Australian Government
Department of Agriculture, Fisheries and Forestry

Mangosteen fruit from Thailand

Final Import Risk Analysis Report

February 2004

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GLOSSARY OF TERMS AND ABBREVIATIONS

ALOP	appropriate level of protection
AQIS	Australian Quarantine and Inspection Service
ARD	Agricultural Regulatory Division of the Department of Agriculture, Thailand
Area	an officially defined country, part of a country or all or parts of several countries
Biosecurity Australia	a major operating group within the Australian Government Department of Agriculture, Fisheries and Forestry
Control (of a pest)	suppression, containment or eradication of a pest population
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
DOA	Department of Agriculture, Thailand
Endangered area	an area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss
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
Establishment	the perpetuation, for the foreseeable future, of a pest within an area after entry
FAO	Food and Agriculture Organization of the United Nations
Fresh	not dried, deep-frozen or otherwise conserved
ICA	Interstate Certification Assurance
ICON	AQIS Import Conditions database
Introduction	entry of a pest resulting in its establishment
IPPC	International Plant Protection Convention, as deposited in 1951 with FAO in Rome and as subsequently amended
IRA	import risk analysis
ISPM	International Standard for Phytosanitary Measures
National Plant Protection	

Organisation	official service established by a government to discharge the functions specified by the IPPC
Non-quarantine pest	pest that is not a quarantine pest for an area
OIE	Office International des Epizooties
Official	established, authorised or performed by a National Plant Protection Organisation
Official control (of a regulated pest)	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
Pathway	the ordered sequence of steps leading to an outcome, or event
PBPM	Plant Biosecurity Policy Memorandum
Pest	any species, strain or biotype of plant, animal, or pathogenic agent, injurious to plants or plant products
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
Pest-free area	an area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained
Pest risk analysis	the process of evaluating biological or other scientific evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it
Phytosanitary measure	any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests
PRA	pest risk analysis
PRA area	area in relation to which a pest risk analysis is conducted
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
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 with the territory of the importing contracting party
Spread	expansion of the geographical distribution of a pest within an area
SPS	Sanitary and Phytosanitary
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures
Stakeholders	Government agencies, individuals, community or industry groups or organisations, whether in Australia or overseas, including the proponent/applicant for a specific proposal
WTO	World Trade Organization

EXECUTIVE SUMMARY

The *Final Import Risk Analysis (IRA) Report* contains the following:

- Australia's framework for biosecurity policy and for import risk analysis, the international framework for trade in plants and plant products, Australia's current policy for importation of mangosteen and information on the background to this IRA;
- an outline of the methodology and results of pest categorisation, risk assessment and risk management;
- import conditions for fresh mangosteen fruit from Thailand;
- further steps in the IRA process; and
- a summary of stakeholder comments received on the draft IRA report and Biosecurity Australia's response.

Detailed risk assessments were conducted to determine an unrestricted risk estimate for those pests that were categorised as quarantine pests. For those pests for which the risk was considered to be above Australia's appropriate level of protection (ALOP), risk management measures have been developed. Consultation with Thailand's Department of Agriculture and input from stakeholders on the draft import conditions has resulted in the adoption of a set of risk management measures that form the basis of import conditions and will maintain Australia's ALOP for fresh mangosteen fruit from Thailand.

The risk assessment identified seven arthropod pests associated with the importation of mangosteen from Thailand that require risk management measures to reduce the risk to an acceptable level. The risks associated with the importation of fresh mangosteen fruit from Thailand would be managed by applying a combination of risk management measures and operational maintenance systems, specifically:

- registration of export orchards and packinghouses;
- harvesting of mature fruit with unbroken skin for freedom from fruit flies;
- cleaning for removal of mealybugs and black ants;
- targeted pre-export inspection by Thailand's Agricultural Regulatory Division (ARD);
- packing, labelling and storage compliance;
- phytosanitary certification by ARD; and
- targeted on-arrival inspection by the Australian Quarantine and Inspection Service (AQIS).

Details on the risk management measures, including their objectives, are provided within this final IRA report.

This final IRA report has now been released to stakeholders, together with a Plant Biosecurity Policy Memorandum (PBPM) containing the Executive Manager of Biosecurity Australia's recommendation for a policy determination. The Executive Manager has recommended that the importation of fresh mangosteens from Thailand be permitted subject to the application of phytosanitary measures as specified in the 'Import Conditions' section of this document.

Stakeholders have 30 days from the publication of this document to lodge an appeal in writing, before the final policy determination is made by the Director of Animal and Plant Quarantine.

BIOSECURITY FRAMEWORK

INTRODUCTION

This section outlines:

- The legislative basis for Australia's biosecurity regime;
- Australia's international rights and obligations;
- Australia's Appropriate Level of Protection;
- Import risk analysis; and
- Policy determination.

AUSTRALIAN LEGISLATION

The *Quarantine Act 1908* and its subordinate legislation, including the *Quarantine Proclamation 1998*, are the legislative basis of human, animal and plant biosecurity in Australia.

Some key provisions are set out below.

Quarantine Act: Scope

Sub section 4 (1) of the *Quarantine Act 1908* defines the scope of quarantine as follows.

> *In this Act, quarantine includes, but is not limited to, measures:*
>
> *(a) for, or in relation to:*
>
> *(i) the examination, exclusion, detention, observation, segregation, isolation, protection, treatment and regulation of vessels, installations, human beings, animals, plants or other goods or things; or*
>
> *(ii) the seizure and destruction of animals, plants, or other goods or things; or*
>
> *(iii) the destruction of premises comprising buildings or other structures when treatment of these premises is not practicable; and*
>
> *(b) having as their object the prevention or control of the introduction, establishment or spread of diseases or pests that will or could cause significant damage to human beings, animals, plants, other aspects of the environment or economic activities.*

Section 5D of the *Quarantine Act 1908* covers the level of quarantine risk.

> *A reference in this Act to a level of quarantine risk is a reference to:*
>
> *(a) the probability of:*
>
> *(i) a disease or pest being introduced, established or spread in Australia or the Cocos Islands; and*

(ii) the disease or pest causing harm to human beings, animals, plants, other aspects of the environment, or economic activities; and

(b) the probable extent of the harm.

Section 5D of the *Quarantine Act 1908* includes harm to the environment as a component of the level of quarantine risk.

Environment is defined in Section 5 of the *Quarantine Act 1908*, in that it:

includes all aspects of the surroundings of human beings, whether natural surroundings or surroundings created by human beings themselves, and whether affecting them as individuals or in social groupings.

Quarantine Proclamation

The *Quarantine Proclamation 1998* is made under the under the *Quarantine Act 1908*. It is the principal legal instrument used to control the importation into Australia of goods of quarantine (or biosecurity) interest. The Proclamation empowers a Director of Quarantine to grant a permit to import.

Section 70 of the *Quarantine Proclamation 1998* sets out the matters to be considered when deciding whether to grant a permit to import:

Things a Director of Quarantine must take into account when deciding whether to grant a permit for importation into Australia

(1) In deciding whether to grant a permit to import a thing into Australia or the Cocos Islands, or for the removal of a thing from the Protected Zone or the Torres Strait Special Quarantine Zone to the rest of Australia, a Director of Quarantine:

(a) must consider the level of quarantine risk if the permit were granted; and

(b) must consider whether, if the permit were granted, the imposition of conditions on it would be necessary to limit the level of quarantine risk to one that is acceptably low; and

(ba) for a permit to import a seed of a kind of plant that was produced by genetic manipulation -- must take into account any risk assessment prepared, and any decision made, in relation to the seed under the Gene Technology Act; and

(c) may take into account anything else that he or she knows that is relevant.

Development of Biosecurity Policy

As can be seen from the above extracts, the legislation establishes the concept of the level of biosecurity (quarantine) risk as the basis of decision-making under Australian quarantine legislation.

Import risk analyses are a significant contribution to the information available to the Director of Animal and Plant Quarantine - a decision maker for the purposes of the

Quarantine Proclamation. Import risk analysis is conducted within an administrative process – known as the IRA process (described in the *IRA Handbook*[1])

The purpose of the IRA process is to deliver a policy recommendation to the Director of Animal and Plant Quarantine that is characterised by sound science and by transparency, fairness and consistency. The key elements of the IRA process are covered in "Import Risk Analysis" below.

AUSTRALIA'S INTERNATIONAL RIGHTS AND OBLIGATIONS

It is important that import risk analysis conforms with Australia's rights and obligations as a WTO Member country. These rights and obligations derive principally from the World Trade Organization's *Agreement on the Application of Sanitary and Phytosanitary Measures* (SPS Agreement), although other WTO agreements may also be relevant. Specific international guidelines on risk analysis developed under the International Plant Protection Convention (IPPC) and by the Office International des Epizooties (OIE) are also relevant.

