7) for strawberries from Japan, the likelihoods of entry of Moderate were verified as appropriate for these thrips (Table 4-2).

A summary of the risk assessment for quarantine thrips is presented in Table 4-3 for convenience.

Table 4-3 Risk estimates for quarantine thrips

Risk component	Rating for quarantine thrips
Likelihood of entry (importation x distribution)	Moderate (High x Moderate)
Likelihood of establishment	High
Likelihood of spread	High
Overall likelihood of entry, establishment and spread	Moderate
Consequences	Low
Unrestricted risk	**Low**

The indicative unrestricted risk estimate for thrips is Low, which does not achieve the ALOP for Australia, as assessed in the thrips Group PRA (Table 4-3).

This indicative unrestricted risk estimate is considered to be applicable for the quarantine thrips species present on the strawberries from Japan pathway. Therefore, specific risk management measures are required for the quarantine thrips to achieve the ALOP for Australia.

Frankliniella occidentalis is identified as a regulated article, because it is capable of harbouring and spreading (vectoring) emerging orthotospoviruses that are quarantine pests for Australia, as detailed in the thrips Group PRA (Australian Government Department of Agriculture and Water Resources 2017).

A regulated article is defined by the IPPC as 'Any plant, plant product, storage place, packaging conveyance, container, soil and any other organisms, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved' (FAO 2019a). For simplicity, thrips identified as regulated articles are referred to as 'regulated thrips'.

The indicative likelihood of entry for all thrips is assessed in the thrips Group PRA as Moderate. This indicative likelihood is also relevant to regulated thrips that can transmit quarantine orthotospoviruses. As indicated earlier in this section, the likelihood of entry of Moderate was verified as appropriate for the regulated thrips (Table 4-2).

A summary of the risk assessment for quarantine orthotospoviruses transmitted by thrips is presented in Table 4-4 for convenience.

Table 4-4 Risk estimates for emerging quarantine orthotospoviruses vectored by thrips

Risk component	Rating for emerging quarantine orthotospoviruses
Likelihood of entry (importation x distribution)	Low (Moderate x Moderate)
Likelihood of establishment	Moderate
Likelihood of spread	High
Overall likelihood of entry, establishment and spread	Low
Consequences	Moderate
Unrestricted risk	**Low**

The indicative unrestricted risk estimate for emerging quarantine orthotospoviruses transmitted by regulated thrips is Low, which does not achieve the ALOP for Australia, as assessed in the thrips Group PRA. (Table 4-4).

This indicative unrestricted risk estimate is considered to be applicable for the emerging orthotospoviruses known to be vectored by the thrips species present on the strawberries from Japan pathway. Therefore, specific risk management measures are required for regulated thrips to mitigate the risks posed by emerging quarantine orthotospoviruses, to achieve the ALOP for Australia.

The conclusion of this risk assessment, which is based on the thrips Group PRA, applies to all phytophagous quarantine thrips and regulated thrips on the strawberries from Japan pathway, irrespective of their specific inclusion in this document.

4.9 Pest risk assessment conclusions

Table 4-5 Summary of unrestricted risk estimates for quarantine pests associated with fresh strawberry fruit from Japan

Pest name	Likelihood of						Consequences	URE
	Entry			Establishment	Spread	EES		
	Importation	Distribution	Overall					
Drosophila [Diptera: Drosophilidae]								
Drosophila pulchrella	Low	High	**Low**	High	High	Low	Moderate	**Low**
Drosophila subpulchrella	Low	High	**Low**	High	High	Low	Moderate	**Low**
Drosophila suzukii (EP)	High	High	**High**	High	High	High	High	**High**
Thrips [Thysanoptera: Thripidae]								
Frankliniella fusca (GP)	High	Moderate	**Moderate**	High	High	Moderate	Low	**Low**
Frankliniella intonsa (GP)	High	Moderate	**Moderate**	High	High	Moderate	Low	**Low**
Frankliniella occidentalis (GP, NT, RA)	High	Moderate	**Moderate**	High	High	Moderate	Low	**Low**
Mites [Trombidiformes: Tetranychidae]								
Amphitetranychus viennensis (EP)	Moderate	Moderate	**Low**	High	Moderate	Low	Moderate	**Low**
Eotetranychus asiaticus	Moderate	Moderate	**Low**	High	Moderate	Low	Moderate	**Low**
Eotetranychus geniculatus	Moderate	Moderate	**Low**	High	Moderate	Low	Moderate	**Low**
Eotetranychus smithi	Moderate	Moderate	**Low**	High	Moderate	Low	Moderate	**Low**
Tetranychus kanzawai (EP)	Moderate	Moderate	**Low**	High	Moderate	Low	Moderate	**Low**
Angular leaf spot [Xamthomonadales: Xanthonomadaceae]								
Xanthomonas fragariae (EP)	Moderate	Low	**Low**	High	Moderate	Low	Moderate	**Low**
Phytophthora [Prenosporales: Preonosporaceae]								
Phytophthora fragariaefolia	Very Low	Very Low	**Extremely Low**	Moderate	Moderate	Extremely Low	Low	**Negligible**

Pest name	Likelihood of						Consequences	URE
	Entry			Establishment	Spread	EES		
	Importation	Distribution	**Overall**					
Anthracnose [Glomerellales: Glomerellaceae]								
Colletotrichum aenigma	Low	Low	**Very Low**	Moderate	Moderate	Very Low	Low	**Negligible**
Brown rot [Helotiales: Sclerotiniaceae]								
Monilia polystroma (EP)	Very Low	High	**Very Low**	High	High	Very Low	Moderate	**Very Low**
Monilinia fructigena (EP)	Very Low	High	**Very Low**	High	High	Very Low	Moderate	**Very Low**

EP: Species has been assessed previously and import policy already exists. **ESS:** Overall likelihood of entry, establishment and spread. **GP:** Species has been assessed previously in a Group PRA and the group PRA has been applied (Australian Government Department of Agriculture and Water Resources 2017). **NT:** Pest of biosecurity concern for the Northern Territory. **RA:** Regulated article, refer to Section 4.8 for definition of a Regulated article**. WA:** Pest of biosecurity concern for Western Australia. **URE:** Unrestricted risk estimate. This is expressed in an ascending scale from negligible to extreme.

4.10 Summary of assessment of quarantine pests of concern

This section provides a summary of the process of assessment of potential and confirmed quarantine pests of concern (shown in Figure 8).

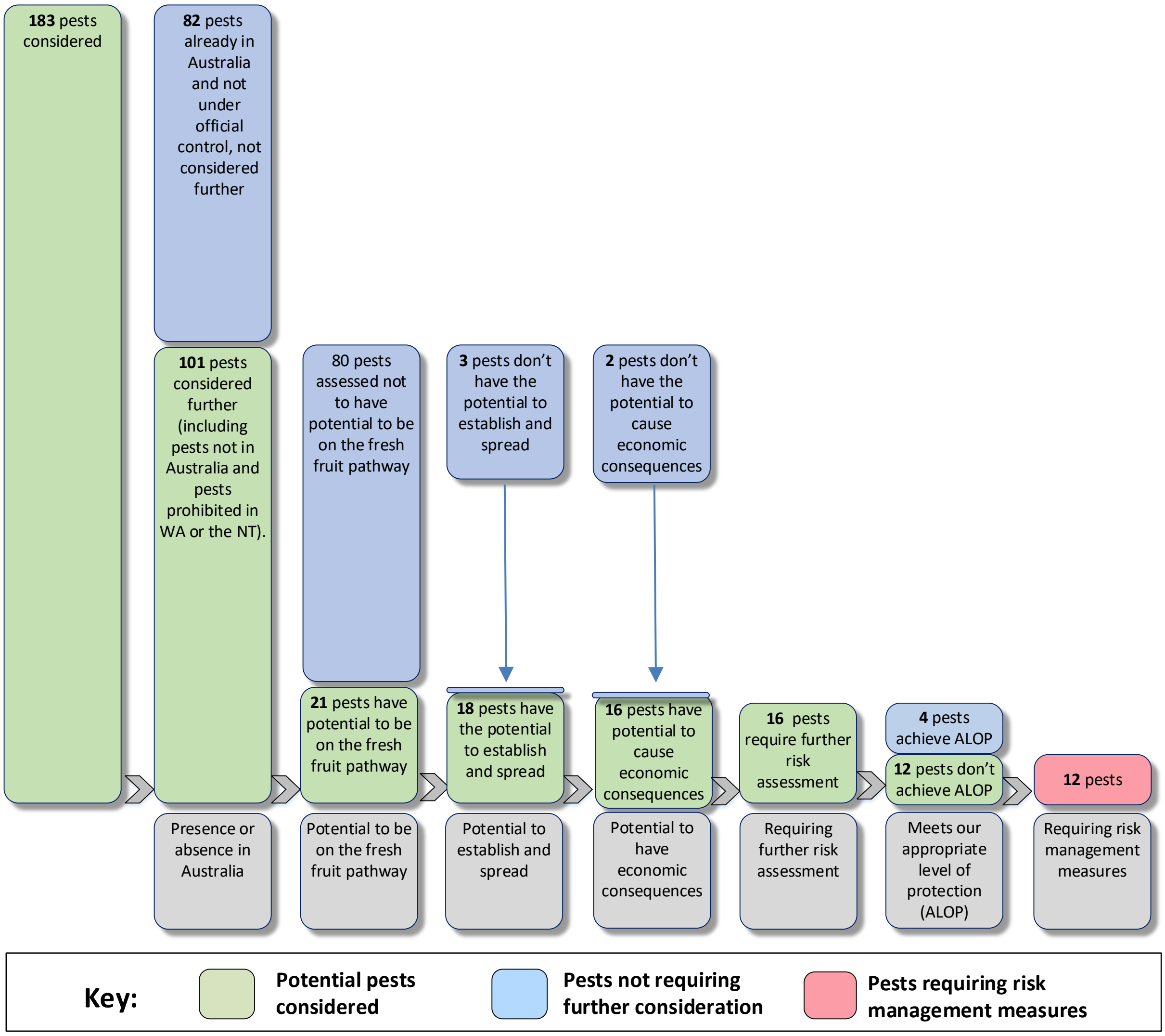
The pest categorisation process (Appendix A) identified 183 pests. Of these 183 pests:

- 82 pests are already present in Australia and not under official control, and therefore were not considered further;
- 80 pests were assessed as not having potential to be on the fresh strawberries pathway, and therefore did not undergo further assessment;
- three pests were assessed as not having potential to establish and spread, and therefore did not undergo further assessment;
- two pests were assessed as not being of potential economic consequence, and therefore did not undergo further assessment.

The outcome of the above process left 16 pests that required further consideration, that is, a pest risk assessment. Pest risk assessments for these 16 species were subsequently completed.

- The estimated unrestricted risks for four pests (one *Phytophthora* species and three fungal species) were assessed as achieving the ALOP for Australia, and therefore no specific risk management measures are required for these pests on this pathway. These pests are:
  - *Phytophthora fragariaefolia* (phytophthora)
  - *Colletotrichum aenigma* (anthracnose)
  - *Monilia polystroma* (brown rot)
  - *Monilinia fructigena* (brown rot)
- The estimated unrestricted risks for 12 pests (three *Drosophila* species, five spider mite species, one bacteria species and three thrips species) were assessed as not achieving the ALOP for Australia, and therefore these 12 pests require specific management measures for this pathway. These pests are:
  - *Drosophila pulchrella* (drosophilid fly)
  - *Drosophila subpulchrella* (drosophilid fly)
  - *Drosophila suzukii* (spotted wing drosophila)
  - *Frankliniella fusca* (tobacco thrips)
  - *Frankliniella intonsa* (Eurasian flower thrips)
  - *Frankliniella occidentalis* (western flower thrips) (also assessed as a regulated article)
  - *Amphitetranychus viennensis* (hawthorn spider mite)
  - *Eotetranychus asiaticus* (spider mite)
  - *Eotetranychus geniculatus* (spider mite)
  - *Eotetranychus smithi* (spider mite)
  - *Tetranychus kanzawai* (Kanzawa spider mite)
  - *Xanthomonas fragariae* (angular leaf spot)

Figure 8 Summary of assessment of quarantine pests of concern



5 Pest risk management

This chapter provides information on the management of quarantine pests and regulated thrips identified as having an unrestricted risk that does not achieve the appropriate level of protection (ALOP) for Australia. The recommended risk management measures for these pests are described in this chapter. This chapter also describes the operational system that is required for the maintenance and verification of the phytosanitary status of fresh strawberry fruit from Japan for export to Australia.

5.1 Pest risk management measures and phytosanitary procedures

Pest risk management evaluates and selects options for measures to reduce the risk of entry, establishment or spread of quarantine pests and regulated thrips for Australia, where they have been assessed to have an unrestricted risk that does not achieve the ALOP for Australia. In calculating the unrestricted risk estimates, the standard commercial production practices in Japan have been considered, including the post-harvest procedures and the packing of fruit (as described in Chapter 3: Japan's commercial production practices for strawberries).

Pest risk management measures identified for quarantine thrips are considered appropriate for the regulated thrips.

In addition to Japan's standard commercial production systems and packing house operations for strawberries (as described in Chapter 3: Japan's commercial production practices for strawberries), specific pest risk management measures, are recommended in order to achieve the ALOP for Australia.

In this chapter, the Department of Agriculture, Water and the Environment has recommended risk management measures that may be applied to consignments of strawberries sourced from Japan. Finalisation of the import conditions may be undertaken with input from the Australian states and territories as appropriate.

5.1.1 Analysis of pest interception data to date

There has previously been trade in strawberries from New Zealand, with over 295 tonnes imported into Australia between 2009 and 2019, and from the State of California, United States of America (USA) with over 152 tonnes imported into Australia between 2009 and 2011, but less than three tonnes in 2012-2013, and no further trade to date. Since trade commenced for strawberries from Korea in 2018, less than one tonne has been imported.

The pest risk analysis identified 12 quarantine pests for Australia requiring management measures, including two pests of regional concern. Examination of interception data collected from imports of strawberries from New Zealand, the State of California, USA and Korea found interceptions of some of these pests through the regulated commercial trade pathway.

There are interception records of thrips, mites, mealybugs and scales on strawberries from New Zealand and the State of California, USA. Contaminant pests and seeds are also occasionally intercepted. In 2010 and 2011, there was a high interception of angular leaf spot on field-grown strawberries from the State of California, USA.

Since import conditions were published in January 2018, three consignments of strawberries from Korea have been imported, and all were cleared at the Australian border.

5.1.2 Pest risk management for quarantine pests and regulated thrips associated with strawberries from Japan

The pest risk assessment identified the quarantine pests listed in Table 5-1 as having unrestricted risks that do not achieve the ALOP for Australia. Therefore, risk management measures are required to manage the risks posed by these pests. The recommended measures are also listed in Table 5-1.

Table 5-1 Risk management measures recommended for quarantine pests and regulated thrips associated with strawberries from Japan

Pest	Common name	Measures
Drosophila		
Drosophila pulchrella	drosophilid flies	Area freedom **a**
Drosophila subpulchrella	drosophilid flies	OR
Drosophila suzukii (EP)	spotted wing drosophila	Fruit treatment considered to be effective against all life stages of *Drosophila* spp. (such as: methyl bromide fumigation or irradiation)
Thrips		
Frankliniella fusca (GP)	tobacco thrips	Pre-export visual inspection and, if found, remedial action **b**
Frankliniella intonsa (GP)	Eurasian flower thrips	
Frankliniella occidentalis (GP, NT, RA)	Western flower thrips	
Spider mites		
Amphitetranychus viennensis (EP)	hawthorn spider mite	Pre-export visual inspection and, if found, remedial action **b**
Eotetranychus asiaticus	spider mite	
Eotetranychus geniculatus	spider mite	
Eotetranychus smithi	spider mite	
Tetranychus kanzawai (EP, WA)	Kanzawa spider mite	
Pathogens		
Xanthomonas fragariae (EP)	angular leaf spot	Area freedom **a** OR Systems approach

a: Area freedom may include pest free areas, pest free places of production or pest free production sites. **b:** Remedial action (by MAFF) may include applying approved treatment to the consignment to ensure that the pest is no longer viable or withdrawing the consignment from export to Australia. **EP:** Species has been assessed previously and import policy already exists. **GP:** Species has been assessed previously in a Group PRA and the Group PRA has been applied. **NT:** pest of biosecurity concern for Northern Territory. **RA:** Regulated article, refer to Section 4.8 for definition of a Regulated article. **WA:** Pest of biosecurity concern for Western Australia.

5.1.3 Risk management measures for quarantine pests and regulated thrips

The thrips Group PRA has identified thrips and emerging orthotospoviruses of biosecurity concern to Australia (Australian Government Department of Agriculture and Water Resources 2017). *Frankliniella fusca*, *F. intonsa* and *F. occidentalis* are associated with strawberries from Japan. Risk management measures are required to reduce the risk posed by these quarantine thrips, and/or the emerging quarantine orthotospoviruses they vector, to achieve the ALOP for Australia. The recommended measures are listed in Table 5-1.

Risk management measures recommended for quarantine pests and regulated thrips are based on existing policies for the import of strawberries from New Zealand, the State of California, USA, and the Republic of Korea (Department of Agriculture and Water Resources 2018c, b), as well as for other fruit commodities such as nectarines from China (Department of Agriculture and Water Resources 2016).

This final report recommends that when the following risk management measures are followed, the restricted risk for all identified quarantine pests and regulated thrips, and hence the orthotospoviruses the thrips may vector, will achieve the appropriate level of protection (ALOP) for Australia. The management measures include:

- area freedom (including pest free places of production or pest free production sites, which may require evidence of a seasonal absence)or fruit treatment (such as methyl bromide fumigation or irradiation) for *Drosophila* species
- pre-export visual inspection and remedial action for spider mites and thrips if live pests are found
- area freedom or a systems approach approved by the Australian Government Department of Agriculture, Water and the Environment for angular leaf spot.

Management for *Drosophila pulchrella, Drosophila subpulchrella* and *Drosophila suzukii*

To manage the risk of the three *Drosophila* species of biosecurity concern (*Drosophila pulchrella, Drosophila subpulchrella* and *Drosophila suzukii*), the Department of Agriculture, Water and the Environment recommends the options of methyl bromide fumigation, irradiation treatment or area freedom as measures for these pests. The objective of the recommended measures is to reduce the risk associated with these pests to achieve the ALOP for Australia.

Recommended measure 1: Methyl bromide fumigation

The Department of Agriculture, Water and the Environment reviewed efficacy data in support of methyl bromide fumigation treatment (Walse, Krugner & Tebbets 2012), and considered the treatment suitable to manage the risk of *Drosophila* species in strawberries. The recommended treatment is:

- 40 grams per cubic metre for three hours at a pulp temperature of 18 degrees Celsius or greater.

Should Japan wish to use methyl bromide fumigation as a phytosanitary measure, MAFF would need to provide a submission to the Australian Government Department of Agriculture, Water and the Environment that demonstrates it has processes and procedures for the registration, approval and audit of treatment facilities. The Australian Government Department of Agriculture, Water and the Environment may request on-site verification of the treatment facilities.

Recommended measure 2: Irradiation

Irradiation treatment is considered a suitable measure for *Drosophila* species based on prior research (Follett, Swedman & Price 2014). The Department of Agriculture, Water and the Environment recommends a treatment schedule of 150 gray minimum absorbed dose, consistent with ISPM 28 Annex 7: *Irradiation treatment for fruit flies of the family Tephritidae* (generic)(FAO 2017c). Although lower doses (78 gray) have been shown to induce sterility of all immature life stages associated with fruit, adults can successfully emerge from irradiated pupae. The detection of a sterilised *Drosophila* species post-border would result in significant regulatory actions. A dose of 150 gray would make adult emergence from irradiated fruit an unlikely event.

The use of irradiation as a phytosanitary measure is subject to approval by the Australian Government Department of Agriculture, Water and the Environment of the irradiation facilities identified by MAFF. Should Japan wish to use irradiation as a phytosanitary measure, MAFF would need to provide a submission to the Australian Government Department of Agriculture, Water and the Environment. The submission must fulfil requirements as set out in ISPM 18: *Guidelines for the use of irradiation as a phytosanitary measure* (FAO 2019d).

Recommended measure 3: Area freedom

The requirements for establishing pest free areas or pest free places of production or pest free production sites are set out in ISPM 4: *Requirements for the establishment of pest free areas* (FAO 2017a) and ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 2016c).

The Department of Agriculture, Water and the Environment recommends pest free production sites as a suitable measure to manage *Drosophila* species during a limited period in winter and spring. This assessment of acceptability of production site freedom is supported by biological information presented in Section 4.2. This information is consistent with the principles of ISPM 10, Section 2.1.1, where factors such as a pest having a low natural spread and low rate of reproduction during a specified period (for example, seasonal absence) are taken to support production site freedom. The biological information is supported by extensive surveillance undertaken by MAFF to confirm seasonal absence of *Drosophila* species during the production of winter strawberries in Japan.

Japan would need to verify the pest freedom of production sites consistent with ISPM 10. It is recommended that MAFF (or suitably qualified personnel authorised by MAFF) initially verify the absence of *Drosophila* species at export production sites by inspection of traps known to be effective at attracting adults (for example food baits) at weekly intervals, and through visual inspections to detect larval damage (for example, of culled fruit). The damage caused by *Drosophila* species larval feeding in strawberries is obvious (Tochigi Prefecture Agricultural and Environmental Training Centre 2018; Walton et al. 2010). Traps would need to be placed inside and immediately outside the production site and sampled at least four times prior to export harvest to verify freedom from *Drosophila* species. Exports cannot commence until one week after the first harvest for each production site to allow sufficient time for any possible larval damage to express and be detected.

Non-secure packing houses would also require weekly monitored trapping programs to verify pest absence to manage any possible post-harvest infestation.

MAFF would be required to notify the Department of Agriculture, Water and the Environment immediately if *Drosophila* species were detected in an export production site. Detection of *Drosophila* species in an export production site would result in the suspension of the pest free production site/area recognition. Exports would still be permitted under an approved treatment.

It is recommended that exports under a pest free production site initially occur from December to March when adult *Drosophila* species activity is known to be low. For example, it is known that *D. suzukii* at a single location in Japan may be active in large numbers at the end of autumn (Beppu 2000, 2006), and initial reproduction post-winter has been recorded from mid-April to May (Mitsui, Beppu & Kimura 2010; Sasaki & Sato 1995b). Surveillance at the start (November) and end (May) of the winter season at export production sites may further inform whether these months could be included in a seasonal absence pest free production site.

Alternatively, production sites that are secure from *Drosophila* species (for example glasshouses with appropriate security at entry points) could be recognised as pest free production sites.

Should Japan wish to use secure production sites as pest free place of production sites, as a management measure for *Drosophila* species, MAFF would need to provide a detailed submission to the Department of Agriculture, Water and the Environment. The submission would need to demonstrate how the secure production sites meet the requirements set out in ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 2016c).

Management for *Amphitetranychus viennensis*, *Eotetranychus asiaticus, Eotetranychus geniculatus, Eotetranychus smithi* and *Tetranychus kanzawai*

The Department of Agriculture, Water and the Environment recommends the option of pre-export visual inspection and, if found, remedial action, as measures for the specified spider mites and the thrips. The objective of the recommended measures is to reduce the risk associated with these pests to achieve the ALOP for Australia.

Recommended measure: Pre-export visual inspection and, if found, remedial action.

All strawberry fruit consignments for export to Australia must be inspected by MAFF and found free from these species of spider mite and thrips. Pre-export visual inspection must be undertaken by MAFF in accordance with ISPM 23: Guidelines for inspection (FAO 2019e) and consistent with the principles of ISPM 31: Methodologies for sampling of consignments (FAO 2016d). Export consignments found to contain these pests must be subjected to remedial action. Remedial action may include withdrawing the consignment from export to Australia, or if available, applying approved treatment to ensure that the pest is no longer viable.

Management for *Xanthomonas fragariae*

The Department of Agriculture, Water and the Environment recommends area freedom or a systems approach such as the combination of disease-free planting material, regular inspection and removal of any plants with disease symptoms, as measures for *Xanthomonas fragariae*. The objective of these recommended measures is to reduce the risk associated with this pest to achieve the ALOP for Australia.

Recommended measure 1: Area freedom

Area freedom is a measure which may be applied to manage the risk posed by *Xanthomonas fragariae*. The requirements for establishing pest free areas or pest free places of production or pest free production sites are set out in ISPM 4: *Requirements for the establishment of pest free areas* (FAO 2017a) and ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 2016c).

Should Japan wish to use area freedom as a measure to manage the risk posed by this pathogen, MAFF would need to provide a submission demonstrating area freedom for approval by the Department of Agriculture, Water and the Environment. The submission demonstrating area freedom must fulfil the requirements as set out in ISPM 4: *Requirements for the establishment of pest free areas* (FAO 2017a)or ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 2016c).

Recommended measure 2: Systems approach

A systems approach that uses the integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the required level of phytosanitary protection, could be used to reduce the risk of *Xanthomonas fragariae* being imported to Australia with consignments of strawberries. Information on a systems approach is set out in ISPM 14: *The use of integrated measures in a systems approach for pest risk management* (FAO 2019c).

The Department of Agriculture, Water and the Environment considers a systems approach could be based on a combination of production site preventative measures, monitoring, and pest control, with post-harvest measures. This series of measures/controls should cumulatively reduce the risk of infected strawberries on the pathway.

Should Japan wish to use a systems approach as a measure to manage the risk posed by these pathogens, MAFF would need to submit a proposal for consideration and approval by the Department of Agriculture, Water and the Environment. The proposal would need to outline all components of the system and how these components would address the risks posed by the pathogen and also fulfil the requirements set out in ISPM 14: *The use of integrated measures in a systems approach for pest risk management* (FAO 2019c).

Management for quarantine thrips and regulated thrips

The Department of Agriculture, Water and the Environment recommends pre-export visual inspection and, if found, remedial action to manage the risk of quarantine thrips and regulated thrips. This measure is consistent with the options provided in the thrips Group PRA (Australian Government Department of Agriculture and Water Resources 2017). The objective of the recommended measure is to reduce the risk associated with these pests to achieve the ALOP for Australia.

The recommended measure applies to all phytophagous quarantine thrips and regulated thrips on the strawberry fruit from Japan pathway, irrespective of their specific identification in this document, consistent with the thrips Group PRA.

Recommended measure: Pre-export visual inspection and, if found, remedial action

All consignments of strawberries exported to Australia must be inspected by MAFF, and found free of quarantine thrips and regulated thrips. Pre-export visual inspection must be undertaken by MAFF in accordance with ISPM 23: *Guidelines for inspection* (FAO 2019e) and consistent with the principles of ISPM 31: *Methodologies for sampling of consignments* (FAO 2016d) ensuring that the inspection method is designed to detect thrips. Export consignments found to contain any quarantine thrips or regulated thrips must be subjected to remedial action. Remedial action may include withdrawing the consignment from export to Australia or, if available, applying approved treatment to the export consignment to ensure that the pest is no longer viable.

5.1.4 Consideration of alternative measures

Consistent with the principle of equivalence detailed in ISPM 11: *Pest risk analysis for quarantine pests* (FAO 2019b), the Department of Agriculture, Water and the Environment will consider any alternative measure proposed by MAFF, providing that it demonstrably manages the target pest to achieve the ALOP for Australia. Evaluation of any such measures will require a technical submission from MAFF that details the proposed measures, including suitable information to support the claimed efficacy, for consideration by the Department of Agriculture, Water and the Environment.

5.2 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 strawberries from Japan at each relevant stage of the export pathway. This is to ensure that the recommended risk management measures have been met and are maintained.

5.2.1 A system of traceability to production sites

The objectives of this recommended requirement are to ensure that:

- Strawberries are sourced only from production sites producing commercial export-quality fruit.
- Production sites from which strawberries are sourced can be identified, so that any investigation and corrective action can be targeted rather than applied to all contributing export sites, in the event that live/viable pests are intercepted.
- Production sites are capable of applying in-field measures (for example, pest free production sites).

Export production sites are registered with MAFF before commencement of harvest each season. The list of registered production sites must be kept by MAFF. MAFF must ensure that strawberries for export to Australia can be traced back to the production site. MAFF is required to ensure the registered production sites are suitably equipped and have a system in place to carry out the specified phytosanitary activities. Records of MAFF's audits must be made available to the Department of Agriculture, Water and the Environment upon request. Records of production site monitoring/management must be made available upon request.

5.2.2 Registration of packing houses and auditing of procedures

The objectives of this recommended procedure is to ensure that:

- Strawberries are sourced only from packing houses approved by MAFF for processing of commercial-quality fresh strawberries.

Export packing houses are registered with MAFF before commencement of harvest each season. The list of registered packing houses must be kept by MAFF. MAFF is required to ensure that registered packing houses are suitably equipped and have a system in place to carry out the specified phytosanitary activities. Records of MAFF's audits must be made available to the Department of Agriculture, Water and the Environment upon request.

5.2.3 Registration of treatment providers and auditing of procedures

The objectives of this recommended procedure is to ensure that:

- Strawberries are treated by treatment providers that have been approved by MAFF

In circumstances where strawberries undergo treatment prior to export, this process must be undertaken by treatment providers that have been registered with and audited by MAFF for that purpose. Records of MAFF registration requirements and audits must be made available to the Department of Agriculture, Water and the Environment upon request.

Approval of treatment providers by MAFF must include verification that suitable systems are in place to ensure compliance with the treatment requirements. This may include:

– documented procedures to ensure strawberries are appropriately treated and safeguarded post treatment

– staff training to ensure compliance with procedures

– record keeping procedures

– suitability of facilities and equipment

– compliance with MAFF's system of oversight of treatment application.

The Australian NPPO provides final approval of facilities, following review of the regulatory oversight provided by the exporting NPPO and the capability demonstrated by the facility. Site visits may be required for the Australian NPPO to have assurance that the treatment can be applied accurately and consistently.

The use of irradiation requires a shared work plan that documents roles and responsibilities of all relevant stakeholders.

5.2.4 Packaging, labelling and containers

The objectives of this recommended procedure are to ensure that:

- strawberries intended for export to Australia, and associated packaging, are not contaminated by quarantine pests or regulated articles (as defined in ISPM 5: *Glossary of phytosanitary terms* (FAO 2019a))
- unprocessed packing material, which is not permitted, as it may vector other pests not associated with strawberries, is not imported with strawberries from Japan
- all wood material associated with the consignment used in packaging and transport of strawberries complies with the Department of Agriculture, Water and the Environment's import conditions, as published on BICON
- secure packaging is used for export of strawberries to Australia to prevent re-infestation during storage and transport and prevent escape of pests during clearance procedures on arrival in Australia. To make consignments insect proof and secure, at least one of the following packaging options must be used:
  - **Integral cartons**: produce may be packed in integral (fully enclosed) cartons (packages) with boxes having no ventilation holes and lids tightly fixed to the bases.
  - **Ventilation holes of cartons covered:** cartons (packages) with ventilation holes must have the holes covered/sealed with a mesh/screen of no more than 0.98 mm pore size and not less than 0.16 mm strand thickness. Alternatively, the vent holes may be taped over.
  - **Polythene liners:** vented cartons (packages) with sealed polythene liners/bags within are acceptable (folded polythene bags are acceptable).

  - **Meshed or shrink wrapped pallets or Unit Loading Devices (ULDs)**: ULDs transporting cartons with open ventilation holes/gaps, or palletised cartons with ventilation holes/gaps must be fully covered or wrapped with polythene/plastic/foil sheet or mesh/screen of no more than 0.98 mm diameter pore size. The wrapped pallet or ULD must be loaded and sealed at packing house or treatment facility.
  - **Produce transported in fully enclosed containers:** cartons (packages) with holes as loose boxes or on pallets may be transported in fully enclosed containers. Enclosed containers include 6-sided container with solid sides, or ULDs with tarpaulin sides that have no holes or gaps. The container must be loaded and sealed at the packing house.
- the packaged strawberries are labelled with sufficient identification for the purposes of traceability. This may include:
  - for treated product: the treatment facility name/number and treatment identification number
  - for strawberries where the measures include area freedom: the orchard and packing house reference/number
  - for strawberries where phytosanitary measures are applied at the packing house: the packing house registration reference/number.

Export packing houses and treatment providers (where applicable) must ensure packaging and labelling are appropriate to maintain phytosanitary status of the export consignments.

5.2.5 Specific conditions for storage and movement

The objective of this recommended procedure is to ensure that the quarantine integrity of the commodity during storage and movement is maintained.

Treated and/or inspected strawberries for export to Australia must be kept secure and segregated at all times from any fruit for domestic or other markets, and from untreated/non pre-inspected product, to prevent mixing or cross-contamination.

5.2.6 Freedom from trash

The objective of this recommended procedure is to ensure that strawberries for export are free from trash (for example, loose stem and leaf material, seeds, soil, animal matter/parts or other extraneous material) and foreign matter.

Freedom from trash must be confirmed by the inspection procedures. Export lots or consignments found to contain trash or foreign matter must be withdrawn from export unless approved remedial action such as reconditioning is available and applied to the export consignment and then re-inspected.

5.2.7 Pre-export phytosanitary inspection and certification by MAFF

The objectives of this recommended procedure are to ensure that Australia’s import conditions have been met.

- All consignments have been inspected in accordance with official procedures for all visually-detectable quarantine pests and other regulated articles (including soil, animal matter and plant debris) using random samples of 600 units per phytosanitary certificate, or equivalent as per ISPM 31: *Methodologies for sampling consignments* (FAO 2016d). One unit is considered to be a single strawberry fruit.

- A phytosanitary certificate must be issued for each consignment upon completion of pre-export inspection to verify that the required risk management measures have been undertaken prior to export and the consignment meets Australia's import requirements.
- Each phytosanitary certificate must include:

– a description of the consignment (including traceability information)

– details of disinfestation treatments (for example methyl bromide fumigation)

– any other statements that may be required such as identification of the consignment as being sourced from a recognised pest free production site.

5.2.8 Phytosanitary inspection by the Department of Agriculture, Water and the Environment

The objectives of this recommended procedure are to ensure that:

- consignments comply with Australian import requirements
- consignments are as described on the phytosanitary certificate and
- quarantine integrity has been maintained.

On arrival in Australia, the Department of Agriculture, Water and the Environment will:

– assess documentation to verify that the consignment is as described on the phytosanitary certificate, that required phytosanitary procedures have been undertaken, and that product security has been maintained

– verify that the biosecurity status of consignments of strawberry from Japan meet Australia's import conditions. When inspecting consignments, the department will use random samples of 600 units, or equivalent per phytosanitary certificate (or as goods are lodged) and inspection methods suitable for the commodity.

5.2.9 Remedial action(s) for non-compliance

The objectives of remedial action(s) for non-compliance are to ensure that:

- any quarantine pest or regulated article, including trash, is addressed by remedial action, as appropriate
- non-compliance with import requirements is addressed, as appropriate.

Any consignment that fails to meet Australia's import conditions will be subject to a suitable remedial treatment where an effective treatment is available and biosecurity risks associated with applying the treatment can be effectively managed, or the imported consignment will be exported or destroyed.

Other actions, including partial or complete suspension of the import pathway, may be taken depending on the identity and/or importance of the pest intercepted, for example, *Drosophila* species of economic importance.

In the event that strawberry consignments are repeatedly non-compliant, the Department of Agriculture, Water and the Environment reserves the right to suspend imports (either of all imports, or of imports from specific pathways), and to conduct an audit of the risk management systems. Imports will recommence only when the Department of Agriculture, Water and the Environment is satisfied that appropriate corrective action has been undertaken.

5.3 Uncategorised pests

If an organism that has not been categorised, including a contaminant pest, is reported on strawberries in Japan or detected on strawberries on arrival in Australia, it will require assessment by the Department of Agriculture, Water and the Environment to determine its quarantine status and whether phytosanitary action is required.

Assessment will also be made if the detected species was categorised as not likely to be on the import pathway. If the detected species was categorised as being on the pathway, but assessed as having an unrestricted risk that achieves the ALOP for Australia, then it may require reassessment. The detection of any pests of biosecurity concern not already identified in the analysis may result in remedial action and/or temporary suspension of trade while a review is conducted to ensure that management measures continue to provide the appropriate level of protection for Australia.