The SPS Agreement recognises the right of WTO Member countries to determine the level of sanitary and phytosanitary protection they deem appropriate, and to take the necessary measures to achieve that protection. Sanitary (human and animal health) and phytosanitary (plant health) measures typically apply to trade in, or movement of, animal and plant based goods within or between countries. The SPS Agreement applies to measures that may directly or indirectly affect international trade and that protect human, animal or plant life or health from pests and diseases or a Member's territory from a pest.

The SPS Agreement provides for the following:

- The right of WTO Member countries to determine the level of sanitary and phytosanitary protection (its appropriate level of protection, or ALOP) they deem appropriate;
- An importing Member has the sovereign right to take measures to achieve the level of protection it deems appropriate to protect human, animal or plant life or health within its territory;
- An SPS measure must be based on scientific principles and not be maintained without sufficient scientific evidence;
- An importing Member shall avoid arbitrary or unjustifiable distinctions in levels of protection, if such distinctions result in discrimination or a disguised restriction on international trade;

1 Biosecurity Australlia (2003) *Import Risk Analysis Handbook*, Department of Agriculture, Fisheries and Forestry.

- An SPS measure must not be more trade restrictive than required to achieve an importing Member's ALOP, taking into account technical and economic feasibility;
- An SPS measure should be based on an international standard, guideline or recommendation where these exist, unless there is a scientific justification for a measure which results in a higher level of SPS protection to meet the importing Member's ALOP;
- An SPS measure conforming to an international standard, guideline or recommendation is deemed to be necessary to protect human, animal or plant life or health, and to be consistent with the SPS Agreement;
- Where an international standard, guideline or recommendation does not exist or where, in order to meet an importing Member's ALOP, a measure needs to provide a higher level of protection than accorded by the relevant international standard, such a measure must be based on a risk assessment; the risk assessment must take into account available scientific evidence and relevant economic factors;
- Where the relevant scientific evidence is insufficient, an importing Member may provisionally adopt SPS measures on the basis of available pertinent information. In such circumstances, Members shall seek to obtain the additional information necessary for a more objective assessment of risk and review the SPS measure accordingly within a reasonable period of time;
- An importing Member shall accept the measures of other countries as equivalent, if it is objectively demonstrated that the measures meet the importing Member's ALOP.

AUSTRALIA'S APPROPRIATE LEVEL OF PROTECTION (ALOP)

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

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

ALOP can be illustrated using a 'risk estimation matrix' Table 1. The cells of this matrix describe the product of likelihood[2] and consequences — termed 'risk'. When interpreting the risk estimation matrix, it should be remembered that, although the descriptors for each

[2] The terms "likelihood" and "probability" are synonymous. "Probability" is used in the *Quarantine Act 1908* while "likelihood" is used in the WTO SPS Agreement. These terms are used interchangeably in this IRA Report.

axis are similar ('low', 'moderate', 'high', etc), the vertical axis refers to *likelihood* and the horizontal axis refers to *consequences*.

Table 1 Risk estimation matrix

Likelihood of entry, establishment or spread	Negligible impact	Very low	Low	Moderate	High	Extreme impact
High likelihood	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 likelihood	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk

Consequences of entry, establishment or spread

The band of cells in Table 1 marked 'very low risk' represents Australia's ALOP, or tolerance of loss.

Risk Management and SPS Measures

Australia's plant and animal health status is maintained through the implementation of measures to facilitate the importation of products while protecting the health of people, animals and plants.

Australia bases its national measures on international standards where they exist and where they deliver the appropriate level of protection from pests and diseases. However, where such standards do not achieve Australia's level of biosecurity protection, or relevant standards do not exist, Australia exercises its right under the SPS Agreement to take appropriate measures, justified on scientific grounds and supported by risk analysis.

Australia's approach to addressing requests for imports of animals, plants and their products where there are biosecurity risks is, where appropriate, to draw on existing sanitary and phytosanitary measures for similar products with comparable risks. However, where measures for comparable biosecurity risks have not previously been established, further action would be required to assess the risks to Australia and determine the sanitary and phytosanitary measures needed to achieve Australia's ALOP.

IMPORT RISK ANALYSIS

Description

In animal and plant biosecurity, import risk analysis identifies the pests and diseases relevant to an import proposal, assesses the risks posed by them and, if those risks are unacceptable, specifies the measures that could be taken to reduce those risks to an acceptable level. These analyses are conducted via an administrative process (described in the *IRA Handbook*) that involves, among other things, notification to the WTO, consultation and appeal.

Undertaking IRAs

Biosecurity Australia may undertake an IRA if:

- there is no relevant existing biosecurity measure for the good and pest/disease combination; or
- a variation in established policy is desirable because pests or diseases, or the likelihood and/or consequences of entry, establishment or spread of the pests or diseases could differ significantly from those previously assessed.

Environment and human health

When undertaking an import risk analysis, Biosecurity Australia takes into account harm to the environment as part of its assessment of biosecurity risks associated with the potential import.

Under the *Environment Protection and Biodiversity Conservation Act 1999*, Environment Australia may assess proposals for the importation of live specimens and their reproductive material. Such an assessment may be used or referred to by Biosecurity Australia in its analyses.

Biosecurity Australia also consults with other Commonwealth agencies where they have responsibilities relevant to the subject matter of the IRA, e.g. Food Standards Australia New Zealand (FSANZ) and the Department of Health and Ageing.

The IRA Process in summary

The process consists of the following major steps:

Initiation**:** This is the stage where the identified need for an IRA originates.

Scheduling and Scoping**:** At this stage, Biosecurity Australia considers all the factors that affect scheduling. Consultation with States, Territories and other Commonwealth agencies is involved. There is opportunity for appeal by stakeholders at this stage.

Risk Assessment and Risk Management**:** Here, the major scientific and technical work relating to risk assessment is performed. There is detailed consultation with stakeholders.

Reporting**:** Here, the results of the IRA are communicated formally. There is consultation with States and Territories. The Executive Manager of Biosecurity Australia then delivers the biosecurity policy recommendation arising from the IRA to the Director of Animal and Plant Quarantine. There is opportunity for appeal by stakeholders at this stage.

POLICY DETERMINATION

The Director of Animal and Plant Quarantine makes the policy determination, which is notified publicly.

METHOD FOR PEST RISK ANALYSIS

The technical component of an IRA for plants or plant products is termed a 'pest risk analysis', or PRA. Biosecurity Australia conducts a PRA in accordance with the International Standard for Phytosanitary Measure (ISPM) 11 *Pest Risk Analysis for Quarantine Pests.* A summary of the requirements of ISPM 11 is given in this section plus descriptions of the methodology used to meet these requirements in this IRA. This summary is given to provide a description of the methodology used for this IRA and to provide a context for the technical information that is provided later in this document.

A PRA comprises three discrete stages

- Stage 1: initiation of the PRA.
- Stage 2: risk assessment.
- Stage 3: risk management.

The *initiation* of a risk analysis involves the identification of the pest(s) and pathways of concern that should be considered for analysis. *Risk assessment* comprises pest categorisation, assessment of the probability of introduction and spread, and assessment of the potential consequences (including environmental consequences). *Risk management* describes the evaluation and selection of options to reduce the risk of introduction and spread of a pest.

STAGE 1: INITIATION

This PRA was initiated by a proposal from Thailand to export commercially produced fresh mangosteens into Australia for human consumption.

The aim of the initiation stage is to identify the pest(s) and pathways (e.g. commodity imports) which are of quarantine concern and should be considered for risk analysis in relation to the identified PRA area.

The 'PRA area' is defined in this PRA as Australia or in the case of regional quarantine pests the "PRA area" is defined by the State or Territory of Australia that has regional freedom from the pest. The 'endangered area' is defined as any area within Australia, where susceptible hosts are present, and in which ecological factors favour the establishment of a pest that might be introduced in association with Thai mangosteens. The pathway is considered to be commercially produced fresh mangosteens from Thailand for human consumption.

STAGE 2: PEST RISK ASSESSMENT

Risk assessment describes the process of identifying pests of biosecurity concern, and estimating the risk (the probability of entry, establishment or spread, and the magnitude of the potential consequences) associated with each.

This pest risk assessment was carried out in accordance with IPPC standards and reported in the following steps:

- pest categorisation;
- assessment of probability of entry, establishment and spread; and
- assessment of potential consequences (including environmental consequences).

Pest risk assessment needs to be only as complex as is technically justified by the circumstances. ISPM 11 allows a specific PRA to be judged against the principles of necessity, minimal impact, transparency, equivalence, risk analysis, managed risk and non-discrimination.