5.4 Review of processes

5.4.1 Verification of protocol

Prior to or during the first season of trade, the Department of Agriculture, Water and the Environment will verify the implementation of the required import conditions and phytosanitary measures including registration, operational procedures and treatment providers, where applicable. For example, for measures conducted pre-export, the department may require information about standard operating procedures (SOPs). This may involve representatives from the Department of Agriculture, Water and the Environment visiting areas in Japan that produce strawberries for export to Australia.

5.4.2 Review of policy

The Department of Agriculture, Water and the Environment will review the import policy after a suitable volume of trade has been achieved. In addition, the department reserves the right to review the import policy as deemed necessary, including if there is reason to believe that the pest or phytosanitary status in Japan has changed.

MAFF must inform the Department of Agriculture, Water and the Environment immediately on detection of any newly identified pests of strawberry that may be of potential biosecurity concern to Australia, or when the phytosanitary status of a pest has changed, in accordance with ISPM 8: *Determination of pest status in an area* (FAO 2017b).

5.5 Meeting Australia's food laws

Imported food for human consumption must comply with the requirements of the *Imported Food Control Act 1992*, as well as Australian state and territory food laws. Among other things, these laws require all food, including imported food, to meet the standards set out in the Australia New Zealand Food Standards Code (the Code).

The Department of Agriculture, Water and the Environment administers the *Imported Food Control Act 1992*. This legislation provides for the inspection and control of imported food using a risk-based border inspection program, the Imported Food Inspection Scheme. More information on this inspection scheme, including the testing of imported food, is available from the department's website at http://agriculture.gov.au/import/goods/food/inspection-compliance/inspection-scheme.

Food Standards Australia New Zealand (FSANZ) is responsible for developing and maintaining the Code, including Standard 1.4.2 - Agvet chemicals. This standard is available on the Federal Register of Legislation at https://www.legislation.gov.au or through the FSANZ website at http://www.foodstandards.gov.au/code/Pages/default.aspx.

Standard 1.4.2 and Schedules 20 and 21 of the Code set out the maximum residue limits (MRLs) and extraneous residue limits (ERLs) for agricultural or veterinary chemicals that are permitted in food, including imported food.

Standard 1.1.1 of the Code specifies that a food must not have, as an ingredient or a component, a detectable amount of an agvet chemical or a metabolite or a degradation product of the agvet chemical; unless expressly permitted by the Code.

Standard 1.5.3 of the Code stipulates the mandatory requirements where irradiation is applied as a phytosanitary measure, including the permitted fruit and vegetables, sources of irradiation, minimum and maximum absorbed doses, and the record keeping and labelling requirements for irradiated produce.

6 Conclusion

The findings of this final risk analysis report for fresh strawberry fruit from Japan are based on a comprehensive scientific analysis of relevant literature, and other avenues of enquiry.

The Department of Agriculture, Water and the Environment considers that the risk management measures recommended in this report will provide an appropriate level of protection against the quarantine pests and regulated thrips identified as associated with the trade of strawberries from Japan.

Appendix A: Initiation and categorisation for pests of fresh strawberry fruit from Japan

The table identifies pests that have the potential to be present on fresh strawberry fruit grown in Japan using standard commercial production and packing procedures, and to be imported into Australia.

The purpose of pest categorisation is to ascertain which of these pests require detailed assessment in order to determine whether phytosanitary measures are appropriate. The steps in the pest categorisation process are considered sequentially. The assessment terminates at 'Yes' for the third column (presence within Australia), except for pests that are present, but under official control and/or pests of regional concern. In cases where this does not apply, assessment terminates at the first 'No' in any of the following columns.

In the final column of the table (column 7) the acronyms 'EP' and 'WA' are used. The acronym EP (existing policy) is used for pests that had previously been assessed by Australia and for which import policy exists. The acronym 'WA' is used to identify organisms that have been recorded in some regions of Australia, but due to interstate quarantine regulations, are considered pests of regional concern to Western Australia.

The *Final group pest risk analysis for thrips and orthotospoviruses on fresh fruit, vegetable, cut-flower and foliage imports* (Australian Government Department of Agriculture and Water Resources 2017) has been applied in this risk analysis. Application of group policy involves identification of up to three species of each relevant group associated with the commodity pathway. However, if any other quarantine pests or regulated articles not included in this risk analysis and/or in the relevant group policies is detected at pre-export or on arrival in Australia, the relevant group policy will also apply.

The *Final pest risk analysis report for Drosophila suzukii* (Department of Agriculture 2013) has been applied in this risk analysis.

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

This is not a comprehensive list of all pests associated with the entire strawberry plant, and it does not include soil-borne pests and pathogens, or wood-borers, root pests and secondary pests, as these are not directly related to the export pathway of fresh fruit. Other pests that may occasionally be detected in trade, which are not specifically associated with strawberry fruit, are not considered here. Any such contaminant pests detected at the border are managed under existing standard operational procedures. It is important to note that any quarantine pests detected on arrival by quarantine inspections will be actioned appropriately, even if they have not been assessed in this report.

The department is aware of the recent changes in fungal nomenclature concerning the separate naming of sexual/asexual states of fungi. However, as the nomenclature for these fungi is in a phase of transition and many priorities of names are still to be resolved, this report uses the generally accepted names and provides alternatively used names as synonyms, where required. The department is also aware of the changes in nomenclature of arthropod species based on the latest morphological and molecular reviews. As official lists of accepted names become available, these names will be adopted.

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
ARTHROPODS						
Coleoptera						
Adoretus sinicus Burmeister, 1855 Synonym: *Adoretus tenuimaculatus* Waterhouse, 1875 [Scarabaeidae} Chinese rose beetle	Yes (UH-CTAHR Department of Entomology & Hawaii Department of Agriculture 2019)	No records found	No. Host plants of *Adoretus sinicus* include over 250 species. Major crops attacked include strawberry (UH-CTAHR Department of Entomology & Hawaii Department of Agriculture 2019). Larvae feed on roots and dead plant tissue in soil, and adults feed on leaves of an extensive number of hosts (Lee et al. 2002; McQuate & Jameson 2011). The large adult beetles (10 millimetres) feed at night and hide during the day under leaves, loose bark or in shallow soil. Females oviposit eggs in soil. Feeding damage is obvious creating a 'lace-like' appearance on leaves. (McQuate & Jameson 2011). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Altica fragariae (Nakane, 1955) [Chrysomelidae] Flea beetle	Yes (MAFF 2016)	No records found	No. Both adults and larvae feed on leaves of strawberry (Zhang, Ge & Yang 2007). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Anomala cuprea Hope, 1839 [Scarabaeidae] Cane white grubs	Yes (Arakaki et al. 2004; Dunlap et al. 2016; Tadauchi & Inoue 2006)	No records found	No. Larvae feed on roots of hosts including sugarcane, turf grasses, beans, sweet potato and peanuts. Adults feed on leaves and are nocturnal (Arakaki et al. 2004; Dunlap et al. 2016). In Japan *Anomala cuprea is* considered a severe pest of soybean, grape and strawberry (Leal, Sawada & Hasegawa 1993). A comprehensive list of hosts of adults in Japan is provided by Yoshida, Nishigaki and Aski (1971). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Anomala orientalis Burmeister, 1844 Synonym: *Blitopertha orientalis* (Waterhouse, 1875) [Scarabaeidae] Oriental beetle	Yes (Hinson 2014; Tadauchi & Inoue 2006)	No records found	No. *Anomala orientalis* eggs are laid in soil, larvae feed on roots of a variety of hosts including strawberry. Adults feed on grass and flowers of some plants, but are not considered to be serious pests (Dunlap et al. 2016; Hinson 2014). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Anthonomus bisignifer Schenkling, 1934 Synonym: *Anthonomus signatus* Kinoshita & Shinkai [Curculionidae] Strawberry weevil	Yes (MAFF 2016)	No records found	No. This species feeds on pollen (University of Illinois 2004). The female lays eggs on excavated strawberry flower buds (EPPO 2019) then damages the stem causing it to hang or fall to the ground preventing fruit development (Plantwise 2019; University of Illinois 2004). No records of association with mature strawberry fruit have been found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Anthonomus rubi (Herbst, 1795) [Curculionidae] Strawberry bud weevil	Yes (Kojima & Morimoto 2004)	No records found	No. This species feeds on young strawberry leaves, flower buds and pollen from open flowers (Aasen 2001). The female lays eggs within flower buds (Aasen 2001; EPPO 2019). Damage caused by oviposition causes flower buds to cease development which reduces subsequent fruit development (Aasen 2001). No records of association with mature strawberry fruit have been found.	Assessment not required	Assessment not required	No
Basilepta fulvipes (Motschulsky, 1860) Synonym: *Nodostoma fulvipes* Motschulsky, 1860 [Chrysomelidae] Golden green minute leaf beetle	Yes (Chujo & Kimoto 1961; JSAEZ 1987)	No records found	No. This species damages corn, millet, soybeans, peanuts, cotton, banana and tea in China (Lu et al. 2015). A single report was found for *Basilepta fulvipes* on strawberries (Chujo & Kimoto 1961). No other records of association with strawberry were found.	Assessment not required	Assessment not required	No
Carpophilus hemipterus (Linnaeus, 1785) [Nitidulidae] Dried fruit beetle	Yes (JSAEZ 1987)	Yes. NSW, NT, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Carpophilus humeralis (Fabricius, 1781) [Nitidulidae] Pineapple sap beetle	Yes (Hayashi 1978)	Yes. NSW, NT, Qld, SA, Vic, WA (James, Faulder & Bartelt 1995; James et al. 2000; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Ceutorhynchus typhae (Herbst, 1795) [Curculionidae]	Yes (Encyclopedia of Life 2019)	No records found	No. *Ceutorhynchus typhae* feeds mainly on seeds of non-cultivated wild cruciferous species (Toshova, Subchev & Tóth 2009). This species has only been sampled from strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013). No other records of association with strawberry have been found.	Assessment not required	Assessment not required	No
Chaetocnema concinna (Marsham, 1802) [Chrysomelidae] Mangold flea beetle	Yes (Honma & Akiyama 1981)	No records found	No. Eggs are laid in soil at the base of host plants, larvae tunnel into roots to feed. Adults feed on leaves of a wide range of hosts, including strawberry (Lesage & Majka 2010; Petrova, Jankevica & Samsone 2013; Westcott et al. 2006). Feeding damage by adults is described as numerous small holes bordered by a narrow line of brown leaf tissue (Lesage & Majka 2010). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Cleoporus variabilis Baly, 1874 [Chrysomelidae] Variable leaf beetle	Yes (GBIF Secretariat 2019)	No records found	No. There is little information available on this species. Other species in the family Chrysomelidae have been known to feed on fruit, flowers and foliage (Erichsen, McGeoch & Schoeman 1993; Gök, Gül Alsan & Aslam 2005; Murray 1982; Waterson & Urquhart 1995) however, *Cleoporus variabilis* has only been found on strawberry leaves in Korea (QIA 2015). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Compsapoderus erythrogaster (Snelle van Vollenhoven, 1865) Synonym: *Apoderus erythrogaster* Snelle van Vollenhoven, 1865 [Attelabidae] Leaf-rolling weevil	Yes (JWDB 2019)	No records found	No. There is little specific information available on *Compsapoderus erythrogaster*. One study recorded feeding on foliage of broad-leaved plants, including that of strawberry (Isagi 1987; QIA 2015). Leaf-rolling species in this family make a 'cradle' out of leaves in which they lay their eggs (Park, Lee & Park 2012). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Galerucella grisescens (Joannis, 1865) [Chrysomelidae] Strawberry leaf beetle	Yes (MAFF 2016)	No records found	No. The female lays its eggs on the stem and leaves of the plant; pupae attach themselves to plant tissue. Both adults and larvae feed externally on foliage (Manguin et al. 1993). Although *Galerucella grisescens* can complete its life cycle on strawberry plants, in no-choice tests adults preferred not to lay eggs and larvae developed slowly (Pan et al. 2000). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Galerucella viridipennis Jacoby, 1885 [Chrysomelidae] Strawberry leaf beetle	Yes (Chujo & Kimoto 1961)	No records found	No. This species feeds on leaves of strawberry (Hori, Ohuchi & Matsuda 2006). The related species *Galerucella sagittariae* is also a pest of strawberry. Eggs are laid on the underside of leaves and leaf petioles. Larvae feed on the leaves before pupating in the soil (Alford 2007). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Longitarsus parvulus (Paykull, 1799) [Chrysomelidae] Strawberry leaf beetle	Yes (Chujo & Kimoto 1961)	No records found	No. *Longitarsus parvulus* is listed as a pest of flax, *Linum* (Bukejs 2010). This species has only been sampled from strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013). No other records of association with strawberry were found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Longitarsus suturellus (Duftschmid, 1825) [Chrysomelidae] Strawberry leaf beetle	Yes (Chujo & Kimoto 1961)	No records found	No. In a paper on the genus *Longitarsus* in Latvia, (Bukejs 2010) does not list strawberry as a host. This species has only been seen on strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013). No other records of association with strawberry were found.	Assessment not required	Assessment not required	No
Monolepta dichroa Harold, 1877 [Chrysomelidae]	Yes (Chujo & Kimoto 1961; MAFF 2016)	No records found	No. There is little information available on *Monolepta dichroa*. It is reported as a pest of strawberries and many cultivated and wild plants (Chujo & Kimoto 1961; MAFF 2016). Species of *Monolepta* are known to feed on fruit, flowers and foliage of their hosts, including avocado, citrus, macadamia and mango (Erichsen, McGeoch & Schoeman 1993; Gök, Gül Alsan & Aslam 2005; Murray 1982). The resulting damage has been described as rendering fruit unmarketable, and therefore unlikely to be harvested.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Monolepta quadriguttata Motschulsky, 1860 [Chrysomelidae]	Yes (Chujo & Kimoto 1961)	No records found	No. There is little information available on *Monolepta quadriguttata*. It is a serious pest of soybean (Bieńkowski & Orlova-Bienkowskaja 2018) and has only been reported on strawberry in Korea (QIA 2015). Species of *Monolepta* are known to feed on fruit, flowers and foliage of their hosts, including avocado, citrus, macadamia and mango (Erichsen, McGeoch & Schoeman 1993; Gök, Gül Alsan & Aslam 2005; Murray 1982). The resulting damage has been described as rendering fruit unmarketable, and therefore unlikely to be harvested.	Assessment not required	Assessment not required	No
Otiorhynchus sulcatus (Fabricius, 1775) [Curculionidae] Black vine weevil	Yes (JSAEZ 1987; Tadauchi & Inoue 2006)	Yes. ACT, NSW, SA, Tas, Vic (Plant Health Australia 2019) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019)	No. Adults of this species feed on buds, leaves and flowers nocturnally; larvae attack roots of hosts including strawberry (Bentley et al. 2009; Fisher 2006; Moorhouse, Charnley & Gillespie 1992). Adults hide in the soil during the day (Moorhouse, Charnley & Gillespie 1992).	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Phyllotreta striolata Fabricius, 1801 [Chrysomelidae] Cabbage flea-beetle / striped flea beetle	Yes (Chujo & Kimoto 1961)	No records found	No. *Phyllotreta striolata* larvae feed on roots. The adults feed on the stem and foliage of cruciferous crops, as well as the pods of *Brassicae* (Hoffmann, Hoebeke & Dillard 2011; Wylie 1979). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Popillia japonica Newman, 1838 [Scarabaeidae] Japanese beetle	Yes (MAFF 2016)	No records found	No. *Popillia japonica* is highly polyphagous; hosts include strawberry (EPPO 2019; Ladd 1989). Eggs are laid in the soil and larvae feed on roots of host plants. Adults feed on foliage, flowers and fruits (EPPO 2019). Adults form aggregations and chew tissue between leaf veins resulting in extensive damage. It is unlikely to be on commercially harvested strawberry fruits as adult beetles are visually obvious and damage is evident.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Pseudocneorhinus bifasciatus (Roelofs, 1880) [Curculionidae] Two banded Japanese weevil	Yes (TISI 2019)	No records found	No. Larvae feed on roots and adults on leaves of host plants, including strawberry. Females fold and glue leaves and lay eggs in the fold (Gyeltshen & Hodges 2016; TISI 2019). *Pseudocneorhinus bifasciatus* adults are easily disturbed, dropping from infested plants (TISI 2019). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Rhinoncus bruchoides (Herbst, 1784) [Curculionidae]	Yes (GBIF Secretariat 2019)	No records found	No. This species has only been sampled from strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova et al. 2005; Petrova, Jankevica & Samsone 2013). No other records of association with strawberry have been found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Sitona lineatus (Linnaeus, 1758) [Curculionidae] Pea leaf weevil	Yes (GBIF Secretariat 2019)	No records found	No. Hosts include peas, legume crops and grasses (TISI 2019). *Sitona lineatus* has also been reported on strawberries but is not concidered as a strawberry pest (Alford 2007; Petrova, Jankevica & Samsone 2013). Eggs are laid in soil, larvae feed on roots and adults on leaves and flowers (Alford 2007). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Synuchus arcuaticollis (Motschulsky, 1860) [Carabidae] Ground beetle	Yes (MAFF 2016)	No records found	No. Carabid beetles are abundant in agricultural settings worldwide. They are also used as bioindicator species (Kikas & Luik 2004). Most carabid inhabit soil and litter layers, are predatory and feed on fallen leaves and other insects (Hong et al. 2017). No records of association with mature strawberry fruit have been found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Tychius picirostris (Fabricius, 1787) [Curculionidae] Clover seed weevil	Yes (GBIF Secretariat 2019)	Absent (PaDIL 2018)	No. Main host is *Trifolium* spp. (BugGuide 2019) (CABI 2019).This species has only been sampled from strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013). No other records of association with strawberry were found.	Assessment not required	Assessment not required	No
Collembola						
Bourletiella hortensis (Fitch, 1863) [Bourletiellidae] Garden springtail	Yes (BugGuide 2019)	Yes. Tas, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Diptera						
Bradysia impatiens (Johannsen, 1912) Synonyms: *Bradysia difformis* Frey, 1948; *Bradysia agrestis* Sasakawa*,* 1978 [Sciaridae] Black fungus gnat	Yes (Menzel, Smith & Colauto 2003)	Yes. NSW, NT, Qld, SA, Tas., Vic., WA (ABRS 2019; Broadley, Kauschke & Mohrig 2018).	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Drosophila pulchrella Tan, Hsu & Sheng, 1949 [Drosophilidae] Drosophilid fly	Yes (Sasaki & Abe 1993; Tochigi Prefecture Agricultural and Environmental Training Centre 2018)	No records found	Yes. *Drosophila pulchrella* is reported for the first time on strawberries in Japan (Tochigi Prefecture Agricultural and Environmental Training Centre 2018)	Yes. *Drosophila pulchrella* adults are capable of sustained flight to locate host material (Coyne, Bryant & Turelli 1987). Suitable climatic conditions can be found in some areas of Australia (Bureau of Meteorology 2018) along with host material (AVH 2018).	Yes. This species is reported to attack strawberries, cherries, blueberries and *Rubus* berries (Sasaki & Sato 1995b). These horticultural crops are grown commercially in Australia.	**Yes**
Drosophila simulans Sturtevant, 1919 [Drosophilidae] Vinegar fly	Yes (Mito & Uesugi 2004; Tadauchi & Inoue 2006)	Yes. NSW, Qld, Tas, Vic, WA (Evenhuis 2007; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Drosophila subpulchrella Takamori & Watabe, 2006 [Drosophilidae] Drosophilid fly	Yes (Takamori et al. 2006)	No records found	Yes. *Drosophila subpulchrella* has a serrated ovipositor similar to *D. pulchrella* and *D. suzukii* and attacks ripe fruits (Atallah et al. 2014; Takamori et al. 2006). Although this species has not been reported on strawberries, it shares a similar host range to *D. pulchrella,* including cherries, blueberries and *Rubus* (Atallah et al. 2014; Girod et al. 2018; Mitsui, Beppu & Kimura 2010).	Yes. *Drosophila subpulchrella* adults are capable of sustained flight to locate host material (Coyne, Bryant & Turelli 1987). Suitable climatic conditions can be found in some areas of Australia (Bureau of Meteorology 2018) along with host material (AVH 2018).	Yes. This species is reported to attack *Prunus*, blueberry, *Rubus* and cherry (Atallah et al. 2014; Girod et al. 2018; Mitsui, Beppu & Kimura 2010). These horticultural crops are grown commercially in Australia.	**Yes**
Drosophila suzukii (Matsumura, 1931) [Drosophilidae] Spotted wing drosophila	Yes (JSAEZ 1987; Kanzawa 1936)	No records found	A pest risk assessment for *Drosophila suzukii* will not be conducted in this risk analysis report for strawberries from Japan. There is existing policy for *D. suzukii* for all commodities, including strawberries, from all countries (Department of Agriculture 2013). Further information on existing policy can be found in the '*Final pest risk analysis report for Drosophila suzukii*' (Department of Agriculture 2013).			

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Ensina sonchi (Linnaeus, 1767) [Tephritidae]	Yes (Kütük 2008)	No records found	No. Larvae infest flowerheads of hosts of the Asteraceae family (Kütük 2008). This species has only been sampled from strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013). No other records of association with strawberry were found.	Assessment not required	Assessment not required	No
Psila nigricornis (Meigen, 1826) Synonym: *Chamaepsila nigricornis* (Meigen, 1826) [Psillidae] Chrysanthemum root fly	Yes (Iwasa 1991)	No records found	No. Eggs are laid in soil and larvae feed on roots and first few inches of stems of chrysanthemum (Barlow 2008). This species has only been sampled from strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013). No other records of association with strawberry were found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Hemiptera						
Adelphocoris lineolatus (Goeze 1778) [Miridae] Alfalfa plant bug	Yes (Yasunaga 1990)	No records found	No. *Adelphocoris lineolatus* has been recorded on strawberries but is most commonly associated with alfalfa (Pansa & Tavella 2009; Petrova, Samsone & Jankevica 2010; Yasunaga 1990). Eggs are laid on stems and petioles of host plants (CABI 2019). Nymphs use piercing and sucking mouthparts to feed on plant tissues also injecting toxic saliva which damages the feeding area (CABI 2019; Ministry of Agriculture 2009). Nymphs and adults are easily disturbed and difficult to catch (Ministry of Agriculture 2009). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Adelphocoris quadripunctatus (Fabricius, 1794) [Miridae] Mirid bugs	Yes (Yasunaga 1990)	No records found	No. There is limited information available on *Adelphocoris quadripunctatus*. Nymphs and adults feed on legumes and sometimes grasses (BugGuide 2019). Its biology and feeding behaviour is similar to *A. lineolatus*. This species has only been sampled from strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013). No other records of association with strawberry have been found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Aguriahana triangularis (Matsumura, 1932) [Cicadellidae] Leafhopper	Yes (MAFF 2016)	No records found	No. *Aguriahana triangularis* is recorded as a pest of strawberry plants (Dmitriev 2013). There is little information on *A. triangularis* but other species in the genus are known to feed on leaves causing obvious damage and discoloration (Alford 2007; Vollenweider & Günthardt-Goerg 2005). Cicadellidae are active plant bugs; adults have hind legs adapted for jumping; nymphs mainly occur on the underside of leaves and scurry away if disturbed (Alford 2007). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Aphis forbesi Weed, 1889 [Aphididae] Root aphid	Yes (MAFF 2016)	Recently detected in WA (DPIRD 2018)	No. Eggs of *Aphis forbesi* are laid on the pedicels of flowers or the underside of strawberry leaves (Marcovitch 1925). Nymphs puncture the developing leaves feeding on leaf sap and secreting honeydew. This attracts ants which carry nymphs to roots where adult aphids feed on sap (Alford 2007; INRA 2019; Marcovitch 1925; Minnesota Department of Agriculture 2015). This species lives in the crown and petioles of strawberry and is a vector of *Strawberry crinkle virus* (Araujo et al. 2016). *Strawberry crinkle virus* is present and widespread in Australia (CABI 2019; Constable et al. 2010; McLean & Price 1984). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Aphis gossypii Glover, 1877 [Aphididae] Cotton aphid / melon aphid	Yes (MAFF 2016)	Yes. NSW, NT, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019; Poole 2010) Because *A. gossypii* is a vector of Strawberry pseudo mild yellow edge virus (which is absent from Australia but is present in Japan) (Martin & Tzanetakis 2006; Yoshikawa & Inouye 1988), the potential to be on the pathway needs to be assessed.	No. *Aphis gossypii* feed on the underside of leaves, or on the growing tips of vines, sucking nutrients from the plant (Capinera 2009). *Aphis gossypii* cluster on the underside of growing leaves, distorting and curling the leaves. A large amount of honeydew is produced (Natwick, Stapleton & Stoddard 2012). *Aphis gossypii* will attack most parts of the plant if population density is high enough, although exceptions include direct feeding on mature reproductive structures (fruits, berries, nuts) and feeding on roots (CABI 2019). Different life stages of this pest may be associated with the calyx and peduncle. However, these life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Aphrodes bicinctus (Schrank, 1776) [Cicadellidae] Strawberry leafhopper	Yes (Hayashi 1996)	No records found	No. Eggs are laid on the surface of soil or in petioles of leaves. Nymphs and adults feed on host plants at or near ground level (Alford 2007; Chiykowski 1970). Feeding damage is unimportant but *Aphrodes bicinctus* vectors Strawberry green petal (Alford 2007; Chiykowski 1970). Strawberry green petal is present in Australia (Padovan, Gibb & Persley 2000; Streten et al. 2005) and is not under official control. No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Aulacorthum solani (Kaltenbach, 1843) [Aphididae] Foxglove aphid	Yes (MAFF 2016)	Yes. ACT, NSW, Qld, SA, Tas, Vic, WA (Berlandier 1997; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Chaetosiphon fragaefolii (Cockerell, 1901) [Aphididae] Strawberry aphid	Yes (MAFF 2016)	Yes. NSW, Qld, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Chaetosiphon minor Forbes, 1884 [Aphididae] Berry aphid / strawberry capitophorus aphid	Yes (MAFF 2016)	No records found	No. *Chaetosiphon minor* adults and nymphs feed on the underside of young leaves and petioles producing sticky honeydew (Williams & Rings 1980). They are not associated with fruits. This pest is of economic importance as a vector of strawberry viruses (Blackman & Frazer 1987; Williams & Rings 1980). The related species *Chaetosiphon fragaefolii* transmits *Strawberry crinkle virus* and *Strawberry mild yellow edge virus* (Alford 2007). *Strawberry crinkle virus* is present and widespread in Australia (CABI 2019; Constable et al. 2010; McLean & Price 1984). *Strawberry mild yellow edge virus* is also present and widespread in Australia (Brunt et al. 1996b; EPPO 2019).	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Dolycoris baccarum (Linnaeus, 1758) [Pentatomidae] Seed sucking bug / sloe bug	Yes (JSAEZ 1987)	No records found	No. *Dolycoris baccarum* is reported as a pest of strawberries; feeding damages fruit causing malformation in addition to an obnoxious odour (Alford 2007). In Japan it is reported on soybeans, cotton, sesame, carots, burdock and rice (Nakamura & Numata 2006). Adults and nymphs are highly mobile and unlikely to remain on fruits during harvest.	Assessment not required	Assessment not required	No
Elymana sulphurella (Zetterstedt, 1828) [Cicadellidae]	Yes (Kamitani 1997)	No records found	No. This genus is restricted to grasses and appears to include mostly host-specialist species (Dietrich 1999). This species has only been sampled from strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013). No other records of association with strawberry have been found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Empoasca nipponica Dworakowska, 1982 Synonym: *Asymmetrasca nipponica* (Dworakowska, 1982) [Cicadellidae] Persimmon leafhopper	Yes (MAFF 2016)	No records found	No. Host range of *Empoasca nipponica* includes persimmon, pears, cowpea, dahlia and hydrangea. Leaves of grapes, watermelons and potatoes are also damaged. Affected fruits display minute black spots (Taguchi et al. 1998). Within Japan's technical market access submission MAFF has listed *Empoasca nipponica* as a pest of strawberries in Japan (MAFF 2016). No records of association with strawberry fruit have been found, however, different life stages of this this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway. In addition, damage to fruits is obvious and would not be harvested for export.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Evancanthus interruptus (Linnaeus, 1785) [Cicadellidae]	Yes (Okudera & Ohara 2014)	No records found	No. *Evancanthus interruptus* eggs are laid in dead wood (for example stumps and fence posts), the nymphs feed on the underside of the leaves of hops and other hosts (Alford 2007). This species has only been sampled from strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013).	Assessment not required	Assessment not required	No
Eysarcoris aeneus (Scopoli, 1763) [Pentatomidae] New forest shieldbug / rice stink bug	Yes (MAFF 2016)	No records found	No. In Asia *Eysarcoris aeneus* feeds on rice (Kiritani 2007; Tsueda et al. 2002). It is associated with heathland, grasslands and woodland where the weed *Hypericum pulchrum* is the only recorded host plant. However, associated plants in Britian include *Leonurus*, *Marrubium*, *Trifolium*, *Fragaria* and *Rosa* and species of *Lamiaceae* (Bantock 2016). No other records of association with strawberry have been found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Halyomorpha halys (Stål, 1855) [Pentatomidae] Brown marmorated stink bug	Yes (MAFF 2016)	No records found	No. This species is highly polyphagous. Feeding occurs on leaves, shoots, stems, fruit and seeds (Department of Agriculture and Water Resources 2017; Martinson et al. 2015). Adults and nymphs are highly mobile and unlikely to remain on fruit during harvesting.	Assessment not required	Assessment not required	No
Macrosiphum euphorbiae (Thomas, 1878) [Aphididae] Potato aphid	Yes (MAFF 2016)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (Hollis & Eastop 2005) (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Macrosteles fascifrons Stål, 1858 [Cicadellidae] Six-spotted leafhopper	Yes (Shiomi & Sugiura 1983)	No records found	No. Leafhoppers feed exclusively on leaf sap (Ishii et al. 2013). *Macrosteles fascifrons* has been reported to transmit strawberry witches' broom in Japan (Shiomi & Sugiura 1983). Strawberry witches' broom ("*Candidatus* Phytoplasma asteris") is assessed separately below. Leafhoppers are highly mobile and easily disturbed. In addition, no records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Macrosteles striifrons Anufriev, 1968 Synonym: *Macrosteles orientalis* Vilbaste, 1968 [Cicadellidae] Leafhopper	Yes (MAFF 2016)	No records found	No. Leafhoppers feed exclusively on leaf sap (Ishii et al. 2013). *Macrosteles striifrons* has been reported to transmit strawberry witches' broom in Japan (Maejima, Oshima & Namba 2014; Shiomi & Sugiura 1983). Strawberry witches' broom ("*Candidatus* Phytoplasma asteris") is assessed separately below. Leafhoppers are highly mobile and easily disturbed. In addition, no records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Myzus persicae Sulzer, 1776 [Aphididae] Green peach aphid / peach curl aphid	Yes (MAFF 2016)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (Martyn & Miller 1963; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Nysius plebejus Distant, 1883 [Lygaeidae] Milkweed bug	Yes (MAFF 2016)	No records found Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019)	No. *Nysius* species feed by piercing plant tissue with their mouthparts, and have been observed feeding on strawberries, causing discolouration and wilting (Dara 2012). *Nysius plebejus* has been recorded as a pest of strawberry; eggs are laid in masses on the surface of leaves or stems of host plants (Schaefer & Panazzi 2000). This may include the calyx and peduncle. However, as the eggs are laid in masses they would be easily identified on commercial fruit during quality checks. In Japan, only adults are present over winter (Schaefer & Panazzi 2000). There is little other specific information on this species; however, adults and nymphs are likely to be disturbed and move away from fruit during harvest, and symptoms of plant damage during high-density infestation are likely to be noticed during harvest.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Orthops kalmii (Linnaeus, 1758) Synonym: *Lygus kalmii* Linnaeus, 1758 [Miridae] Lygus bug	Yes (Kuwayama, Kuribayashi & Oshima 1925)	No records found	No. *Orthops kalmii* is usually associated with crops and weeds in the Umbelliferae/Apiaceae family (Hosseini 2014; Petrova, Samsone & Jankevica 2010). *Orthops kalmii* has only been associated with strawberries in Lativa, and at very low levels (Petrova, Samsone & Jankevica 2010). There are no reports of *O. kalmii* associated with strawberries in Japan.	Assessment not required	Assessment not required	No
Orthotylus flavosparsus (Sahlberg, 1841) [Miridae]	Yes (Jung, Kim & Duwal 2017; Yasunaga 1999)	No records found	No. This species has only been seen on strawberries in Latvia and is not listed as a strawberry pest or a potential strawberry pest (Petrova, Jankevica & Samsone 2013). No other records of association with strawberry have been found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Philaenus spumarius Linnaeus, 1758 [Cercopidae] Meadow froghopper / meadow spittlebug	Yes (JSAEZ 1987)	No. There is one record from 1996 in Qld but this was an international interception (Plant Health Australia 2019) It is recognised that this species is absent from Australia (CABI 2019)	No. Nymphs feed at the base of the strawberry plants, but later move to developing tender leaves. This feeding causes leaf distortion and stunted growth of berries (Brust 2011; Spangler, Agnello & Schaefers 1988). Occasionally they also feed on strawberry fruits. Presence of spittlebugs can be recognised by the white masses of foam found on leaves, petioles and stems of the plants, and adults are very active and readily jump when disturbed (Brust 2011). This species is unlikely to be associated with commercially produced strawberry fruit.	Assessment not required	Assessment not required	No
Plagiognathus arbustorum (Fabricius, 1794) [Miridae]	Yes (GBIF Secretariat 2019)	No records found	No. *Plagiognathus arbustorum* is mainly a predatory species, but also found in orchards and associated with soft fruits including strawberries (Alford 2007). Eggs are laid in leaf stalks; in laboratory tests adults preferentially fed on flowers and fruits resulting in deformed fruits (Taksdal & Sørum 1970). Adults and nymphs are highly mobile and would be likely to fall from the fruit during harvesting. In addition, fruit damaged by *P. arbustorum* becomes distorted and would not be harvested.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Planococcus citri (Risso, 1813) [Pseudococcidae] Citrus mealybug	Yes (MAFF 2016)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (García Morales et al. 2019; Plant Health Australia 2019; Smith, Beattie & Broadley 1997)	Assessment not required	Assessment not required	Assessment not required	No
Plautia stali Scott, 1874 [Pentatomidae] Brown winged green bug	Yes (MAFF 2016; Panizzi et al. 2000)	No records found	No. This species attacks a variety of fruit trees and plants including strawberry in Japan. Fruit is mostly attacked near ripening or when ripe causing obvious blemishing and internal damage (Panizzi et al. 2000). In Japan, adults diapause over winter triggered by short-day length and juvenile hormone (Numata 2004; Panizzi et al. 2000). If present, this species would be likely to be removed from the pathway during harvesting and processing of fruit.	Assessment not required	Assessment not required	No
Rhodobium porosum (Sanderson, 1990) [Aphididae] Yellow rose aphid	Yes (MAFF 2016)	Yes. SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Riptortus clavatus (Thunberg, 1783) [Alydidae] Bean bug	Yes (MAFF 2016)	No records found	No. This species is not known to occur on strawberries. Hosts are members of Fabaceae including soybean, common bean and cow pea as well as persimmon (Ikeura & Kuroda 2013; Son, Yun & Park 2009). Although there are reports of eggs laid on non-host plants (Son, Yun & Park 2009), Ikeura and Kuroda (2013) showed that females can distinguish between host and non-host plants, and preferentially lay on host plants.	Assessment not required	Assessment not required	No
Riptortus pedestris (Fabricius, 1775) [Alydidae] Bean bug	Yes (Kim et al. 2015b; Suzaki et al. 2015)	No records found	No. This species is not known to occur on strawberries. Hosts include legumes and grains (Lim et al. 2015). Adults feed on persimmon fruits but it is not a suitable host with no reproduction occurring (Lim et al. 2015). However, females are known to lay eggs on non-host plants. Under these circumstances the nymph can only develop to second instar and must find an appropriate host in order to survive (Tabuchi, Moriya & Ishizaki 2007).	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Sitobion avenae (Fabricius, 1775) Synonym: *Macrosiphum akebiae* Shinji, 1935 / *Sitobion akebiae* (Shinji, 1935) [Aphididae] Grain aphid	Yes (Choe, Lee & Lee 2006; MAFF 2016)	No (Weppler 2009)	No. This species is not known to occur on strawberries. Adults feed on foliage, seedlings and panicles of grains. Hosts are members of the Poaceae family (Weppler 2009).	Assessment not required	Assessment not required	No
Trialeurodes packardi (Morrill, 1903) [Aleyrodidae] Strawberry whitefly	Yes (MAFF 2016)	No records found	No. Eggs are laid on the underside of leaves. Once hatched, sessile nymphs puncture the leaf tissue feeding on leaf sap. Nymphs secrete honeydew almost always resulting in sooty mould growing on the plant (Burrack 2014; Picha 1999; Rao & Welter 1997; Zalom et al. 2014). The presence of honeydew and sooty mould are obvious symptoms and would require pest management. It is unlikely sessile nymphs or adults would be associated with mature commercially produced strawberry fruits; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway..	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Trialeurodes vaporariorum (Westwood, 1956) [Aleyrodidae] Greenhouse whitefly	Yes (MAFF 2016)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Hymenoptera						
Allantus albicinctus (Matsumura, 1912) [Tenthredinidae] Strawberry sawfly	Yes (Hill 1987; MAFF 2016)	No records found	No. Little is known of the hosts and habits of species of the family Tenthredininae. Adults are commonly found on flowers where they feed on pollen and other insects. All members of the family are external leaf feeders. Eggs are laid in slits made in leaves of hosts. Larvae are often confused with lepidopteran larvae (Hill 1987; Smith 1993). Feeding damage on leaves is visually obvious. No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Cladius pectinicornis (Geoffroy, 1785) [Tenthredinidae] Strawberry sawfly	Yes (Kamijo 1994)	No records found	No. Sawfly larvae feed on leaves of hosts including strawberry. Eggs are laid singly in leaf stalks and larvae feed on underside of leaves (Alford 2007). Larvae are often confused with lepidopteran larvae (Hill 1987; Smith 1993). Feeding damage on leaves is visually obvious. No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Lepidoptera						
Acleris comariana (Lienig & Zeller, 1846) [Tortricidae] Strawberry tortrix	Yes (MAFF 2016)	No records found	No. Eggs are laid on stipules or petioles and larvae feed on leaves or flowers. On strawberry, flower feeding leads to development of distorted fruits developing (Gilligan et al. 2017; Turner 1968). No records of association with mature strawberry fruit have been found.	Assessment not required	Assessment not required	No
Agrotis ipsilon (Hufnagel, 1766) [Noctuidae] Black cutworm	Yes (JSAEZ 1987; Mizukoshi 1999)	Yes. ACT, NSW, NT, Qld, SA, Tas, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Agrotis segetum (Denis and Schiffermuller, 1775) [Noctuidae] Turnip moth	Yes (Tadauchi & Inoue 2006)	No records found	No. *Agrotis* cutworms feed on buds, shoots and stalks of strawberry, and only at night. During the day they hide in soil or litter (Lucidcentral 2017). Harvest of strawberry fruits occurs in the morning hours.	Assessment not required	Assessment not required	No
Archips breviplicanus (Walsingham, 1900) Synonym: *Archips breviplicana* Walsingham, 1900 [Tortricidae] Asiatic leafroller	Yes (Meijerman & Ulenberg 2000)	No records found	No. Larvae feed on lower surface of leaves, buds and the surface of fruit in contact with leaves. They diapause over winter, triggered by short day length, in shelters spun from leaves and bark (Meijerman & Ulenberg 2000). Therefore, they are unlikely to be found on strawberry fruit, and damaged fruit would be noticed and unlikely to be picked during harvest.	Assessment not required	Assessment not required	No
Archips fuscocupreanus Walsingham 1900 Synonym: *Archips fuscocupreana* Walsingham 1900 [Tortricidae] Apple tortrix	Yes (BugGuide 2019)	No records found	No. Young larvae feed on developing leaves. Older larvae eat flowers and may graze on developing fruit (CABI 2019). Eggs are laid on trunks and limbs of trees (Gilligan et al. 2017). Not a pest of mature fruit (CABI 2019).	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Choristoneura lafauryana (Ragonot, 1875) Synonym: *Cornicacoecia lafauryana* Ragonot, 1875 [Tortricidae] Gray tortrix	Yes (MAFF 2016)	No records found	No. Reported to be a minor pest in strawberries in Europe. Larvae feed on the apical leaves of shoots and graze on fruit superficially (Meijerman & Ulenberg 2000). Eggs are laid on upper surface of leaves. Adults rest in foliage during the day and are easily disturbed (Bland, Hancock & Razowski 2014); however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Cnephasia stephensiana (Doubleday, 1849) [Tortricidae] Gray tortrix	Yes (MAFF 2016)	No records found	No. Larvae are pests of cultivated plants in gardens and glasshouses, feeding on leaves and flowers (Meijerman & Ulenberg 2000). This pest is polyphagous recorded on more than 120 species of plant, including strawberry (CDFA (California Department of Food and Agriculture) 2017; Petrova, Jankevica & Samsone 2013). First instar larvae mine leaves. Later instars live inside leaves spun together and can also feed on flowers. Damage to hosts is limited to the larval stage (CDFA (California Department of Food and Agriculture) 2017). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Helicoverpa armigera (Hubner, 1808) [Noctuidae] Cotton bollworm	Yes (MAFF 2016)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (ABRS 2019; CSIRO 2004; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Lamoria glaucalis Caradja, 1925 [Pyralidae] Snout moth	Yes (MAFF 2016)	No records found	No. Within Japan's technical market access submission MAFF has listed *Lamoria glaucalis* as a pest of strawberries in Japan (MAFF 2016). There is very limited information regarding the biology and hosts of *Lamoria glaucalis*. Species from the genus have been reared out on fruit in both Kenya and Papua New Guinea but the type of fruit was not specified (Sam et al. 2017). The subtribe Galleriinae is most noted for its members that feed on grains/seeds of agricultural crops and combs of hymenopteran nests (Munroe & Solis 1999; Solis 1997). The larvae of species that feed on plants are either external feeders or concealed feeders folding, rolling or webbing leaves together (Solis 1997). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Mamestra brassicae (Linnaeus, 1758) [Noctuidae] Cabbage moth	Yes (MAFF 2016)	No records found	No. Within Japan's technical market access submission MAFF has listed *Mamestra brassicae* as a pest of strawberries in Japan (MAFF 2016). Early instar *Mamestra brassicae* larvae feed on foliage. Later instars may bore into fruits but damage is obvious due to size of hole and frass left near the entry. The larvae grow up to 50 millimetres in length (CABI 2019). Damaged fruit would be noticed and unlikely to be picked during harvest.	Assessment not required	Assessment not required	No
Pandemis heparana (Denis & Schiffermüller, 1775) [Tortricidae] Apple brown tortrix / dark fruit-tree tortrix	Yes (MAFF 2016)	No records found	No. Within Japan's technical market access submission MAFF has listed *Pandemis heparana* as a pest of strawberries in Japan (MAFF 2016). Eggs are laid on the surface of leaves and larvae feed on flowers, fruitlets, young shoots and leaves. Larvae may graze on the surface of ripening fruit of a variety of plants (Alford 2007; Hill 1987; Meijerman & Ulenberg 2000; Yasuda 1972). Damaged fruit would be noticed and unlikely to be picked during harvest.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Peridroma saucia (Hubner, 1808) [Noctuidae] Black variegated cutworm	Yes (CABI 2019).	No records found	No. Reported on strawberry in Chile (Klein Koch & Waterhouse 2000). Adult females oviposit on the ground or on the leaves of weeds. Upon hatching, larvae feed on the leaves of hosts and fully grown larvae overwinter in the soil (Kuang 1985). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Sparganothis pilleriana (Denis & Schiffermuller, 1775) [Tortricidae]	Yes (MAFF 2016)	No records found	No. On strawberry, eggs are laid on leaves close to soil; larvae feed on shoot tips, leaves, inflorescences and fruit and cause reduction of fruiting (Alford 2007; Pykhova 1968; Schmidt-Tiedemann et al. 2001). The main host is grape but other hosts include strawberry. Larvae are up to 30 millimetres long, form silken shelters and can damage fruitlets at any stage (Alford 2007). The size of larvae mean they would be easily detected during harvesting and processing.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Spodoptera exigua (Hubner, 1808) [Noctuidae] Beet armyworm	Yes (MAFF 2016)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Spodoptera litura (Fabricius, 1775) [Noctuidae] Cotton cutworm	Yes (MAFF 2016)	Yes. ACT, NSW, NT, Qld, Tas, Vic, WA (ABRS 2019; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Viminia rumicis (Linnaeus, 1758) Synonym: *Acronicta rumicis* (Linnaeus, 1758) [Noctuidae] Knot grass moth	Yes (MAFF 2016)	No records found	No. The larvae feed on leaves and stems of its host plants. (Doremi 2017). No records of association with strawberry fruit have been found; however, different life stages of this pest may be associated with the calyx and peduncle. These life stages would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No
Thysanoptera						
Frankliniella fusca (Hinds, 1902) [Thripidae] Tobacco thrips	Yes (Nakao et al. 2011)	No records found	Yes. *Frankliniella fusca* were associated with strawberry plants in Iowa, USA (Matos & Obrycki 2004). *Frankliniella* sp. thrips are routinely intercepted on horticultural products at the Australian border (Australian Government Department of Agriculture and Water Resources 2017).	Yes. Assessed in the thrips group PRA (Australian Government Department of Agriculture and Water Resources 2017)	Yes. Assessed in the thrips group PRA (Australian Government Department of Agriculture and Water Resources 2017)	Thrips group PRA applied (Australian Government Department of Agriculture and Water Resources 2017)