Pest categorisation

Pest categorisation is a process to examine for each pest whether the criteria in the definition of a quarantine pest are satisfied. That is, whether the pests identified in Stage 1 (Initiation of the PRA) are 'quarantine pests' or not.

As stated in ISPM 11, 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. An 'endangered area' is an area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss. Under IPPC and FAO terminology, 'official control' means 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 the management of regulated non-quarantine pests.

On the basis of these definitions, the process of pest categorisation is summarised by the IPPC in the five elements outlined below:

- *Identity of the pest*. The identity of the pest should be clearly defined to ensure that the assessment is being performed on a distinct organism, and that biological and other information used in the assessment is relevant to the organism in question. If this is not possible because the causal agent of particular symptoms has not yet been fully identified, then it should have been shown to produce consistent symptoms and to be transmissible.

  The taxonomic unit for the pest is generally species. The use of a higher or lower taxonomic level should be supported by scientifically sound rationale. For levels below the species, this should include evidence demonstrating that factors such as differences in virulence, host range or vector relationships are significant enough to affect phytosanitary status.

Where a vector is involved, the vector may also be considered a pest to the extent that it is associated with the causal organism and is required for transmission of the pest.

- *Presence or absence in the endangered area*. The pest should be absent from all or part of the endangered area.
- *Regulatory status*. If the pest is present but not widely distributed in the PRA area, it should be under official control or be expected to be under official control in the near future.
- *Potential for establishment and spread in the PRA area*. Evidence should be available to support the conclusion that the pest could become established or spread in the PRA area. The PRA area should have ecological/climatic conditions including those in protected conditions suitable for the establishment and spread of the pest where relevant, host species (or near relatives), alternate hosts and vectors should be present in the PRA area.
- *Potential for consequences in the endangered area*. There should be clear indication that the pest is likely to have an unacceptable consequence (including environmental consequences) in the PRA area.

Pest categorisation was carried out in two stages for this IRA.

A list of pests of mangosteens in Thailand was categorised according to the presence or absence of each pest in Australia, and the association of each pest with mangosteen fruit. This stage of the categorisation was released in the *Technical Issues Paper: Import Risk Analysis (IRA) for the importation of fresh mangosteen fruit from Thailand* in February 2003.

The second stage of pest categorisation was documented in the draft IRA report. This stage was based on the categorisation of each pest absent from Australia (or part(s) of Australia) and with potential for entry according to (a) its potential to establish or spread in Australia, and, (b) its potential for consequences. Categorisation of potential for establishment or spread and potential for consequences was dichotomous, and expressed using the terms 'feasible' / 'not feasible', and 'significant' / 'not significant', respectively. A summary of the results of pest categorisation for this IRA is given in the 'Pest Categorisation' section of this document.

Pests found to have potential for entry, establishment or spread and potential for consequences satisfy the criteria for a quarantine pest. Further background and methodology for the detailed assessments conducted on the quarantine pests is provided below.

Assessment of the probability of entry, establishment or spread

Details on assessing the 'probability of entry', 'probability of establishment' and 'probability of spread after establishment' of a pest are given in ISPM 11. A synopsis of these details is given below, followed by a description of the qualitative methodology used in this IRA.

Probability of entry

The 'probability of entry' describes the probability that a quarantine pest will enter Australia as a result of trade in a given commodity, be distributed in a viable state to an endangered area and subsequently be transferred to a suitable host.

Steps identified in ISPM 11 relevant to PRA initiated by a pathway are:

- *Probability of the pest being associated with the pathway at origin* – e.g. prevalence in the source area, occurrence of life stages that would be associated with the commodity, volume and frequency of movement along the pathway, seasonal timing, pest management, cultural and commercial procedures applied at the place of origin.
- *Probability of survival during transport or storage* – e.g. speed and conditions of transport and duration of the life cycle, vulnerability of the life-stages during transport or storage, prevalence of the pest, commercial procedures applied.
- *Probability of pest surviving existing pest management procedures*
- *Probability of transfer to a suitable host* – e.g. dispersal mechanisms, whether the imported commodity is sent to few or many destination points in the PRA area, time of year at which import takes place, intended use of the commodity, risks from by-products and waste.

The probability of entry may be divided for administrative purposes into the following components:

- **The probability of importation:** the probability that a pest will arrive in Australia when a given commodity is imported; and
- **The probability of distribution:** the probability that the pest will be distributed (as a result of the processing, sale or disposal of the commodity) to the endangered area and subsequently transferred to a suitable site on a susceptible host.

In breaking down the probability of entry into these two components, Biosecurity Australia has not altered the original meaning. The two components have been identified and separated to enable onshore and offshore pathways to be described individually.

The probability of importation and the probability of distribution are obtained from pathway scenarios depicting necessary steps in (a) the sourcing of the commodity for export; (b) its processing, transport and storage; (c) its utilisation in Australia; and (d) the generation and disposal of waste.

Probability of establishment

In order to estimate the probability of establishment of a pest, reliable biological information (life cycle, host range, epidemiology, survival, etc.) should be obtained from the areas where the pest currently occurs. The situation in the PRA area can then be compared with that in the areas where it currently occurs and expert judgement used to assess the probability of establishment. Examples provided in ISPM 11 of factors to consider are:

- Availability, quantity and distribution of hosts in the PRA area;
- Environmental suitability in the PRA area;
- Potential for adaptation of the pest;
- Reproductive strategy of the pest;
- Method of pest survival; and
- Cultural practices and control measures.

Probability of spread after establishment

In order to estimate the probability of spread of the pest, reliable biological information should be obtained from areas where the pest currently occurs. The situation in the PRA area can then be carefully compared with that in the areas where the pest currently occurs and expert judgement used to assess the probability of spread. Examples provided in ISPM 11 of factors to consider are:

- Suitability of the natural and/or managed environment for natural spread of the pest;
- Presence of natural barriers;
- The potential for movement with commodities or conveyances;
- Intended use of the commodity;
- Potential vectors of the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

Method for evaluating the probability of entry, establishment or spread in this IRA

Evaluation and reporting of likelihoods can be done qualitatively, semi-quantitatively or quantitatively. For qualitative evaluation, likelihoods assigned to steps in the scenarios are categorised according to a descriptive scale – e.g. ‘low’, ‘moderate’, ‘high’, etc – where no attempt has been made to equate descriptors with numeric values or scores. For semi-quantitative evaluation, likelihoods are given numeric ‘scores’ (e.g. 1, 2, 3), or probabilities and/or probability intervals (e.g. 0–0.0001, 0.0001–0.001, 0.001–0.01, 0.01–1). For quantitative evaluation, likelihoods are described in purely numeric terms.

Each of these three approaches to likelihood evaluation has its advantages and constraints and the choice of approach depends on both technical and practical considerations. For this IRA, likelihood was evaluated and reported qualitatively using the terms described in Table 2.

Table 2 Nomenclature for qualitative likelihoods

Likelihood	Descriptive definition
High	The event would be very likely to occur
Moderate	The event would occur with an even probability
Low	The event would be unlikely to occur
Very low	The event would be very unlikely to occur
Extremely low	The event would be extremely unlikely to occur
Negligible	The event would almost certainly not occur

Qualitative likelihoods can be assigned to individual steps or to the probability that all the steps will occur. If the likelihoods have been assigned to individual steps then some form of 'combination rule' is needed for calculating the probability that all steps will occur. For this IRA the likelihoods were combined using a tabular matrix, as shown in Table 3.

Table 3 Matrix of rules for combining descriptive likelihoods

	High	**Moderate**	**Low**	**V. Low**	**E. Low**	**Negligible**
High	High	Moderate	Low	V. Low	E. Low	Negligible
Moderate		Low	Low	V. Low	E. Low	Negligible
Low			V. Low	V. Low	E. Low	Negligible
Very low				E. Low	E. Low	Negligible
E. low					Negligible	Negligible
Negligible						Negligible

In this IRA, qualitative likelihoods were assigned to the probability of entry (comprising an importation step and a distribution step), the probability of establishment and the probability of spread. In other IRAs it may be considered relevant to assign qualitative likelihoods to additional steps. This would depend on the complexity of the issue and the information that was available. For example, within the importation step, separate qualitative likelihoods could be assigned to the probabilities that source fruit is infested, that the pest survives packinghouse procedures and that it survives storage and transport.

The procedure for combining likelihoods is illustrated in Table 4. A likelihood is assigned to the probability of importation (low) and the probability of distribution (moderate) then they are combined to give the probability of entry (low). The likelihoods are combined using the ‘rules’ provided in Table 3. The probability of entry is then combined with the likelihoods assigned to the probability of establishment (high) and probability of spread (very low) to give the overall probability of entry, establishment and spread (very low).