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Frankliniella intonsa Trybom 1895 [Thripidae] Eurasian flower thrips	Yes (MAFF 2016)	No record found (Australian Government Department of Agriculture and Water Resources 2017)	Yes. *Frankliniella intonsa* oviposits on and feeds on fruit, flowers and leaves of a range of hosts, causing suction injury, premature fruit drop and discoloration (Plantwise 2019). *Frankliniella* sp. thrips are routinely intercepted on horticultural products at the Australian border (Australian Government Department of Agriculture and Water Resources 2017)	Yes. Assessed in the thrips group PRA (Australian Government Department of Agriculture and Water Resources 2017)	Yes. Assessed in the thrips group PRA (Australian Government Department of Agriculture and Water Resources 2017)	Thrips group PRA applied (Australian Government Department of Agriculture and Water Resources 2017)
Frankliniella occidentalis Pergande 1895 [Thripidae] Western flower thrips	Yes (MAFF 2016)	Yes, all states except the NT (Australian Government Department of Agriculture and Water Resources 2017)	Yes. *Frankliniella occidentalis* feed on leaves, stems, flowers and fruit of strawberries causing deformed fruit (Childers 1997). Generally, adults, eggs, larvae and pupae can be carried on the fruit in trade (CABI 2019). *Frankliniella* sp. thrips are routinely intercepted on horticultural products at the Australian border (Australian Government Department of Agriculture and Water Resources 2017)	Yes. Assessed in the thrips group PRA (Australian Government Department of Agriculture and Water Resources 2017)	Yes. Assessed in the thrips group PRA (Australian Government Department of Agriculture and Water Resources 2017)	Thrips group PRA applied (Australian Government Department of Agriculture and Water Resources 2017)

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Trombidiformes						
Amphitetranychus viennensis (Zacher, 1920) Synonym: *Tetranychus viennensis* Zacher, 1920 [Tetranychidae] Hawthorn spider mite	Yes (Ehara 1956)	No records found	Yes. Hawthorn spider mites live and breed under light canopies of webbing. Female mites over-winter in cracks and under the bark of stems and branches, emerging in spring to lay eggs on the underside of leaves (Alford 2007). When populations are high spider mites may occur on fruits and may over-winter in the calyx crevices when temperatures are not optimal (NAPPO 2014). Tetranychus mites have been intercepted on strawberries from the United States (unpublished data DAWR).	Yes. This species is polyphagous. Hosts include peanut, quince, fig, strawberry, cotton, apple, cherry, plum, peach, pear and raspberry (CABI 2019; Migeon & Dorkeld 2019).These hosts are widely available throughout Australia. This species is found in many parts of temperate Asia and Europe (Migeon & Dorkeld 2019). Many parts of temperate Australia have similar climatic conditions to regions where the pest is currently established.	Yes. This species is an important pest of apple, peach, pear, apricot, plum, hawthorn, cherry, sweet cherry and raspberry in Asia and Europe (Jeppson, Keifer & Baker 1975).	**Yes (EP)**
Brevipalpus obovatus Donnadieu, 1875 [Tenuipalpidae] Privet mite	Yes (MAFF 2016)	Yes. NSW, Qld, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Bryobia praetiosa Koch, 1835 [Tetranychidae] Clover mite	Yes (MAFF 2016)	Yes. NSW, SA, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Eotetranychus asiaticus Ehara, 1966 [Tetranychidae] Spider mite	Yes (Ehara 1999; MAFF 2016).	No records found The former decision of *Eotetranychus asiaticus* as a synonym of *E. sexmaculatus* was based on Ehara in 1973, but later considered a separate species by Ehara in 1993. The decision that *E. asiaticus* is a separate species was based solely on aedeagal morphology (Seeman, Beard & Zhang 2017).	Yes. *Eotetranychus asiaticus* has been recorded as a pest of strawberry in Japan (MAFF 2016; Osakabe 2002). When populations are high spider mites may occur on fruits and may over-winter in the calyx crevices when temperatures are not optimal (NAPPO 2014).	This species has been reported on strawberry, table grapes, citrus and persimmons (Ehara 1999; USDA 1995). These hosts are widely distributed throughout Australia. This species is found in Japan, Korea, Taiwan and China (Ehara 1999; USDA 1995). Parts of Australia have similar climatic conditions to regions where the pest is currently established.	Yes. This species is a pest of important economic crops citrus and table grapes (Ehara 1999; USDA 1995).	**Yes**
Eotetranychus geniculatus Ehara, 1966 [Tetranychidae] Spider mite	Yes (Ehara 1969; Migeon & Dorkeld 2019)	No records found	Yes. *Eotetranychus geniculatus* is recorded on strawberry in Japan (Ehara 1969). When populations are high spider mites may occur on fruits and may over-winter in the calyx crevices when temperatures are not optimal (NAPPO 2014). Tetranychus mites have been intercepted in strawberries from the United States (unpublished data DAWR).	Yes. This species is a pest of strawberry and table grapes (Migeon & Dorkeld 2019). These hosts are widely available throughout Australia. This species is found only in Japan and China (Migeon & Dorkeld 2019). Parts of Australia have similar climatic conditions to regions where the pest is currently established.	Yes. This species is a pest of strawberry and table grapes (Migeon & Dorkeld 2019).	**Yes**

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Eotetranychus smithi Pritchard & Baker, 1955 [Tetranychidae] Spider mite	Yes (MAFF 2016)	No records found	Yes. This mite generally feeds on leaves and does not produce much webbing (Jeppson, Keifer & Baker 1975), however, when populations are high spider mites may occur on fruits and may over-winter in the calyx crevices when temperatures are not optimal (NAPPO 2014).	Host plants of *E. smithi* include 25 species in six families, which include important economic crops such as cotton, apple, grape and peach (Migeon & Dorkeld 2019; Vacante 2016). These hosts are widely available throughout Australia. This species is found in Japan, Korea, the Phillipines, Taiwan, Madagascar, USA and China (Migeon & Dorkeld 2019; Vacante 2016). Parts of Australia have similar climatic conditions to regions where the pest is currently established.	Yes. *Eotetranychus smithi* is a pest of a wide range of economically important plant species including, apples, grapes and cotton (Vacante 2016).	**Yes**
Eutetranychus orientalis (Klein, 1936) [Tetranychidae] Oriental spider mite	Yes (Migeon & Dorkeld 2019)	Yes. NSW, NT, Qld, WA (ABRS 2019; CABI 2019; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Petrobia latens (Muller, 1776) [Tetranychidae] Brown wheat mite	Yes (MAFF 2016)	Yes. NSW, Qld, Tas, WA (Broadley 1982; Halliday 1998; Miller 1966; Plant Health Australia 2019; Poole 2010)	Assessment not required	Assessment not required	Assessment not required	No
Phytonemus pallidus (Banks, 1899) [Tarsonemidae] Cyclamen mite	Yes (MAFF 2016)	Yes. NSW, Tas, WA (Miller 1952; Plant Health Australia 2019; Poole 2010)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Polyphagotarsonemus latus (Banks, 1904) [Tarsonemidae] Broad mite	Yes (MAFF 2016)	Yes. NSW, NT, Qld, SA, Vic, WA (Gerson 1992; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Panonychus ulmi (Koch, 1836) [Tetranychidae] European fruit tree red spider mite	Yes (Migeon & Dorkeld 2019)	Yes. NSW, Qld, SA, Tas, Vic, WA WA (Halliday 1998; Miller 1966; Plant Health Australia 2019; Poole 2010)	Assessment not required	Assessment not required	Assessment not required	No
Tetranychus cinnabarinus (Boisduval, 1867) [Tetranychidae] Carmine spider mite	Yes. (JSAEZ 1987; Migeon & Dorkeld 2019)	Yes. NSW, Qld, SA, Tas, Vic, WA (Poole 2010)	Assessment not required	Assessment not required	Assessment not required	No
Tetranychus kanzawai Kishida, 1927 [Tetranychidae] Kanzawa spider mite / tea red spider mite	Yes (MAFF 2016)	Yes. NSW, Qld (CSIRO 2004; Gutierrez & Schicha 1983; Plant Health Australia 2019) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019)	Yes. *Tetranychus kanzawai* mites and webbing are often found on the underside of leaves and stems of strawberry plants (Zhang et al. 1996). They can cause leaf necrosis, mottling and bark discoloration (CABI 2019; Plantwise 2019). Flower heads can also become deformed (Gutierrez & Schicha 1983). Tetranychus mites have been intercepted in strawberries from the United States (unpublished data DAWR).	Yes. *Tetranychus kanzawai* is polyphagous and many of its known hosts are widely available in Australia (CABI 2019; Migeon & Dorkeld 2019). *Tetranychus kanzawai* is found in many coastal regions of East Asia (CABI 2019).There may be similar climates between these areas and parts of WA. It has been introduced to and successfully established in Qld and NSW (Gutierrez & Schicha 1983).	Yes. *Tetranychus kanzawai* is found on a wide range of plant species including crop species such as pear, apples and strawberries (CABI 2019; Gomi & Gotoh 1996; QIA 2015). *Tetranychus kanzawai* is subject to quarantine measures in many parts of the world (Navajas et al. 2001).	**Yes (EP)**