Table 4 Qualitative evaluation of the imported fruit scenario

Step	Qualitative descriptor	Product of likelihoods
Probability of importation	Low	
Probability of distribution	Moderate	
...... ➔ Probability of entry	➔	Low
Probability of establishment	High .... ➔	Low
Probability of spread	V. Low	
...... ➔ Probability of entry, establishment and spread	➔	V. Low

Assessment of consequences

The basic requirements for the assessment of consequences are described in the SPS Agreement with Article 5.3 stating that:

> *"Members shall take into account as relevant economic factors: the potential damage in terms of loss of production or sales in the event of the entry, establishment or spread of a pest or disease; the costs of control or eradication in the territory of the importing Member; and the relative cost-effectiveness of alternative approaches to limiting risks."*

Assessment of consequences is also referred to Annex A of the SPS Agreement in the definition of risk assessment:

> "*The evaluation of the likelihood of entry, establishment or spread of a pest or disease within the Territory of an importing Member according to the sanitary or phytosanitary measures which might be applied, and of the associated potential biological and economic consequences."*

Further detail on assessing these "relevant economic factors" or "associated potential biological and economic consequences" for plant-based analysis is given under the "potential economic consequences" section in ISPM 11[3]. This ISPM separates the consequences into "direct" and "indirect" and provides examples of factors to consider within each. These examples are listed below under the headings where they may be considered in an IRA. This is followed by a description of the methodology used in this IRA.

[3] A revised version of ISPM 11 was released in April 2003. The supplement on analysis of environmental risks endorsed by the ICPM has been integrated into ISPM 11 to produce ISPM No. 11 Rev. 1.

In this IRA, the term "consequence" is used to reflect the "relevant economic factors"/ "associated potential biological and economic consequences" and "potential economic consequences" terms as used in the SPS Agreement and ISPM 11 respectively.

Direct pest effects

Plant life or health

Examples from ISPM 11 that could be considered for the direct consequences on plant life or health:

- Known or potential host plants;
- Types, amount and frequency of damage;
- Crop losses, in yield and quality;
- Biotic factors (e.g. adaptability and virulence of the pest) affecting damage and losses;
- Abiotic factors (e.g. climate) affecting damage and losses;
- Rate of spread;
- Rate of reproduction;
- Control measures (including existing measures), their efficacy and cost;
- Effect of existing production practices; and
- Environmental effects.

Any other aspects of the environment

Examples from ISPM 11 that could be considered for the direct consequences on any other aspects of the environment:

- Environmental effects *(listed as a general example in ISPM 11)*;
- Reduction of keystone plant species;
- Reduction of plant species that are major components of ecosystems (in terms of abundance or size), and endangered native plant species (including effects below species level where there is evidence of such effects being significant); and
- Significant reduction, displacement or elimination of other plant species.

Indirect pest effects

Eradication, control etc

Examples from ISPM 11 that could be considered for the indirect consequences on eradication, control etc:

- Changes to producer costs or input demands, including control costs;
- Feasibility and cost of eradication or containment;
- Capacity to act as a vector for other pests; and

- Resources needed for additional research and advice.

Domestic trade & *International trade*

Examples from ISPM 11 that could be considered for the indirect consequences on domestic and international trade (the two are considered separately):

- Effects on domestic and export markets, including particular effects on export market access; and
- Changes to domestic or foreign consumer demand for a product resulting from quality changes.

Environment

Examples from ISPM 11 that could be considered for the indirect consequences on the environment:

- Environmental and other undesired effects of control measures;
- Social and other effects (e.g. tourism);
- Significant effects on plant communities;
- Significant effects on designated environmentally sensitive or protected areas;
- Significant change in ecological processes and the structure, stability or processes of an ecosystem (including further effects on plant species, erosion, water table changes, increased fire hazard, nutrient cycling, etc);
- Effects on human use (e.g. water quality, recreational uses, tourism, animal grazing, hunting, fishing); and
- Costs of environmental restoration.

Method for assessing consequences in this IRA

The relevant examples of direct and indirect consequences from ISPM 11 are considered for each of the broad groups (as listed above) and estimates of the consequences are assigned. The broad groups are shown in table form in the 'Risk Assessments for Quarantine Pests' section of this document.

The direct and indirect consequences are estimated based on four geographic levels. The terms 'local', 'district', 'regional' and 'national' are defined as:

Local: an aggregate of households or enterprises — e.g. 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, such as the 'North West Slopes and Plains' or 'Far North Queensland'.

Region: a geographically or geopolitically associated collection of districts — generally a State, although there may be exceptions with larger States such as Western Australia.

National: Australia-wide.

The consequence was described as 'unlikely to be discernible', of 'minor significance', significant' or 'highly significant':

- an '*unlikely to be discernible*' consequence is not usually distinguishable from normal day-to-day variation in the criterion;
- a consequence of '*minor significance*' is not expected to threaten economic viability, but would lead to a minor increase in mortality/morbidity or a minor decrease in production. For non-commercial factors, the consequence is not expected to threaten the intrinsic 'value' of the criterion — though the value of the criterion would be considered as 'disturbed'. Effects would generally be reversible;
- a '*significant*' consequence would threaten economic viability through a moderate increase in mortality/morbidity, or a moderate decrease in production. For non-commercial factors, the intrinsic 'value' of the criterion would be considered as significantly diminished or threatened. Effects may not be reversible; and
- a '*highly significant*' consequence would threaten economic viability through a large increase in mortality/morbidity, or a large decrease in production. For non-commercial factors, the intrinsic 'value' of the criterion would be considered as severely or irreversibly damaged.

The values were translated into a qualitative score (A–F) using the schema outlined in Table 5.

Table 5 The assessment of local, district, regional and national consequences

Impact score	Local	District	Regional	National
F	-	-	-	Highly significant
E	-	-	Highly significant	Significant
D	-	Highly significant	Significant	Minor
C	Highly significant	Significant	Minor	Unlikely to be discernible
B	Significant	Minor	Unlikely to be discernible	Unlikely to be discernible
A	Minor	Unlikely to be discernible	Unlikely to be discernible	Unlikely to be discernible

Level

The overall consequence for each pest was achieved by combining the qualitative scores (A–F) for each direct and indirect consequence using a series of decision rules. These rules are mutually exclusive, and were addressed in the order that they appeared in the list — for example, if the first rule did not apply, the second rule was considered. If the second rule did not apply, the third rule was considered and so on until one of the rules applied:

- Where the consequences of a pest with respect to any direct or indirect criterion is 'F', the overall consequences are considered to be 'extreme'.
- Where the consequences of a pest with respect to more than one criterion is 'E', the overall consequences are considered to be 'extreme'.
- Where the consequences of a pest with respect to a single criterion is 'E' and the consequences of a pest with respect to each remaining criterion is 'D', the overall consequences are considered to be 'extreme'.
- Where the consequences of a pest with respect to a single criterion is 'E' and the consequences of a pest with respect to remaining criteria is not unanimously 'D', the overall consequences are considered to be 'high'.
- Where the consequences of a pest with respect to all criteria is 'D', the overall consequences are considered to be 'high'.
- Where the consequences of a pest with respect to one or more criteria is 'D', the overall consequences are considered to be 'moderate'.
- Where the consequences of a pest with respect to all criteria is 'C', the overall consequences are considered to be 'moderate'.
- Where the consequences of a pest with respect to one or more criteria is considered 'C', the overall consequences are considered to be 'low'.

- Where the consequences of a pest with respect to all criteria is 'B', the overall consequences are considered to be 'low'.
- Where the consequences of a pest with respect to one or more criteria is considered 'B', the overall consequences are considered to be 'very low'.
- Where the consequences of a pest with respect to all criteria is 'A', the overall consequences are considered to be 'negligible'.

STAGE 3: PEST RISK MANAGEMENT

The conclusions from pest risk assessment are used to decide whether risk management is required and if so, the strength of measures to be used. Since zero-risk is not a reasonable option, the guiding principle for risk management is to manage risk to achieve the required degree of safety that can be justified and is feasible within the limits of available options and resources. Pest risk management (in the analytical sense) is the process of identifying ways to react to a perceived risk, evaluating the efficacy of these actions, and identifying the most appropriate options.

Overall risk is determined by the examination of the outputs of the assessments of the probability of entry, establishment or spread and the consequence. If the risk is found to be unacceptable, then the first step in risk management is to identify possible phytosanitary measures that will reduce the risk to, or below, an acceptable level.

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

Examples given of measures commonly applied to traded commodities include:

- *Options for consignments* – e.g. inspection or testing for freedom, prohibition of parts of the host, a pre-entry or post-entry quarantine system, specified conditions on preparation of the consignment, specified treatment of the consignment, restrictions on end use, distribution and periods of entry of the commodity.
- *Options preventing or reducing infestation in the crop* – e.g. treatment of the crop, restriction on the composition of a consignment so it is composed of plants belonging to resistant or less susceptible species, harvesting of plants at a certain age or specified time of the year, production in a certification scheme.
- *Options ensuring that the area, place or site of production or crop is free from the pest* – e.g. pest-free area, pest-free place of production or pest-free production site.
- *Options for other types of pathways* – e.g. consider natural spread, measures for human travellers and their baggage, cleaning or disinfestation of contaminated machinery.
- *Options within the importing country* – e.g. surveillance and eradication programs.

- *Prohibition of commodities* – e.g. if no satisfactory measure can be found.

The result of the pest risk management procedure will be either that no measures are identified which are considered appropriate or the selection of one or more management options that have been found to lower the risk associated with the pest(s) to an acceptable level. These management options form the basis of phytosanitary regulations or requirements.

Method for pest risk management in this IRA

The unrestricted risk estimate for each pest is determined by combining the overall estimate for 'entry, establishment and spread potential' with the overall expected consequence using a risk estimate matrix (Table 1). The requirement for risk management is then determined by comparing the unrestricted risk estimate with Australia's ALOP. Australia's ALOP is represented in this matrix by the row of cells marked 'very low risk'.

Where the estimate of unrestricted risk does not exceed Australia's ALOP, risk management is not required. Where the unrestricted risk estimate exceeds Australia's ALOP, risk management measures are required to reduce the risk to an acceptable level. Using this risk estimation matrix, risk management measures are required when the unrestricted risk estimate is low, moderate, high or extreme. Risk management measures are not required when the unrestricted risk estimate is very low or negligible.

Risk management measures are identified for each pest as required and are presented in the 'Risk Management' section of this document. The proposed phytosanitary regulations based on these measures are presented in the 'Import Conditions' section of this document.

PROPOSAL TO IMPORT MANGOSTEENS FROM THAILAND

BACKGROUND

Plant Biosecurity Policy Memorandum (PBPM) 2002/06 of February 2002 advised stakeholders that Biosecurity Australia was conducting an IRA for the importation of mangosteen from Thailand.

Biosecurity Australia notified stakeholders of the availability of a Technical Issues Paper for this IRA in PBPM 2003/7 of 17 February 2003, and invited stakeholder comments. The Technical Issues Paper included background to the IRA and preliminary results of pest categorisation.

A Draft IRA Report was released on 25 August 2003 and stakeholders were requested to provide comments within 60 days of release. Biosecurity Australia received comments from 26 stakeholders. Stakeholder comments were considered and incorporated into the final IRA report where appropriate and relevant.

Biosecurity Australia held a meeting with stakeholders in Cairns, Queensland on 30 September 2003 to discuss the draft IRA report for fresh mangosteen fruit from Thailand. Biosecurity Australia provided stakeholders with a copy of the minutes of this workshop in PBPM 2003/31 of 24 October 2003.

ADMINISTRATION

Timetable

The section ‘Further steps in the Import Risk Analysis process’ presented later in this report lists the steps for completion of this IRA.

Scope

This IRA considers quarantine risks that may be associated with the importation of fresh mangosteen (*Garcinia mangostana* L.) fruit from Thailand into Australia for human consumption. The produce will have been cultivated, harvested, packed and transported to Australia under commercial conditions.

AUSTRALIA'S CURRENT QUARANTINE POLICY FOR IMPORTS OF MANGOSTEEN

International arrangements

Fresh fruit — Imports of fresh mangosteen fruit into Australia for human consumption are not currently permitted from any country.

Non-tissue culture nursery stock — *In vivo* mangosteen nursery stock (e.g. whole plants, cuttings) may be imported from any country subject to the following requirements: an import permit, new packaging, packages labelled with the correct scientific name, specimens free from soil, disease symptoms and other extraneous contamination, inspection on arrival, methyl bromide fumigation and a minimum of nine months growth in a Government post-entry quarantine facility for visual disease screening.

Tissue culture nursery stock — *In vitro* mangosteen material may be imported from any country subject to the following requirements: an import permit, inspection on arrival and a minimum of nine months growth (out of tissue culture) in closed quarantine at a Government post-entry quarantine facility with disease screening.

Seed — Mangosteen seeds for sowing may be imported from any country subject to on-arrival inspection and other requirements, including freedom from soil, live insects, plant material (e.g. fruit pulp, leaf or stem material), and contamination with prohibited seeds. Seeds must be packed in new containers that are clearly labelled with the scientific name.

Further details on import conditions for mangosteen are available in the AQIS Import Conditions database (ICON)[4].

Domestic arrangements

The Commonwealth Government is responsible for regulating the movement of plants and their products into and out of Australia, but the State and Territory Governments have primary responsibility for plant health controls within Australia. 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.

Some states (i.e. New South Wales, Victoria and South Australia) accept that mangosteen with unbroken skin is a conditional non-host for Queensland fruit fly [*Bactrocera tryoni*] under the Interstate Certification Assurance (ICA)-13 scheme. ICA-13 covers approved fruit of durian, jaboticaba, jackfruit, longan, lychee, mangosteen, rambutan and pomegranate with unbroken skin (i.e. without any pre-harvest crack, puncture, pulled stem

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[4] Available at http://www.aqis.gov.au/icon/

or other break of the skin that penetrates through to the flesh and has not healed with callus tissue) (QDPI, 2001).

PEST CATEGORISATION

For this IRA, pest categorisation was conducted using the method described in the 'Method for Pest Risk Analysis' section of this document. Pests of mangosteens were categorised according to their presence or absence in Australia and their association with the pathway under consideration in this IRA (i.e. fresh mature mangosteen fruit) (Appendix 1). Potential quarantine pests were then considered further according to their potential for establishment and spread and their potential consequences (Appendix 2). These criteria were used to categorise and subsequently identify the quarantine pests of mangosteen fruit from Thailand.

Following comments received from stakeholders on the draft IRA report and further review of available literature, the list of potential quarantine pests was revised (Appendix 1). All weed species listed in the Technical Issues Paper have been included in Appendix 1 of this document.

Table 6 presents a list of the seven quarantine pests for mangosteens from Thailand. Detailed risk assessments for these quarantine pests are presented in the next section.

Table 6 Quarantine pests for fresh mangosteen fruit from Thailand

Scientific name	Common name
ARTHROPODA	
Bactrocera carambolae (Drew & Hancock) [Diptera: Tephritidae]	Carambola fruit fly
Bactrocera dorsalis Hendel [Diptera: Tephritidae]	Oriental fruit fly
Bactrocera papayae Drew & Hancock [Diptera: Tephritidae]	Papaya fruit fly
Dolichoderus sp. [Hymenoptera: Formicidae]	Black ant
Dysmicoccus neobrevipes Beardsley [Hemiptera: Pseudococcidae]	Gray pineapple mealybug
Pseudococcus cryptus (Hempel) [Hemiptera: Pseudococcidae]	Cryptic mealybug
Technomyrmex butteli Forel [Hymenoptera: Formicidae]	Black ant

RISK ASSESSMENTS FOR QUARANTINE PESTS

Detailed risk assessments were conducted for quarantine pests identified in the pest categorisation stage. Where pests shared similar biological characteristics, risk assessments were based on groupings of such pests (e.g. fruit flies). The risk management measures were also developed for these groups of pests.

The risk assessments were conducted on the basis of the standard cultivation, harvesting and packing activities involved in the commercial production of mangosteen fruit, for example, in-field hygiene and management of pests (e.g. orchard control program), cleaning and hygiene during packing, and commercial quality control activities.

Risk assessments are provided for the following pest groups: fruit flies (3 species), mealybugs (2 species), and ants (2 species). Each risk assessment includes a summary of supporting evidence with each likelihood estimate. Technical information used in the detailed risk assessments on each quarantine pest is provided in the datasheets (Appendix 2 of this document).

FRUIT FLIES

Fruit flies are serious pests of a wide variety of fruit and vegetable crops and are of major economic importance. The fruit flies examined in this import risk analysis are:

- *Bactrocera carambolae* (Drew & Hancock) (carambola fruit fly)
- *Bactrocera dorsalis* (Hendel) (Oriental fruit fly)
- *Bactrocera papayae* Drew & Hancock (papaya fruit fly).

Introduction and spread potential

Probability of importation

The likelihood that fruit flies will arrive in Australia with the importation of fresh mangosteens from Thailand: **Very low**.