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Tetranychus urticae Koch, 1836 Synonym: *Tetranychus telarius* (Linnaeus, 1758) [Tetranychidae] Two-spotted spider mite	Yes (MAFF 2016)	Yes. NSW, NT, Qld, SA, Tas, Vic, WA (Miller 1966; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
GASTROPODA						
Stylommatophora						
Deroceras laeve (Muller, 1774) [Agriolimacidae] Marsh slug	Yes (MAFF 2016)	Yes (Hutchinson, Reise & Robinson 2014) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019)	No. Strawberry is a main host of *Deroceras laeve* (CABI 2019). Eggs of snails and slugs are laid in soil crevices or in leaf litter (Clemente et al. 2008; Faberi et al. 2006). All land gastropods leave highly noticeable mucus trails in the course of their activity (University of California 2009), meaning that juveniles and adults are likely to be noticed and removed during harvesting and packing procedures.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Incillaria confusa (Cockarell) [Philomycidae] Japanese native slug	Yes (Tanaka & Toyama 1957)	No records found	No. *Incillaria confusa* is known to feed on strawberry leaves, stems, flowers and fruit in Korea (QIA 2015). Eggs of snails and slugs are laid in soil crevices or in leaf litter (Clemente et al. 2008; Faberi et al. 2006). All land gastropods leave highly noticeable mucus trails in the course of their activity (University of California 2009), meaning that juveniles and adults are likely to be noticed and removed during harvesting and packing procedures.	Assessment not required	Assessment not required	No
Limax flavus Linnaeus, 1758 [Limacidae] Cellar slug / yellow cellar slug / yellow garden slug	Yes (MAFF 2016)	Yes (Mc Donnell, Paine & Gormally 2009)	Assessment not required	Assessment not required	Assessment not required	No
Limax valentiana (Ferussac, 1822) Synonym: *Lehmannia valentiana* (Ferussac, 1822) [Limacidae] Valencia slug	Yes (MAFF 2016)	Yes (Mc Donnell, Paine & Gormally 2009)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Meghimatium bilineatum (Benson, 1842) [Philomycidae] Chinese slug	Yes (MAFF 2016)	No records found	No. *Meghimatium bilineatum* is a pest of strawberry in Japan (MAFF 2016). Slugs are known to feed on strawberry leaves, stems, flowers and fruit (QIA 2015). Eggs of snails and slugs are laid in soil crevices or in leaf litter (Clemente et al. 2008; Faberi et al. 2006). All land gastropods leave highly noticeable mucus trails in the course of their activity (University of California 2009), meaning that juveniles and adults are likely to be noticed and removed during harvesting and packing procedures.	Assessment not required	Assessment not required	No
NEMATODA						
Panagrolaimida						
Aphelenchoides besseyi Christie 1942 [Aphelenchoidae] Spring dwarf crimp	Yes (Inagaki 1985; Kobayashi 1976; NARO 2019)	Yes. NT, Qld (Nobbs 2003) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019)	No. *Aphelenchoides besseyi* is an economically important species on rice. It infects plants by migrating up stems and entering stomata in leaves feeding internally on plant tissues (Kohl 2011). No records of association with strawberry fruit have been found; however, this pest may be associated with the calyx and peduncle. Symptoms caused by this pest would likely be identified on commercial fruit during quality checks and therefore removed from the pathway.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Aphelenchoides fragariae (Ritzema-Bos 1891) Christie 1932 [Aphelenchoidae] Strawberry crimp nematode	Yes (Inagaki 1985)	Yes. NSW, Qld, SA, Tas, Vic, WA (McLeod, Reay & Smyth 1994; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Aphelenchoides ritzemabosi Schwartz 1911 [Aphelenchoidae] Chrysanthemum eelworm	Yes (Inagaki 1985)	Yes. NSW, NT, Qld, Tas, Vic, WA (McLeod, Reay & Smyth 1994; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Ditylenchus acris (Thorne 1941) [Anguinidae] Synonym: *Nothotylenchus acris* Thorne 1941 Strawberry bud nematode	Yes (Inagaki 1985; Kondo & Ishibashi 1977) (NARO 2019)	No records found	No. *Ditylenchus acris* lives as an ectoparasite on developing buds and leaflets (Kim, Kim & Lee 2005). Infection causes stunted growth with deformed stems, crinkled leaves, malformed flowers and fruits (Kim, Kim & Lee 2005). Infected plants are unlikely to produce commercial quality fruit. In addition, there are no records of this species associated with strawberry fruit, calyx or peduncle.	Assessment not required	Assessment not required	No
Ditylenchus dipsaci (Kühn 1857) Filip'ev 1936 [Anguinidae] Stem eelworm / stem and bud nematode	Yes (Inagaki 1985; NARO 2019)	Yes. NSW, Qld, SA, Tas, Vic, WA (McLeod, Reay & Smyth 1994)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Pratylenchus coffeae (Zimmermann 1898) Filipjev & Schuurmans Stekhoven 1941 [Pratylenchidae] Banana root lesion nematode / coffee root lesion nematode	Yes (Inagaki 1985; NARO 2019)	Yes. NSW, Qld, SA, Tas, Vic, WA (Khair 1986; McLeod, Reay & Smyth 1994; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Pratylenchus neglectus (Rensch 1924) Filipjev & Schuurmans Stekhoven 1941 [Pratylenchidae] Root lesion nematode	Yes (Inagaki 1985)	Yes. NSW, Qld, SA, Tas, Vic, WA (Hay & Pethybridge 2005; McLeod, Reay & Smyth 1994; Plant Health Australia 2019; Riley & Kelly 2002)	Assessment not required	Assessment not required	Assessment not required	No
Pratylenchus penetrans (Cobb 1917) Filipjev & Schuurmans Stekhoven 1941 [Pratylenchidae] Cobb's root-lesion nematode	Yes (Gotoh & Ohshima 1963; Inagaki 1985)	Yes. NSW, Qld, SA, Tas, Vic, WA (Hay & Pethybridge 2005; McLeod, Reay & Smyth 1994; Plant Health Australia 2019; Riley & Kelly 2002)	Assessment not required	Assessment not required	Assessment not required	No
Pratylenchus scribneri Sterner [Pratylenchidae] Scribner's root-lesion nematode	Yes (Gotoh 1974)	Yes. NSW, NT, Qld, SA, Vic, WA (Khair 1986; Plant Health Australia 2019; Riley & Kelly 2002)	Assessment not required	Assessment not required	Assessment not required	No
Pratylenchus thornei Sher & Allen 1953 [Pratylenchidae] Root lesion nematode / Thorne's root lesion nematode	Yes (Gotoh & Ohshima 1963)	Yes. NSW, Qld, SA, Vic, WA (Hay & Pethybridge 2005; McLeod, Reay & Smyth 1994; Plant Health Australia 2019; Riley & Kelly 2002)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Pratylenchus vulnus Allen & Jensen 1951 [Pratylenchidae] Root lesion nematode / walnut root lesion nematode	Yes (Abe & Hyakutake 1981; Inagaki 1985)	Yes. NSW, Qld, SA, Vic, WA (Khair 1986; McLeod, Reay & Smyth 1994; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
PATHOGENS						
BACTERIA						
Burkholderia andropogonis (Smith 1911) Gillis et al. 1995 Synonym: *Pseudomonas andropogonis* (Smith 1911) Stapp 1928 [Burkholderiales: Burkholderiaceae]	Yes (Kijima, Ishihara & Kobayashi 1989)	Yes. NSW, NT, Qld, Vic, WA (Moffett, Hayward & Fahy 1986; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Erwinia pyrifoliae Kim et al. 1999 [Enterobacteriales: Enterobacteriaceae] Necrotic disease / bacterial shoot blight	Yes (Geider et al. 2009; USDA-APHIS-PPQ 2017)	No records found	No. Strawberry is a minor host. This species was reported to infect immature strawberry fruit in the Netherlands (NPPO the Netherlands 2014; Wenneker & Bergsma-Vlami 2015). This is the only known report of this pest infecting strawberries. There are no records of infection of mature commercial fruit. Further, it is uncertain whether the strains in the Netherlands and in Japan are the same (EPPO 2014). *Erwinia pyrifoliae* has never been observed to infect strawberries in Japan. The department will continue to monitor relevant information relating to this pest, including its status in Japan. The department will re-assess if new information warrants it.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Pseudomonas marginalis pv. *marginalis* (Brown 1981) Sevents 1925 [Pseudomonadales: Pseudomonadaceae]	Yes (Kijima, Ishihara & Kobayashi 1989)	Yes. NSW, Qld, Vic (Plant Health Australia 2019) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019) No specific domestic movement controls in place for this pest	Assessment not required	Assessment not required	Assessment not required	No
Pseudomonas syringae pv. *syringae* van Hall 1902 Synonym: *Pseudomonas syringae* f. sp. *prunicola* (Wormald) Dowson 1949 [Pseudomonadales: Pseudomonadaceae] Bacterial canker	Yes (Bradbury 1986; NARO 2019)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (Bradbury 1986; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Ralstonia solanacearum (Smith 1896) Yabuuchi, Kosako, Yano, Hotta & Nishiuchi 1996; Biovar 3, Race 1 (Phylotype II) Synonyms: *Bacterium solanacearum* (Smith) Chester / *Pseudomonas solanacearum* (Smith) Smith [Pseudomonadales: Pseudomonadaceae] Bacterial wilt	Yes (Horita et al. 2014; Kawaguchi, Ohta & Goto 1981; NARO 2019)	Yes. NT, Qld (Elphinstone 2005; Plant Health Australia 2019) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019) Regulated pest for Tas. under Section 11 of the Plant Quarantine Act 1997 (DPIPWE Tasmania 2019)	No. *Ralstonia solanacearum* infects the xylem of its host (Pegg & Manners 2014; Tahat & Sijam 2010). The bacteria enters through wounds and openings in the roots and spreads through the vascular system. Older leaves show wilting first, wilting then occurs in younger leaves before it becomes permanent and the plant dies (Tahat & Sijam 2010). Bacterial wilt of strawberry plants caused by *R. solanacearum* is found on younger seedlings in nurseries but rarely in mature plants (Kawaguchi, Ohta & Goto 1981; Maas 1998). No records of association with mature strawberry fruit have been found.	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Xanthomonas fragariae Kennedy & King 1962 [Xanthomonadales: Xanthomonadaceae] Angular leaf spot	Yes (Kijima, Ishihara & Kobayashi 1989; MAFF 2016; NARO 2019; Togawa & Ikeda 2001)	No. Eradicated (Australian Government Department of Agriculture 2012; CABI 2019; Plant Health Australia 2015).	Yes. In addition to leaves, the calyx of mature strawberry fruit can also be infected with this pest (Anco & Ellis 2011; Kwon et al. 2010; Peres 2014; van der Gaag et al. 2013).	Yes. *Xanthomonas fragariae* is found in multiple countries over a variety of climatic conditions (EPPO 2019; Kim et al. 2015a; NPPO the Netherlands 2013). The pathogen has previously established in areas of NSW, Vic, SA and Qld before being eradicated (Australian Government Department of Agriculture 2012; CABI 2019; NPPO the Netherlands 2013).	Yes. *Xanthomonas fragariae* has caused serious problems for strawberry production in many countries where it is present (EPPO 2019; Kim et al. 2015a; NPPO the Netherlands 2013). Heavy losses could occur in open field with frequent overhead irrigation (CABI 2019; NPPO the Netherlands 2013). If established in Australia, it would result in substantial costs to eradicate the disease as with previous incursions or to implement a control programme (McGechan & Fahy 1976; Plant Health Australia 2015; Young et al. 2011).	**Yes (EP)**

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MYCOPLASMA						
"Candidatus Phlomobacter fragariae" Zreik et al. 1998 Enterobacteriales: Enterobacteriaceae] Strawberry marginal chlorosis	Yes (Tanaka, Nao & Usugi 2006)	No records found	Yes. "*Candidatus* Phlomobacter fragariae" causes little leaf proliferation, malformation of fruits and marginal chlorosis of leaves (Tanaka, Nao & Usugi 2006).	No. "*Candidatus* Phlomobacter fragariae" is transmitted by the planthopper *Cixius wagneri* (Danet et al. 2003; Tanaka, Nao & Usugi 2006). *Cixius wagneri* is not recorded in Australia. In the absence of a vector it is unlikely that *Ca.* Phlomobacter fragariae will establish and spread in Australia if it is imported with infected fruits. If a suitable vector is present in Australia, it would be unlikely to feed on discarded, dehydrated strawberry fruits. Strawberry fruits are highly perishable and very susceptible to water loss (Shin et al. 2008). Huberty and Denno (2004) demonstrated phloem-feeding arthropods experience negative responses when forced to feed on water-stressed hosts.	Assessment not required	No

"Candidatus Phytoplasma asteris" Lee et al. 2004 Aster yellows (AY) group (16SrI) [Acholeplasmatales: Acholeplasmataceae] Strawberry phylloid fruit phytoplasma / strawberry witches' broom	Yes (Maejima, Oshima & Namba 2014; NARO 2019; Okuda et al. 1997)	Not known to occur	Yes. Symptoms can vary depending on the strain but typically include greening of flower petals, phyllody (production of leaves and other vegetative organs from fruit), yellowing of leaves, elongation of internodes, excessive branching of axillary shoots, witches' broom-like symptoms and general stunting (Bertaccini & Duduk 2009; Bertaccini et al. 2014; Lee et al. 2004; Maejima, Oshima & Namba 2014). Strawberry plants infected with phytoplasmas produce malformed fruits (Bolda & Koike 2015) that are not suitable for commercial sale. However, it is possible latent or early infection of a strawberry plant could result in infected asymptomatic fruits.	No. Phytoplasmas can only survive in living plant tissue and suitable vectors (Bertaccini & Duduk 2009). Strawberry fruits are highly perishable and very susceptible to water loss (Shin et al. 2008). Exposed to the environment, the fruit would quickly desiccate. The main host *Macrosteles quadrilineatus* is not recorded in Australia. If a suitable vector is present, it would be unlikely to feed on discarded, dehydrated strawberry fruits. In addition Huberty and Denno (2004) demonstrated phloem-feeding arthropods experience negative responses when forced to feed on water-stressed hosts. There are recent reports of phytoplasmas being found in seed but this is unusual and has not been reported for strawberries (Calari et al. 2011). In addition, reproduction from strawberry seeds is unlikely in commercial fruit imported for human consumption.	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
”*Candidatus* Phytoplasma fragariae” Valinus et al. 2006 [Acholeplasmatales: Acholeplasmataceae] Strawberry yellows	Yes (NARO 2019)	No records found	Yes. ”*Candidatus* Phytoplasma fragariae” resides in the sieve elements of phloem tissue and causes general stunting and yellowing of leaves in diseased cultivated strawberry (Valiunas, Staniulis & Davis 2006).	No. No vector is known for “*Candidatus* Phytoplasma fragariae”; the only known means of spread is infected plant material (DEFRA 2015). If a suitable vector is present in Australia, it would be unlikely to feed on discarded, dehydrated strawberry fruits. Strawberry fruits are highly perishable and very susceptible to water loss (Shin et al. 2008). Huberty and Denno (2004) demonstrated phloem-feeding arthropods experience negative responses when forced to feed on water-stressed hosts. There are recent reports of phytoplasmas being found in seed but this is unusual and has not been reported for strawberries (Calari et al. 2011). In addition, reproduction from strawberry seeds is unlikely in commercial fruit imported for human consumption.	Assessment not required	No

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CHROMALVEOLATA						
Phytophthora cactorum (Lebert & Cohn) J. Schröt. [Peronosporales: Peronosporaceae] Phytophthora blight	Yes (Li et al. 2011)	Yes. ACT, NSW, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Phytophthora capsici Leonian [Peronosporales: Pythiaceae] Phytopthora blight / damping off	Yes (Kimishima & Kobayashi 1994; NARO 2019)	Yes. Qld(Plant Health Australia 2019) Listed as a permitted organism (section 11) under the Western Australia *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019) Notifiable disease for NSW (NSW DPI 2016) and exotic disease for Vic (Agriculture Victoria 2017) No specific domestic movement controls in place for this pest	Assessment not required	Assessment not required	Assessment not required	No
Phytophthora fragariae var. *fragariae* Hickman [Peronosporales: Peronosporaceae] Stele root rot	Yes (Morita 1965; NARO 2019)	No records found	No. The pathogen causes severe root rot of strawberry plants and is transmitted by soil and planting material (Maas 1998). It is not known to be associated with fruits, calyx or peduncle (CABI 2019).	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Phytophthora fragariaefolia M.Z. Rahman, S. Uematsu, T. Takeuchi, K. Shirai & K. Kageyama [Prenosporales: Preonosporaceae] Phytophthora blight	Yes (NARO 2019; Rahman et al. 2014)	No records found	Yes. There is limited information available on *Phytophthora fragariaefolia* as it was only described very recently (Rahman et al. 2014; Shirai et al. 2006). Crown rot of strawberries caused by *P. fragariaefolia* is reported to be similar to that caused by *P. nicotianae* observed in Japan which attacked crown, petiole, fruit, root, leaf and runners (Rahman et al. 2014; Suzui, Makino & Ogoshi 1980). Japanese varieties of strawberries are susceptible to Phytophthora species (Li et al. 2011).	Yes. *Phytophthora* spores disperse through a variety of mechanisms including rainsplash and aerial dispersal from lesions on aerial plant parts (Ristaino & Gumpertz 2000). Spores may be associated with any above ground part of the plant including fruit.	Yes. *Phytophthora* species are well known to cause significant damage to a range of economically important crops (Ristaino & Gumpertz 2000). Several species of *Phytophthora* are responsible for major disease in strawberry including *P. cactorum* and *P. fragariae* var. *fargariae* (EPPO 2019; Maas 1998).	**Yes**
Phytophthora nicotianae Breda de Haan Synonyms: *Phytophthora nicotianae* var. *nicotianae* Tucker / *Phytophthora parasitica* Dastur. / *Phytophthora nicotianae* var. *parasitica* (Dastur) G. M. Waterh. [Peronosporales: Peronosporaceae] Phytophthora blight	Yes (Li et al. 2011)	Yes. NSW, NT, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Phytopythium helicoides (Drechsler) Abad, de Cock, Bala, Robideau, Lodhi & Lévesque Synonym: *Pythium helicoides* Drechsler [Peronosporales: Pythiaceae] Pythium root rot	Yes (Abdul, Suga & Kageyama 2013)	Yes. NSW, Qld, WA (Anderson 2014; Plant Health Australia 2019; Teakle 1960)	Assessment not required	Assessment not required	Assessment not required	No
Pythium myriotylum Drechsler [Peronosporales: Pythiaceae] Brown rot of groundnut	Yes (NARO 2019; Watanabe, Hashimoto & Sato 1977)	Yes. NSW, Qld, Vic (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Pythium sylvaticum W.A. Campb. & F.F. Hendrix [Peronosporales: Pythiaceae] Pythium root rot	Yes (Watanabe, Hashimoto & Sato 1977)	Yes. SA, Vic (Petkowski et al. 2013; Plant Health Australia 2019) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019)	No. *Pythium sylvaticum* is a soil-borne fungus isolated from the roots of strawberries (Nemec 1970; Watanabe, Hashimoto & Sato 1977). It can cause damping off in seedlings and is transmitted through contaminated soil, organic matter (oospores), and water (sporangia) (Spencer 2005). No record of association with strawberry fruit, calyx or peduncle have been found.	Assessment not required	Assessment not required	No
Pythium torulosum Coker & P. Patt [Peronosporales: Pythiaceae] Pythium root rot	Yes (Watanabe, Hashimoto & Sato 1977)	Yes. NSW, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Pythium ultimum var. *ultimum* Trow [Peronosporales: Pythiaceae]	Yes (MAFF 2016; Watanabe, Hashimoto & Sato 1977)	Yes. ACT, NSW, Qld, SA, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
FUNGI						
Alternaria alternata (Fr.) Keissl. [Pleosporales: Pleosporaceae] Alternaria leaf spot	Yes (Maekawa et al. 1984)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Alternaria tenuissima (Kunze) Wiltshire [Pleosporales: Pleosporaceae] Fruit rot	Yes (Honda et al. 2001)	Yes. NSW, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Athelia rolfsii (Curzi) C.C. Tu & Kimbr. Synonym: *Sclerotium rolfsii* Sacc. [Atheliales: Atheliaceae] Stem, root, and fruit rot / southern blight	Yes (Okabe et al. 1998)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (as S. rolfsii) (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Botrytis cinerea Pers. [Helotiales: Sclerotiniaceae] Grey mould	Yes (MAFF 2016; Watanabe et al. 2011)	Yes. ACT, NSW, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Cladosporium herbarum (Pers.) Link [Capnodiales: Cladosporiaceae] Scab	Yes (Watanabe et al. 2011)	Yes. NSW, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Colletotrichum acutatum J.H. Simmomds [Glomerellales: Glomerellaceae] Black spot of strawberry	Yes (Moriwaki, Tsukiboshi & Sato 2002; NARO 2019)	Yes. NSW, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019; Shivas et al. 2016)	Assessment not required	Assessment not required	Assessment not required	No
Colletotrichum aenigma B.S. Weir & P.R. Johnston [Glomerellales: Glomerellaceae] Anthracnose / fruit rot	Yes (Gan et al. 2016)	No (Shivas et al. 2016; Weir, Johnston & Damm 2012)	Yes. Fruits can be infected (Baroncelli et al. 2015) but usually display symptoms of rot/disease. It has been reported on a number of hosts in Asia and appears to be common but is obscured by other *Colletotrichum* species. It is a minor disease of strawberry in Japan (Gan et al. 2016).	Yes. The main source of *Colletotrichum* inoculum is infected nursery stock; conidia are spread by water splash, rain or insects (Maas 1998). *Colletotrichum aenigma* has been isolated from a variety of hosts including pear, grape vine, strawberry and apple (Jayawardena et al. 2016b; Wang et al. 2015). Hosts are present and widespread in Australia. The optimum temperature for growth is 28 °C (Han et al. 2016), similar to average summer temperatures in Australia.	Yes. *Colletotrichum aenigma* is reported to cause economic losses in apple (Wang et al. 2015).	**Yes**

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Colletotrichum fructicola Prihast., L. Cai & K.D. Hyde Synonym: *Glomerella cingulata* var. *minor* Wolenw. [Glomerellales: Glomerellaceae] Anthracnose / fruit rot	Yes (Gan et al. 2016)	Yes. NSW, Qld (Farr & Rossman 2019; Plant Health Australia 2019; Weir, Johnston & Damm 2012) *Colletotrichum fructicola* is part of the *C. gloeosporioides* species complex that is widespread in Australia (Plant Health Australia 2019; Shivas et al. 2016)	Assessment not required	Assessment not required	Assessment not required	No
Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. Synonym: *Glomerella cingulata* (Stoneman) Spauld. & H. Schrenk. [Glomerellales: Glomerellaceae] Anthracnose	Yes (NARO 2019; Suzuki et al. 2010)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019; Shivas et al. 2016)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Colletotrichum theobromicola Delacr. Synonym: *Colletotrichum fragariae* A.N. Brooks [Glomerellales: Glomerellaceae] Anthracnose / fruit rot	Yes (Tanaka & Nonaka 1979)	Yes. NSW, NT, Qld (DEEDI 2009; Shivas et al. 2016) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019) No specific domestic movement controls in place for this pest	Assessment not required	Assessment not required	Assessment not required	No
Colletotrichum siamense Prihastuti, L. Cai & K.D. Hyde [Glomerellales: Glomerellaceae]	Yes (Gan et al. 2016)	Yes. NSW, NT, Qld (James et al. 2014; Plant Health Australia 2019; Shivas et al. 2016; Weir, Johnston & Damm 2012)	Assessment not required	Assessment not required	Assessment not required	No
Cylindrocladium canadense J.C. Kang, Crous & C.L. Schoch [Hypocreales: Nectriaceae] Damping off of strawberry	Yes (Hirooka et al. 2009)	No records found	No. This is a foliar disease of seedlings. The plants wither and defoliate before fruit is produced (Hirooka et al. 2009).	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Diplocarpon fragariae (Sacc.) Rossman Synonyms: *Marssonina fragariae* Sacc./ *Diplocarpon earlianum* (Ellis & Everh.) F.A. Wolf [Helotiales: Dermateaceae] Leaf scorch	Yes (MAFF 2016; NARO 2019)	Yes. NSW, Qld, SA, Tas, Vic, WA (CABI 2019; Floyd 1994; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Fusarium oxysporum f. sp. *fragariae* Winks & Y.N. Williams [Hypocreales: Nectriaceae] Fusarium wilt	Yes (NARO 2019)	Yes. Qld, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Fusarium solani Teliomorph: *Haemanectria haematococca* [Hypocreales: Nectriaceae]	Yes (NARO 2019)	Yes. NSW, NT, Qld, Tas, Vic, WA (Plant Health Australia 2019; Summerell et al. 2011)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Ilyonectria destructans (Zinssm.) Rossman, L. Lombard & Crous Synonyms: *Cylindrocarpon destructans* (Zinssm.) Scholten / *Neonectria radicicola* (Gerlach & L. Nilsson) Mantiri & Samuels [Hypocreales: Nectriaceae] Root rot	Yes (Hirooka & Kobayashi 2007)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Macrophomina phaseolina (Tassi) Goid. [Botryosphaeriales: Botryosphaeriaceae] Charcoal rot	Yes (Fujinaga et al. 2002)	Yes. ACT, NSW, NT, Qld, SA, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Monilia polystroma G.C.M.Leeuwen Synonym: *Monilinia polystroma* (G.C.M. Leeuwen) Kohn [Helotiales: Sclerotiniaceae] Asiatic brown rot	In Japan a new distinct species (*Monilia polystroma*) was identified from isolates previously identified as *Monilinia fructigena*. It has been suggested that isolates of *M. fructigena* from other East Asian countries such as China, Russia and Korea should be re-examined to determine whether some of them are in fact isolates of *M. polystroma* (Chalkley 2010; Van Leeuwen et al. 2002). *Monilia polystroma* has now been reported from China (Zhu & Guo 2010), and several European countries (CABI 2019; Di Francesco et al. 2015; Martini et al. 2015; Martini et al. 2014; Petróczy & Palkovics 2009; Vasić, Duduk & Ivanović 2013).	No records found	Yes. *Monilia polystroma* is considered to share known hosts with *M fructigena* (USDA 2015). Strawberry is susceptible to *M. fructigena* and is considered a minor host (CABI 2019). *Monilia fructigena* causes brown rot on fruits resulting in raised light brown pustules on the fruit surface that often expand enclosing the fruit to form a dark, wrinkled, hard mummified fruit (Farr & Rossman 2019; Ogawa, Zehr & Biggs 1995; USDA-APHIS 2004).	Yes. The major hosts, pome and stone fruit species and many other hosts (CABI 2019) are widespread in Australia. Conditions for the natural dispersal of this pathogen (USDA 2015) are available in Australia.	Yes. Brown rot disease, caused by *M. fructigena*, causes in pome and stone fruit soft decay of fruit flesh and blighting of spurs and blossoms (Mackie, Eyres & Kumar 2005). This results in significant pre- and post-harvest fruit losses and causes considerable economic losses worldwide (Jones 1990; Mackie, Eyres & Kumar 2005; USDA 2015). Similar effects are expected for *M. polystroma*.	**Yes (EP)**

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Monilinia fructigena Honey ex Whetzel [Helotiales: Sclerotiniaceae] Brown rot	Isolates of *Monilinia fructigena* from Japan were found to be distinct and a new species was described *Monilia polystroma* (Van Leeuwen et al. 2002). It is unclear if all isolates from Japan are *M. polystroma* or if *Monilinia fructigena* also occurs in Japan.	No records found	Yes. Strawberry is susceptible to *Monilinia fructigena* and is considered a minor host (CABI 2019). *Monilinia fructigena* causes brown rot on fruits resulting in raised light brown pustules on the fruit surface that often expand enclosing the fruit to form a dark, wrinkled, hard mummified fruit (Farr & Rossman 2019; Ogawa, Zehr & Biggs 1995; USDA-APHIS 2004).	Yes. The major hosts, pome and stone fruit species and many other hosts (CABI 2019; Ogawa, Zehr & Biggs 1995) are widespread in Australia. Conditions for the natural dispersal of the pathogen (USDA 2015) are available in Australia.	Yes. *Monilinia fructigena* causes brown rot disease in pome and stone fruit which is the soft decay of fruit flesh and blighting of spurs and blossoms (Mackie, Eyres & Kumar 2005). This results in significant pre- and post-harvest fruit losses on susceptible hosts and results in considerable economic losses worldwide (Jones 1990; Mackie, Eyres & Kumar 2005; USDA 2015).	**Yes (EP)**
Mycosphaerella fragariae (Tul. & C. Tul.) Lindau [Capnodiales: Mycosphaerellaceae] Leaf spot	Yes (MAFF 2016)	Yes. NSW, Qld, SA, Tas, Vic, WA (CABI & EPPO 1982; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Phomopsis obscurans (Ellis & Everh.) B. Sutton Synonym: *Dendrophoma obscurans* (Ellis & Everh.) H.W Anderson [Diaporthales: Diaporthaceae] Leaf blight / fruit rot	Yes (NARO 2019). Udayanga et al. (2011) reports this species is present in China and requires reassessment to determine presence in Asia.	Yes. NSW, NT, Qld, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Phyllosticta fragariicola Roberge ex Desm. [as *'Phyllosticta fragaricola'*] [Botryosphaeriales: Phyllostictaceae] Leaf spot	Yes (NARO 2019)	No. Previous records unreliable (IPPC 2016a)	Yes. *Phyllosticta fragariicola* has been reported affecting leaves (Anderson 1920; Sharma & Bhardwaj 1999). There is uncertainty whether it affects the calyx. Symptoms include obvious small white/grey centred spots on the upper surface of leaves (Anderson 1920; Sharma & Bhardwaj 1999).	Yes. This species has a wide global distribution. It has been recorded in China, Germany, Canada, India and Korea (Anderson 1920; NPQS 2008; Schellenberg 1917; Sharma & Bhardwaj 1999; Zhang, Shivas & Cai 2015).	No. *Phyllosticta fragariicola*, though widespread, is rarely reported and in many cases misidentified (Anderson 1920; IPPC 2016a). No economic losses or consequences have been reported thus far anywhere in this species' recorded range. Australia already treats its strawberry production for leaf spot and leaf scorch meaning it is unlikely extra treatment would be required for this species (Ullio 2009).	No
Pilidium concavum (Desm.) Rossman Synonyms: *Hainesia lythri* (Desm.) Höhn / *Discohainesia oenotherae* (Cooke & Ellis) Nannf [Helotiales: Chaetomellaceae] Tan-brown rot	Yes (Palm 1991)	Yes. Qld, NSW, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Podosphaera aphanis (Wallr.) U. Braun & S. Takam. Synonyms: *Sphaerotheca aphanis* (Wallr.) U. Braun / *Sphaerotheca macularis* f. sp. *fragariae* (Harz) Jacz. / *Sphaerotheca macularis* (Wallr.) Magnus [Erysiphales: Erysiphaceae] Powdery mildew	Yes (MAFF 2016)	Yes. Qld, SA, Vic, WA (CABI 2019; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Rhizoctonia fragariae S.S. Hussain & W.E. McKeen [Cantharellales: Ceratobasidiaceae] Rhizoctonia bud rot / black root rot of strawberry	Yes (Watanabe, Hashimoto & Sato 1977)	Yes. WA (Fang, Finnegan & Barbetti 2013) Very likely present in other states; there are over 900 *Rhizoctonia* sp. records in ACT, NSW, Qld, SA, Tas, Vic and WA, including some on strawberry (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Rhizopus stolonifer (Ehrenb.) Vuill Synonym: *Rhizopus nigricans* Ehrenb. [Mucorales: Rhizopodaceae] Fruit rot	Yes (MAFF 2016)	Yes. NSW, NT, Qld, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Sclerotinia sclerotiorum (Lib.) de Bary [Helotiales: Sclerotiniaceae] Sclerotinia rot	Yes (MAFF 2016)	Yes. ACT, NSW, Qld, SA, Tas, Vic, WA (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Septoria fragariae Desm. [Capnodiales: Mycosphaerellaceae] Leaf spot	Yes (NARO 2019)	No. Previous records unreliable (IPPC 2016b)	Yes. *Septoria fragariae* affects strawberry leaves causing brown spots with purplish margin on the leaves (Garrido et al. 2011; Sesan 2006). Without providing any evidence, Maas (1998) claimed that this species may affect sepals (calyx). No records of this fungus affecting calyx have been found.	Yes. The host (strawberry) is widespread in Australia. *Septoria* spp. spreads through rain splash and wind dispersal (Forest Health Protection 2011).	No. *Septoria fragariae* is reported as a minor pest, occurring occasionally, and with no major economic consequences reported (Garrido et al. 2011; Maas 1998).	No
Thanatephorus cucumeris (A.B. Frank) Donk Synonym: *Rhizoctonia solani* J.G. Kühn [Cantharellales: Ceratobasidiaceae] Rhizoctonia bud rot / root rot / fruit rot	Yes (Ogoshi 1987)	Yes. ACT, NSW, NT, Qld, SA, Tas, Vic, WA (as *R. solani*) (Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Verticillium albo-atrum Reinke & Berthold [Not Assigned: Plectosphaerellaceae] Verticillium wilt	Yes (Koike et al. 1996)	Yes. Qld, SA, Tas, Vic (Plant Health Australia 2019) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019)	No. *Verticillium albo-atrum* is a soil-borne fungus that causes necrosis and stunting of the stem and leaf of strawberry plants (Maas 1998; University of Illinois 2001). Though it has been reported as seed transmitted in some species, no records of seed transmission in strawberries have been found.	Assessment not required	Assessment not required	No
Verticillium dahliae Kleb. [Not Assigned: Plectosphaerellaceae] Verticillium wilt	Yes (Koike et al. 1996)	Yes. ACT, NSW, Qld, SA, Tas, Vic, WA (Kirkby & Smith 2015; Plant Health Australia 2019) *Verticillium dahliae* VCG2 is considered to be the strain responsible for disease in strawberries (Bhat & Subbarao 1999). *Verticillium dahliae* VCG1 (cotton) is present in Australia (Chapman et al. 2016). Records of *Verticillium dahliae* infecting strawberries has also been recorded in Australia (ALA 2019).	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
VIRUSES						
Alfalfa mosaic virus [Bromoviridae: Alfamovirus]	Yes (Matsumoto, Kodama & Murayama 1968)	Yes. NSW, Qld, SA, Tas, Vic, WA (CABI 2019; Plant Health Australia 2019).	Assessment not required	Assessment not required	Assessment not required	No
Apple mosaic virus [Bromoviridae: Ilarvirus]	Yes (Kanno, Yoshikawa & Takahashi 1993)	Yes. Qld, SA, Tas, Vic, WA (EPPO 2019; Government of Western Australia 2019; Grimova et al. 2016; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Arabis mosaic virus [Picornavirales: Secoviridae]	Yes (Iwaki & Komuro 1974)	Yes. Tas, Vic (CABI 2019; Munro 1987; Plant Health Australia 2013b; Sharkey, Hepworth & Whattam 1996). Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019) No specific domestic movement controls in place for this pest	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Beet pseudo-yellows virus [Closteroviridae: Crinivirus]	Yes (CABI 2019).	Yes. Tas (CABI 2019; Constable et al. 2010) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019) No specific domestic movement controls in place for this pest	Assessment not required	Assessment not required	Assessment not required	No
Cucumber mosaic virus [Bromoviridae: Cucumovirus]	Yes (Maeda, Wakimoto & Inouye 1983)	Yes. NSW, Qld, SA, Tas, Vic, WA }(CABI 2019; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Strawberry crinkle virus [Rhabdoviridae: Cytorhabdovirus]	Yes (EPPO 2019)	Yes. NSW, Qld, Tas, Vic, WA (CABI 2019; Constable et al. 2010; McLean & Price 1984)	Assessment not required	Assessment not required	Assessment not required	No
Strawberry mild yellow edge virus [Alpahflexiviridae: Potexvirus]	Yes (Yoshikawa & Inouye 1988)	Yes. Qld, Tas, Vic, WA (Büchen-Osmond et al. 1988; CABI 2019; Constable et al. 2010)	Assessment not required	Assessment not required	Assessment not required	No
Strawberry mottle virus [Secoviridae: Unassigned]	Yes (Yoshikawa & Inouye 1988)	Yes. Qld, Vic (CABI 2019; Constable et al. 2010; Plant Health Australia 2019)	Assessment not required	Assessment not required	Assessment not required	No
Strawberry necrotic shock virus [Bromoviridae: Illavirus]	Yes (Tzanetakis, Mackey & Martin 2004)	Yes. Qld (Sharman et al. 2011; Sharman & Thomas 2013)	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Strawberry pseudo mild yellow edge virus [Tymovirales: Betaflexiviridae]	Yes (Martin & Tzanetakis 2006; Yoshikawa & Inouye 1988)	No records found	No. The virus is known to be transmitted by insect vectors such as *Aphis gossypii* and *Chaetosiphon fragaraefolii* in a semi-persistant manner. The vectors lose the virus during a moult. This virus cannot be transmitted mechanically or by seed (Brunt et al. 1996a).	Assessment not required	Assessment not required	No
Strawberry vein banding virus [Caulimoviridae: Caulimovirus]	Yes (Yoshikawa & Inouye 1988)	Yes. NSW, Tas, Vic (CABI 2019; Constable et al. 2010)	Assessment not required	Assessment not required	Assessment not required	No
Tobacco necrosis virus [Tombusviridae: Betanecrovirus]	Yes (Maas 1998)	Yes. Qld, Vic (Finlay & Teakle 1969; Plant Health Australia 2019; Teakle 1988) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019) No specific domestic movement controls in place for this pest	Assessment not required	Assessment not required	Assessment not required	No