There is evidence that mangosteen is a conditional non-host to many Tephritidae fruit fly species (Leach, 1997; Unahawutti and Oonthonglang, 2002), although mangosteen was recorded as a host of *B. dorsalis* in Thailand by Burikam *et al*. (1991).

Studies conducted by Leach (1997) in Queensland have shown that mangosteen is a conditional non-host to papaya fruit fly [*B. papayae*] and Queensland fruit fly [*B. tryoni*] (Leach, 2003, pers. comm.) and that only damaged ripe fruits can be infested. Likewise, *B.*

carambolae can infest mangosteen fruit with damaged or broken skin (Vijaysegaran, 2003, pers. comm.).

Studies carried out on *B. dorsalis* in Thailand have shown that mangosteen is a conditional non-host to this pest (Unahawutti and Oonthonglang, 2002). A pest risk assessment conducted in Hawaii also indicated that mangosteen may be a possible non-host for fruit flies (Follett, 1998).

In trials on mangosteens, only one *Bactrocera carambolae* was reared out of 48 fruit samples collected (Allwood *et al*., 1999). There is no indication from this study whether the fruits were harvested by hand from the tree or picked from the ground. Fruits dropped on the ground may be bruised and have cracks that would allow the fruit fly to oviposit inside the fallen fruit. In Thailand, mangosteen fruits are individually harvested and placed immediately into bins, thereby avoiding contact with the ground and reducing bruising and injury to the fruit.

Probability of distribution

The likelihood that fruit flies will be distributed as a result of the processing, sale or disposal of fresh mangosteens from Thailand, to the endangered area: **Moderate**.

Fruit infested with eggs and larvae are likely be distributed throughout Australia for retail sale. Adults, larvae and eggs are likely to be associated with infested waste. However, only damaged fruit are likely to be infested (Leach, 1997; Unahawutti and Oonthonglang, 2002). Although damaged fruit are likely to be detected and removed from consignments due to quality concerns, fruit flies have the capacity to complete their development in discarded fruit. Eggs can produce larvae within stored fruit, at the point of sale or after purchase by consumers. Adult flies are strong flyers and able to move directly from fruit into the environment to find a suitable host.

Probability of entry (importation × distribution)

The likelihood that fruit flies will enter Australia as a result of trade in fresh mangosteens from Thailand and be distributed in a viable state to the endangered area: **Very low**.

The overall probability of entry is determined by combining the likelihoods of importation and distribution using the matrix of 'rules' for combining descriptive likelihoods (Table 3).

Probability of establishment

Comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

For pests to establish and spread, a threshold limit must be reached. This threshold limit is the smallest number of pests capable of establishing a colony. One infested fruit is likely to contain many fruit fly larvae e.g. clutch sizes of 3-30 eggs have been recorded for *B. dorsalis* (Fletcher, 1989). However, the larval load on/in mangosteen fruit is likely to be considerably lower.

Surviving female flies must be successful in locating suitable mating partners and fruiting hosts to lay eggs. The mating behaviour of *B. dorsalis* requires that males gather to form aggregations or leks (Shelly and Kaneshiro, 1991). Females fly to such male aggregations to increase their chances of mating. However, there will be a limited number of males available to form a lek, therefore reducing the probability of a successful mating. Shelly (2001) reported that *B. dorsalis* females were observed more frequently at larger leks (of 18 males or more). There is a likelihood of many suitable hosts for fruit fly species around the vicinity of the port of entry and other suburban areas around Australia. *B. carambolae* and *B. papayae* are members of the *B. dorsalis* complex of fruit flies (CAB International, 2002), and would have similar mating behaviour to *B. dorsalis*.

There have been exotic fruit fly incursions in Australia, all of which have been eradicated. *B. papayae* was detected around Cairns, northern Queensland in 1995. It was eradicated from Queensland by implementing an eradication programme using male annihilation and protein bait spraying (SPC, 2002). This example demonstrates that fruit fly species from the *B. dorsalis* complex can establish in Australia.

Probability of spread

Comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **High**.

Fruit flies possess many characteristics that facilitate successful colonisation. These include a high reproductive rate, longevity of adult flies, broad environmental tolerances and host range of both commercial and wild species, which are widespread in Australia. The incidence of *B. papayae* in northern Australia in 1995 is indicative of the ability of introduced fruit fly species to spread. Initially, the infested area covered 4,500 km^2 (Allwood, 1995), and was centred around Cairns. The declared pest quarantine area later expanded to 78,000 km^2 of north Queensland, including urban areas, farms, rivers, coastline and a large part of the Wet Tropics World Heritage Area (Cantrell *et al*., 2002). *B. carambolae* and *B. dorsalis* would have a similar capacity to spread in Australia due to their close biological relationship to *B. papayae* as members of the *B. dorsalis* complex, and in view of their wide host range.

Probability of entry, establishment and spread

The overall likelihood that fruit flies will enter Australia as a result of trade in fresh mangosteens from Thailand, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Very low**.

The probability of entry, establishment and spread is determined by combining the likelihoods of entry, establishment and spread using the matrix of 'rules' for combining descriptive likelihoods (Table 3).

Consequences

Consideration of the direct and indirect consequences of fruit flies: **High**.

Criterion	Estimate
Direct consequences	
Plant life or health	**D** — Fruit flies can cause direct harm to a wide range of plant hosts and are estimated to have consequences of minor significance at the national level.
Any other aspects of the environment	**A** — Fruit flies introduced into a new environment will compete for resources with the native species. They are estimated to have consequences that are unlikely to be discernible at the national level and of minor significance at the local level.
Indirect consequences	
Eradication, control etc.	**E** — A control program would add considerably to the cost of production of the host fruit, costing between $200-900 per ha depending on the variety of fruit produced and the time of harvest (Anon., 1991). In 1995, the *B. papayae* (papaya fruit fly) eradication programme using male annihilation and protein bait spraying cost AU$35 million (SPC, 2002). Fruit flies are estimated to have significant consequences at the national level and highly significant consequences at the regional level.
Domestic trade	**D** — The presence of fruit flies in commercial production areas will have a significant effect at the regional level due to any resulting interstate trade restrictions on a wide range of commodities.
International trade	**D** — Fruit flies are regarded as the most destructive horticultural pests in the world. While they can cause considerable yield losses in orchards and suburban backyards, the major consequence facing Australian horticultural industries is the negative effect they have on gaining and maintaining export markets. When the Papaya fruit fly outbreak occurred in north Queensland, Australia experienced trade effects that affected the whole country. Fruit flies are estimated to have consequences of minor significance at the national level.
Environment	**A** — Pesticides required to control fruit flies are estimated to have consequences that are unlikely to be discernible at the national level and of minor significance at the local level.

Unrestricted risk estimate

Low. The unrestricted risk estimate is determined by combining the overall 'probability of entry, establishment and spread' with the 'consequences' using the risk estimation matrix (Table 1).

MEALYBUGS

Mealybugs injure plants by sucking sap through their tubular stylets. Heavy infestations may damage plants directly, while indirect damage may result from the ability of some mealybugs to vector plant viruses. Many mealybug species pose particularly serious problems to agriculture when introduced into new areas of the world where their natural enemies are not present (Miller *et al*., 2002). The mealybugs examined in this import risk analysis are:

- *Dysmicoccus neobrevipes* Beardsley (gray pineapple mealybug)
- *Pseudococcus cryptus* Hempel (cryptic mealybug).

Introduction and spread potential

Probability of importation

The likelihood that mealybugs will arrive in Australia with the importation of fresh mangosteens from Thailand: **High**.

Mangosteen orchards in Thailand are commonly infested with mealybug species, so fruit packed for export is likely to contain these pests as they can hide beneath the calyces (Lim *et al*., 1998).

Mealybugs have limited mobility, are small (1.4-3 mm) and often inconspicuous and usually live around or under the calyx of the fruit in the period from flowering onwards. On mangosteen they generally remain anchored on the fruit underneath the calyx.

As these pests hide under the fruit calyx, they are unlikely to be detected during routine visual quality inspection procedures within the packinghouse. Inspection procedures carried out in the packing station are concerned primarily with quality standards of fruit with regard to blemishes, premature ripening and visible splits, cracks, bruising or damage to the skin and calyces. Although all fruit are visually inspected, the procedures are not specifically directed at the detection of small arthropod pests that may be present under the calyx.

Routine washing procedures undertaken within the packinghouse may not totally remove all pests under the calyx. This is particularly true of those adult females or nymphs that have found protective spaces under the calyx or are protected by waxy cocoons.

The pests are likely to survive storage and transportation. Evidence regarding the tolerance of adult mealybugs or nymphs to a prolonged period of modified atmosphere and cool storage for these particular mealybug species could not be found. However, the pseudococcid species *Pseudococcus affinis* can survive for up 42 days storage at 0°C (Hoy and Whiting, 1997). There is a high likelihood that viable mealybugs present in fruit would remain viable on arrival in Australia.

Probability of distribution

The likelihood that mealybugs will be distributed as a result of the processing, sale or disposal of fresh mangosteens from Thailand, to the endangered area: **Moderate**.

The pests are likely to survive storage and transportation. Evidence regarding the tolerance of adult mealybugs or nymphs to a prolonged period of modified atmosphere and cool storage for these particular mealybug species could not be found. However, the pseudococcid species *Pseudococcus affinis* can survive for up 42 days storage at 0°C (Hoy and Whiting, 1997). There is a high likelihood that viable mealybugs present in fruit would remain viable on arrival in Australia.

Adults and nymphs are likely to be associated with infested waste. Mealybugs can enter the environment in three ways: adults can be associated with discarded mangosteen skin, first instar nymphs (crawlers) may be discarded with waste carton and liners, or crawlers can be blown by wind, or carried by other vectors, from mangosteen at the point of sale or after purchase by consumers. Long-range dispersal of these pests would require movement of adults and nymphs on infested vegetative material or fruit. Shorter-range dispersal would occur readily through the random movement of crawlers with wind currents or biological or mechanical vectors. Mealybugs imported with fruit are likely to be at non-mobile stages and can be transported by ants to a suitable host. Because all stages of mealybugs survive in the environment for some time, they could be transferred to a susceptible host because they are highly polyphagous.

Adult female mealybugs would need to be carried onto hosts by vectors such as people or other insects. Adult males are winged but fragile and short-lived and do not persist for more than several days (Kessing and Mau, 1992). Crawlers are small and less robust than adult females, but can be dispersed onto other plants up to several hundred yards by wind (Rohrbach *et al*., 1988).

Probability of entry (importation × distribution)

The likelihood that mealybugs will enter Australia as a result of trade in fresh mangosteens from Thailand and be distributed in a viable state to the endangered area: **Moderate**.

The overall probability of entry is determined by combining the likelihoods of importation and distribution using the matrix of 'rules' for combining descriptive likelihoods (Table 3).

Probability of establishment

Comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

Mealybugs are highly polyphagous and host plants are common in Australia (e.g. citrus, mango and pineapple). The skin of infested fruit is likely to be discarded and thereby provide a pathway for mealybugs to establish on suitable hosts especially in the warmer subtropical and tropical regions of Australia.

This group of pests has a high reproductive rate. The reproductive strategy, and thus persistence, of these pests is based largely on the longevity and fecundity of the adult female, the mobility of the short-lived adult male and the ability of the crawlers to disperse via crawling, vectors or wind and locate new hosts. *D. neobrevipes* is known to reproduce sexually, and mating must occur for larvae to be produced. Unmated females of *D. neobrevipes* live for an average length of 148 days, while mated females an average of 95 days (Ito, 1938). Adult males are short-lived (Kessing and Mau, 1992). Females of *D. neobrevipes* produce between 350-1000 larvae during their lifetime (Kessing and Mau, 1992). The first instar larvae or 'crawlers' disperse to suitable feeding sites on their hosts or new plants. Nymphs are active during the first instar stage and can travel some distance to a new plant before their mobility becomes limited for the remaining nymphal (larval) instars. Crawlers can survive only about a day without feeding.

Many mealybugs are considered invasive and have been introduced into new areas and established (Miller *et al*., 2002). These two species have shown that they have the ability to establish after being introduced into new environments. For example, *D. neobrevipes* is native to the Neotropicals (Miller *et al*., 2002) and has now established in North America, Southeast Asia and the Pacific.

Probability of spread

Comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **High**.

Once second and then subsequent generations of mealybugs are established on commercial, susceptible household and wild host plants, mealybugs are likely to persist indefinitely and to spread progressively over time. This spread would be assisted by wind dispersal, vectors and by the movement of plant material. It is very unlikely that mealybugs would be contained by management practices or by regulation.

Tropical or subtropical areas of Australia would be suitable for the spread of these mealybugs because they are recorded from these environments. Adults and nymphs can be moved within and between plantations with the movement of equipment and personnel, and crawlers can be dispersed onto other plants up to several hundred yards by wind (Rohrbach *et al*., 1988). The relevance of natural enemies in Australia is not known.

Probability of entry, establishment and spread

The overall likelihood that mealybugs will enter Australia as a result of trade in fresh mangosteens from Thailand, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Moderate**.

The probability of entry, establishment and spread is determined by combining the likelihoods of entry, establishment and spread using the matrix of 'rules' for combining descriptive likelihoods (Table 3).

Consequences

Consideration of the direct and indirect consequences of mealybugs: **Low**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — Mealybugs can cause direct harm to a wide range of plant hosts and have also been reported as disease vectors e.g. pineapple wilt disease (Rohrbach *et al*., 1988). Fruit quality can be reduced by the presence of secondary sooty mould. These mealybug species are highly polyphagous and host plants are common in Australia e.g. citrus, mango, pineapple. Mealybugs are estimated to have consequences that are unlikely to be discernible at the national level and of minor significance at the regional level.
Any other aspects of the environment	**A** — Mealybugs introduced into a new environment will compete for resources with the native species. They are estimated to have consequences that are unlikely to be discernible at the national level and of minor significance at the local level.
Indirect consequences	
Eradication, control etc.	**B** — Programs to minimise the impact of these pests on host plants are likely to be costly and include pesticide applications and crop monitoring. Existing control programs can be effective for some hosts (e.g. broad spectrum pesticide applications) but not all hosts (e.g. where specific integrated pest management programs are used). Mealybugs are estimated to have consequences that are unlikely to be discernible at the national level and of minor significance at the district level.
Domestic trade	**B** — The presence of these pests in commercial production areas can have a significant effect at the local level due to any resulting interstate trade restrictions on a wide range of commodities. These restrictions can lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**B** — for *Dysmicoccus neobrevipes* **C** — for *Pseudococcus cryptus* The presence of these pests in commercial production areas of a wide range of commodities (e.g. citrus, mango) can have a significant effect at the local level due to any limitations to access to overseas markets where these pests

	are absent. Both species considered in this analysis feed on citrus. Australia exports citrus fruit worth $40-60 million to the USA from the Riverland-Sunraysia-Riverina (R-S-R) area. Extension of this area has also been negotiated for the USA market. Consideration for export of citrus from areas in Queensland and New South Wales to the USA market is also underway. *D. neobrevipes* has been reported from Florida (Miller and Miller, 2002) and therefore, will not be likely to affect citrus trade with the USA if it became established in Australia. *P. cryptus*, however, does not occur in the continental USA and, if it became established in the R-S-R and other possible export areas in Australia, would complicate citrus trade with the USA and might result in the reintroduction of fumigation for unidentifiable mealybugs or the necessity for pest survey to verify the mealybugs in the export citrus orchards.
Environment	**A** — Although additional pesticide applications would be required to control these pests on susceptible crops, this is not considered to impact on the environment. They are estimated to have consequences that are unlikely to be discernible at the national level and of minor significance at the local level.

Unrestricted risk estimate

Low. The unrestricted risk estimate is determined by combining the overall 'probability of entry, establishment and spread' with the 'consequences' using the risk estimation matrix (Table 1).

BLACK ANTS

While black ants are not plant pests as such, they are associated with a group of pests of mangosteen in Thailand (mealybugs). The black ants examined in this import risk analysis are:

- *Technomyrmex butteli* Forel.
- *Dolichoderus* sp.

Introduction and spread potential

Probability of importation

The likelihood that black ants will arrive in Australia with the importation of fresh mangosteens from Thailand: **Moderate**.

Both genera are commonly found in the tropics and subtropics (Shattuck and Barnett, 2001), although generally in small numbers. Black ants are minute (2-4 mm) and have been observed hiding under the calyces of mangosteen fruit in Thailand and Australia (BA, 2003; RTEGA, 2004, pers. comm.).

Black ants such as *Technomyrmex butteli* and *Dolichoderus* sp. are attracted to honeydew secretions made by mealybugs (Shattuck and Barnett, 2001) and therefore, may be found attending on mangosteens. These foraging ants nest either in the soil or arboreally, and sometimes use organic material such as plant fibres to construct nests (Shattuck and Barnett, 2001). There is a possibility that a single, mated *Technomyrmex* queen will form a colony under the fruit calyx, as they are an opportunistic species. However, the normal method of colonisation for both genera is for queens to search for a suitable nest site in the soil (Shattuck, 2003, pers. comm.). Black ants have been observed to carry soil and construct nests under the calyces of mangosteen fruit in Thailand (BA, 2003). As many ants treat aerial soil and litter as though it were the ground (Longion and Nadkarni, 1990), it is likely that Thai black ants may nest in soil under the calyces of mangosteen fruit.