Pest	Present in Japan	Present within Australia	Potential to be on pathway	Potential for establishment and spread	Potential for economic consequences	Pest risk assessment required
Tobacco streak virus [Bromoviridae: Ilavirus]	Yes (Tomaru et al. 1985)	Yes. Qld (Maas 1998; Sharman, Thomas & Persley 2015) Regulated as a Declared Organism (Prohibited (s. 12)) by WA under the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2019) Regulated pest for Tas. under Section 11 of the Plant Quarantine Act 1997 (DPIPWE Tasmania 2019) No specific domestic movement controls in place for this pest	Assessment not required	Assessment not required	Assessment not required	No
Tomato black ring nepovirus [Comoviridae: Nepovirus]	Yes (Brunt et al. 1996b; EPPO 2019; Iwaki & Komuro 1973)	No records found	No. No records of *Tomato black ring nepovirus* have been found on strawberries in Japan, only in hosts narcissus and gerbera (Iwaki & Komuro 1973; MAFF 2017).	Assessment not required	Assessment not required	No
Tomato ringspot nepovirus [Comoviridae: Nepovirus]	Yes (Brunt et al. 1996b; Iwaki & Komuro 1971)	Absent (Eradicated) (CABI 2019; IPPC 2013)	No. No records of *Tomato ringspot nepovirus* have been found on strawberries in Japan, only in hosts narcissus petunia and melon (Iwaki & Komuro 1971; MAFF 2017).	Assessment not required	Assessment not required	No

Appendix B: Issues raised in stakeholder comments

This section includes key technical issues raised by stakeholders during consultation on the draft report, and the department's responses. Additional information on other issues commonly raised by stakeholders, which may be outside the scope of this technical report, is available on the department's website.

Issue 1: Clarification and recommended review of potential pathway association of pests of concern on the strawberry fruit including the peduncle, calyx and achenes.

The department has reviewed the pathway association of species in Appendix A. The review identified species that may remain associated with commercially produced fruit and require further consideration.

After review, *Eotetranychus smithi* was added to the spider mite pest risk assessment in Chapter 4 of the report and changes were made to Appendix A, to clarify the association of some pests on the fruit pathway. Note that *Eotetranychus asiaticus* was added to the spider mite pest risk assessment in Chapter 4 of the report due to a taxonomic revision, see 'Other issues' within Appendix B.

Issue 2: Recommended review of the likelihood of distribution, establishment and spread in the pest risk assessment for *Colletotrichum aenigma*.

The department has reviewed the risk assessment for *Colletotrichum aenigma* and considers the risk ratings are appropriate. The risk assessment took into account the key attributes of the pest including its diverse host range, spore production and survival. As outlined in detail in Chapter 4 of the report under 4.6 Anthracnose, these key attributes are moderated due to the specific conditions needed for the pathogen to produce spores, and the fact that spores are only able to disperse very short distances.

Issue 3: Comments about use of pest free places of production as a suitable risk management measure to manage *Drosophila* species during winter and spring.

Stakeholders raised concerns and sought clarification on the use of pest free production sites as a suitable risk management measure for *Drosophila* species (the key concern was with regard to *Drosophila suzukii*, spotted wing drosophila) during winter and spring. Queries raised were specifically around the presence of *Drosophila* species in production areas of Japan, overwintering survival, pest reproductive rate during the specified period and inspection of the fruit.

Chapter 4: Pest risk assessments for quarantine pests, section 4.2: Spotted wing drosophila, provides an overview of biological information of *D. suzukii* and states that *D. suzukii* is native to temperate parts of Asia (Rota-Stabelli, Blaxter & Anfora 2013) and is present in Japan, including on the four main islands (Department of Agriculture 2013). It also notes that adult flies can be found in suitable microclimates in winter in Japan. This chapter also discusses the pest's ability to overwinter in temperate regions and its reproductive development thresholds.

Natural winter conditions in Japan impose a significant stress on *D. suzukii* that results in very high levels of mortality, significantly limits adult flight activity, and induces reproductive diapause in the small number of surviving adults.

Japan has an extensive surveillance system that operates in all prefectures that produce strawberries, and there are no reports of *Drosophila* species in commercial production sites of strawberries in Japan in winter production for the last 40 years.

The pest's biology and confirmed absence over a significant period were taken into account in the assessment of pest free production sites as an appropriate risk management measure from December to March in Japan.

The pest free production site risk management measure requires verification of absence of *Drosophila* species through trapping, and through visual inspection of fruit. In addition there is pre-export phytosanitary inspection and certification by MAFF.

On arrival in Australia, consignments will be inspected, using optical enhancement, by the Department of Agriculture, Water and the Environment to ensure import conditions have been met.

Additional detail is provided in Chapter 5: Pest Risk Management, Section 5.1.4: Management for *Drosophila pulchrella, Drosophila subpulchrella* and *Drosophila suzukii* and Section 5.2 Operational system for the maintenance and verification of phytosanitary status.

Issue 4: Comments about the proposed fumigation pathway for *Drosophila* species.

Since the release of the Final pest risk analysis report for *Drosophila suzukii* in April 2013, the department has reviewed the research data published in 'Postharvest treatment of strawberries with methyl bromide to control spotted wing drosophila, *Drosophila suzukii'* (Walse, Krugner & Tebbets 2012) and cited in the risk management section for *Drosophila suzukii* on page 71 (Department of Agriculture 2013). The department considers that the treatment schedule of 40 grams per cubic metre for three hours is effective, as it exceeds the dosage rate found to reach 100% mortality of all life stages for *D. suzukii* in strawberries. This treatment rate was first recommended in the department's Final report for the non-regulated analysis of existing policy for fresh strawberry fruit from the Republic of Korea in 2017, and is also discussed in Appendix B of that report.

The department notes that the more stringent methyl bromide treatment schedule (48 grams per cubic metre) for strawberries from California is an existing treatment (prior to spotted wing drosophila becoming established in the USA) used to manage other pests on the pathway.

Other issues

The department has made a number of changes to the risk analysis following consideration of stakeholder comments on the draft report and subsequent review of scientific literature. These include:

- Removal of *Otiorhynchus ovatus* from the pest categorisation table (Appendix A). After a further review of the literature it was determined that this species is not present in Japan.
- Removal of five species from the family Scarabaeidae (for example *Anomala viridana*) from the pest categorisation table (Appendix A). After a further review of the literature it was determined that these species had no association with strawberries.
- Removal of *Eotetranychus sexmaculatus* and addition of *Eotetranychus asiaticus* to the pest categorisation table.

  - After further consideration of scientific literature on the taxonomic status of these species, the department has concluded that *E. sexmaculatus* is not present in Australia or Japan.
  - After review it was determined that *E. asiaticus* is not a synonym of *E. sexmaculatus*. *Eotetranychus asiaticus* has been recorded as a pest of strawberry in Japan and a pest risk assessment was required.

- Amendments in the pest risk management section (Chapter 5) to include specific requirements for containers, and updating of the hyperlink to information on packaging requirements.
- Minor corrections, rewording and editorial changes for consistency, clarity and web-accessibility.

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 2019a).
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).
Appropriate level of protection (ALOP) for Australia	The *Biosecurity Act 2015* defines the appropriate level of protection (or ALOP) for Australia as a high level of sanitary and phytosanitary protection aimed at reducing biosecurity risks to very low, but not to zero.
Area	An officially defined country, part of a country or all or parts of several countries (FAO 2019a).
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 2019a).
Arthropod	The largest phylum of animals, including the insects, arachnids and crustaceans.
Asexual reproduction	The development of new individual from a single cell or group of cells in the absence of meiosis.
Australian territory	Australian territory as referenced in the *Biosecurity Act 2015* refers to Australia, Christmas Island and Cocos (Keeling) Islands.
Biosecurity	The prevention of the entry, establishment or spread of unwanted pests and infectious disease agents to protect human, animal or plant health or life, and the environment.
Biosecurity measures	The *Biosecurity Act 2015* defines biosecurity measures as measures to manage any of the following: biosecurity risk, the risk of contagion of a listed human disease, the risk of listed human diseases entering, emerging, establishing themselves or spreading in Australian territory, and biosecurity emergencies and human biosecurity emergencies.
Biosecurity import risk analysis (BIRA)	The *Biosecurity Act 2015* defines a BIRA as an evaluation of the level of biosecurity risk associated with particular goods, or a particular class of goods, that may be imported, or proposed to be imported, into Australian territory, including, if necessary, the identification of conditions that must be met to manage the level of biosecurity risk associated with the goods, or the class of goods, to a level that achieves the ALOP for Australia. The risk analysis process is regulated under legislation.
Biosecurity risk	The *Biosecurity Act 2015* refers to biosecurity risk as the likelihood of a disease or pest entering, establishing or spreading in Australian territory, and the potential for the disease or pest causing harm to human, animal or plant health, the environment, economic or community activities.
Calyx	A collective term referring to all of the sepals in a flower.
Commodity	A type of plant, plant product, or other article being moved for trade or other purpose (FAO 2019a). In this report the commodity is fresh strawberry fruit.
Consignment	A quantity of plants, plant products 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 2019a).
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO 2019a).
Crawler	Intermediate mobile nymph stage of certain Arthropods.

Term or abbreviation	Definition
Diapause	Period of suspended development/growth occurring in some insects, in which metabolism is decreased.
The department	The Department of Agriculture, Water and the Environment.
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 2019a).
Endemic	Belonging to, native to, or prevalent in a particular geography, area or environment.
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 2019a).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2019a).
Fresh	Living; not dried, deep-frozen or otherwise conserved (FAO 2019a).
Fumigation	Treatment with a chemical agent that reaches the commodity wholly or primarily in a gaseous state (FAO 2019a).
Genus	A taxonomic category ranking below a family and above a species and generally consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature the genus name is used, either alone or followed by a Latin adjective or epithet, to form the name of a species.
Goods	The *Biosecurity Act 2015* defines goods as an animal, a plant (whether moveable or not), a sample or specimen of a disease agent, a pest, mail or any other article, substance or thing (including, but not limited to, any kind of moveable property).
Host	An organism that harbours a parasite, mutual partner, or commensal partner, typically providing nourishment and shelter.
Host range	Species capable, under natural conditions, of sustaining a specific pest or other organism(FAO 2019a).
Import permit	Official document authorising importation of a commodity in accordance with specified phytosanitary import requirements (FAO 2019a).
Infection	The internal 'endophytic' colonisation of a plant, or plant organ, and is generally associated with the development of disease symptoms as the integrity of cells and/or biological processes are disrupted.
Infestation (of a commodity)	Presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection (FAO 2019a).
Inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present or to determine compliance with phytosanitary regulations (FAO 2019a).
Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced or used (FAO 2019a).
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2019a).
International Plant Protection Convention (IPPC)	The IPPC is an international plant health agreement, established in 1952, that aims to protect cultivated and wild plants by preventing the introduction and spread of pests. The IPPC provides an international framework for plant protection that includes developing International Standards for Phytosanitary Measures (ISPMs) for safeguarding plant resources.
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 IPPC (FAO 2019a).
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO 2019a).
Larva	A juvenile form of animal with indirect development, undergoing metamorphosis (for example, insects or amphibians).

Term or abbreviation	Definition
Lot	A number of units of a single commodity, identifiable by its homogeneity of composition, origin et cetera, forming part of a consignment (FAO 2019a).Within this report a 'lot' refers to a quantity of fruit of a single variety, harvested from a single production site during a single pick and packed at one time.
Mature fruit	Commercial maturity is the start of the ripening process. The ripening process will then continue and provide a product that is consumer-acceptable. Maturity assessments include colour, starch, index, soluble solids content, flesh firmness, acidity, and ethylene production rate.
National Plant Protection Organization (NPPO)	Official service established by a government to discharge the functions specified by the IPPC (FAO 2019a).
Non-regulated risk analysis	Refers to the process for conducting a risk analysis that is not regulated under legislation (Biosecurity import risk analysis guidelines 2016).
Nymph	The immature form of some insect species that undergoes incomplete metamorphosis. It is not to be confused with larva, as its overall form is already that of the adult.
Official	Established, authorized or performed by a national plant protection organization (FAO 2019a).
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 2019a).
Pathogen	A biological agent that can cause disease to its host.
Pathway	Any means that allows the entry or spread of a pest (FAO 2019a).
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2019a).
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 2019a).
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 2019a).
Pest free place of production	Place of production in which a specific pest is absent as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period (FAO 2019a).
Pest free production site	A production site in which a specific pest is absent as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period (FAO 2019a).
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 2019a).
Pest risk assessment (for quarantine pests)	Evaluation of the probability of the introduction and spread of a pest and of the magnitude of the associated potential economic consequences (FAO 2019a).
Pest risk assessment (for regulated non-quarantine pests)	Evaluation of the probability that a pest in plants for planting affects the intended use of those plants with an economically unacceptable impact (FAO 2019a).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2019a).
Pest risk management (for regulated non-quarantine pests)	Evaluation and selection of options to reduce the risk that a pest in plants for planting causes an economically unacceptable impact on the intended use of those plants (FAO 2019a).
Pest status (in an area)	Presence or absence, at the present time, of a pest in an area, including where appropriate its distribution, as officially determined using expert judgement on

Term or abbreviation	Definition
	the basis of current and historical pest records and other information (FAO 2019a).
Phytosanitary certificate	An official paper document or its official electronic equivalent, consistent with the model of certificates of the IPPC, attesting that a consignment meets phytosanitary import requirements (FAO 2019a).
Phytosanitary certification	Use of phytosanitary procedures leading to the issue of a phytosanitary certificate (FAO 2019a).
Phytosanitary measure	Phytosanitary relates to the health of plants. 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 2019a).In this risk analysis the term 'phytosanitary measure' and 'risk management measure' may be used interchangeably.
Phytosanitary procedure	Any official method for implementing phytosanitary measures including the performance of inspections, tests, surveillance or treatments in connection with regulated pests (FAO 2019a).
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 2019a).
Place of production	Any premises or collection of fields operated as a single production or farming unit (FAO 2019a).
Polyphagous	Feeding on a relatively large number of hosts from different plant family and/or genera.
PRA area	Area in relation to which a pest risk analysis is conducted (FAO 2019a).
Practically free (of a consignment, field or place of production)	Without pests (or a specific pest) in numbers or quantities in excess of those that can be expected to result from, and be consistent with good cultural and handling practices employed in the production and marketing of the commodity (FAO 2019a).
Prefecture	Government and/or administration division of Japan, similar to Australian states and territories.
Production site	A defined part of a place of production, that is managed as a separate unit for phytosanitary purposes (FAO 2019a). In this report, a production site is a continuous planting of strawberry runners treated as a single unit for pest management purposes.
Pupa	An inactive life stage that only occurs in insects that undergo complete metamorphosis, for example butterflies and moths (Lepidoptera), beetles (Coleoptera) and bees, wasps and ants (Hymenoptera).
Quarantine	Official confinement of regulated articles, pests or beneficial organisms for inspection, testing, treatment, observation or research (FAO 2019a).
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 2019a).
Regulated article	Any plant, plant product, storage place, packaging, 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 2019a).
Regulated non-quarantine pest	A non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party (FAO 2019a).
Regulated pest	A quarantine pest or a regulated non-quarantine pest (FAO 2019a).
Restricted risk	Restricted risk is the risk estimate when risk management measures are applied.

Term or abbreviation	Definition
Risk analysis	Refers to the technical or scientific process for assessing the level of biosecurity risk associated with the goods, or the class of goods, and if necessary, the identification of conditions that must be met to manage the level of biosecurity risk associated with the goods, or class of goods to a level that achieves the ALOP for Australia.
Risk management measure	Are conditions that must be met to manage the level of biosecurity risk associated with the goods or the class of goods, to a level that achieves the ALOP for Australia. In this risk analysis, the term 'risk management measure' and 'phytosanitary measure' may be used interchangeably.
Saprophyte	An organism deriving its nourishment from dead organic matter.
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO 2019a).
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures.
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.
Surveillance	An official process which collects and records data on pest occurrence or absence by surveying, monitoring or other procedures (FAO 2019a).
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.
Trash	Soil, splinters, twigs, leaves and other plant material, other than fruit as defined in the scope of this risk analysis. For example, stem and leaf material, seeds, soil, animal matter/parts or other extraneous material
Treatment	Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalisation (FAO 2019a).
Unrestricted risk	Unrestricted risk estimates apply in the absence of risk management measures.
Vector	An organism that does not cause disease itself, but which causes infection by conveying pathogens from one host to another.
Viable	Alive, able to germinate or capable of growth.

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