Queens are capable of forming a colony without worker ants and can survive for six months without feeding, as long as moisture is present (Shattuck, 2003, pers. comm.). However, queens of both genera are vulnerable to predation by other ant species and predators and have a low survival rate (Shattuck, 2003, pers. comm.).

Probability of distribution

The likelihood that black ants will be distributed as a result of the processing, sale or disposal of fresh mangosteens from Thailand, to the endangered area: **High**.

Although both genera are commonly found in the tropics and subtropics (Shattuck and Barnett, 2001), they are highly adaptive and are likely to survive cold storage and transportation. The queen can survive without feeding for six months, provided there is moisture present (Shattuck, 2003, pers. comm.). Males and female reproductives are winged and mating flights are the primary means of colony propagation for both genera (Shattuck, 2003, pers. comm.).

Probability of entry (importation × distribution)

The likelihood that black ants will enter Australia as a result of trade in fresh mangosteens from Thailand and be distributed in a viable state to the endangered area: **Moderate**.

The overall probability of entry is determined by combining the likelihoods of importation and distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 3).

Probability of establishment

Comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **Moderate**.

Both genera are highly adaptable as the ants can nest in both open and shaded situations (Shattuck and Barnett, 2001). Workers of *Dolichoderus* are general scavengers and also tend mealybugs to collect their honeydew. Both genera nest either in the soil or arboreally. *Technomyrmex* can be common in disturbed habitats and are known to survive in cool climates by living indoors (Shattuck and Barnett, 2001). Ants of both genera are already present in Australia, which indicates that the climate is suitable for their establishment, particularly in tropical and subtropical areas.

Some *Technomyrmex* species are known to have worker-like males and queens (Terron, 1972). However, workers from either genus are not capable of transforming into a queen (Shattuck, 2003, pers. comm.). In general, at least 50-100 ants with a mated queen are needed to form a viable colony, but a queen is capable of forming a colony without worker ants (Shattuck, 2003, pers. comm.). Queens can survive for six months without feeding, as long as moisture is present, although a colony will die if the queen dies (Shattuck, 2003, pers. comm.).

Probability of spread

Comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **High**.

Mating flights are the primary means of colony propagation for both genera (Shattuck, 2003, pers. comm.). Satellite nesting (or budding) is known to occur in *Technomyrmex* in which a portion of a colony becomes an autonomous unit (Shattuck, 2003, pers. comm.). Environmental triggers cause the simultaneous release of queens and males from the vast majority of nests of a given species in a given area (Shattuck and Barnett, 2001). Because of this, huge numbers of queens and males can be released on the same day, sometimes over hundreds of kilometres (Shattuck and Barnett, 2001). These mass emergences last only a few days, with the queens mating and attempting to establish new nests while the males generally die within several days of leaving their nests (Shattuck and Barnett, 2001).

Ants are capable of expanding naturally and steadily into new territories because of their high reproductive rate. Nests of black ants usually have more than one laying queen. Some species of *Technomyrmex* are known to have a high fecundity which, coupled with a rapid development of workers, can lead to an increased population in a relatively short timeframe.

Probability of entry, establishment and spread

The overall likelihood that black ants will enter Australia as a result of trade in fresh mangosteens from Thailand, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Moderate**.

The probability of entry, establishment and spread is determined by combining the likelihoods of entry, establishment and spread using the matrix of 'rules' for combining descriptive likelihoods (Table 3).

Consequences

Consideration of the direct and indirect consequences of black ants: **Low**.

Criterion	Estimate
Direct consequences	
Plant life or health	**B** — Black ants do not directly affect the health of the tree or fruit. They tend honeydew-secreting pests, increasing their numbers and promote the proliferation of sooty moulds (Gullan, 1997). They are estimated to have consequences that are unlikely to be discernible at the national level and of minor significance at the district level.
Any other aspects of the environment	**C** — Introduction of black ants into a new environment can be significant at the district level. Both species exhibit high adaptive ability, food searching and competitive ability and could have impacts on native fauna and flora, particularly in disturbed areas. Black ants introduced into a new environment may compete for resources with the native species.
Indirect consequences	
Eradication, control etc.	**B** — Both ants can increase the cost of pest control both in the field and during postharvest treatment and handling. It would also be costly to eradicate them. State authorities in Australia are in the process of eradicating the red imported fire ant by using low-toxic bait and chemical treatments (QDPI, 2002). Black ants are estimated to have consequences which are unlikely to be discernible at the national level and of minor significance at the district level.
Domestic trade	**B** — The presence of these pests in commercial production areas can have a significant effect at the local level due to any resulting interstate trade restrictions on a wide range of commodities. These restrictions can lead to a loss of markets.
International trade	**B** — The presence of these pests in commercial production areas of a range of commodities (e.g. mangosteen) can have a significant effect at the local level due to any limitations to access to overseas markets where these pests are absent.
Environment	**A** — Although additional pesticide applications would be required to control these pests on susceptible crops, this is not considered to otherwise impact on the environment. They are estimated to have consequences that are unlikely to be discernible at the national level and of minor significance at the local level.

Unrestricted risk estimate

Low. The unrestricted risk estimate is determined by combining the overall 'probability of entry, establishment and spread' with the 'consequences' using the risk estimation matrix (Table 1).

CONCLUSION: RISK ASSESSMENTS

The results of the risk assessments are summarised in Table 7. The results show that unrestricted risk estimates for fruit flies, mealybugs and black ants all exceed Australia's ALOP. Hence, risk management measures are required for these pests. The proposed risk management measures are described in the following section.

Table 7 Results of the risk assessments

Scientific name	Common name	Probability of Entry	Probability of Establishment	Probability of Spread	Overall Probability of entry, establishment and spread	Consequences	Unrestricted Risk
Bactrocera carambolae	carambola fruit fly	Very low	High	High	Very low	High	Low
Bactrocera dorsalis	Oriental fruit fly	Very low	High	High	Very low	High	Low
Bactrocera papayae	papaya fruit fly	Very low	High	High	Very low	High	Low
Dolichoderus sp.	black ant	Moderate	Moderate	High	Moderate	Low	Low
Dysmicoccus neobrevipes	gray pineapple mealybug	Moderate	High	High	Moderate	Low	Low
Pseudococcus cryptus	cryptic mealybug	Moderate	High	High	Moderate	Low	Low
Technomyrmex butteli Forel	black ant	Moderate	Moderate	High	Moderate	Low	Low

RISK MANAGEMENT

Pest risk management evaluates and selects options for measures to reduce the risk of entry, establishment or spread of quarantine pests assessed to pose an unacceptable level of risk to Australia via the importation of commercially produced mangosteens from Thailand i.e. mangosteens produced under standard cultivation, harvesting and packing activities.

Biosecurity Australia considers that the risk management measures below are commensurate with the identified risks. The measures described below will form the basis of import conditions for fresh mangosteens from Thailand, which are further detailed in the 'Import Conditions' section of this document.

RISK MANAGEMENT MEASURES

There are three categories of measures to manage the risks identified in the pest risk assessment:

- harvesting of mature fruit with unbroken skin for freedom from fruit flies,
- cleaning for removal of mealybugs and black ants, and
- supporting operational maintenance systems and verification of phytosanitary status.

[1] Harvesting of mature fruit with unbroken skin for freedom from fruit flies

Bactrocera carambolae, *B. dorsalis* and *B. papayae* were assessed to have an unrestricted risk estimate of low; therefore measures are required to mitigate that risk. Visual inspection alone is not considered to be an appropriate risk management option in view of the level of risk identified and because clear visual external signs of infestation (particularly in recently infested fruit) may not always be present. If infested fruit was not detected at inspection, fruit flies may enter, establish and spread. Harvesting of mature fruit with unbroken skin is considered to be an appropriate phytosanitary risk management measure for fruit flies.

Other postharvest disinfestation treatments (e.g. chemical dipping and methyl bromide fumigation) were identified as in-principle options for these pests but were considered to be no more effective and clearly more costly than the described measure.

Australia has conducted host status tests for papaya fruit fly (*B. papayae*) on mangosteen. Scientists from Thailand have also conducted similar studies with Oriental fruit fly (*B. dorsalis*). Results from both studies confirmed that mangosteen fruit at the mature stage (pink to maroon) with unbroken skin is a conditional non-host to these fruit fly species (Leach, 1997; Unahawutti and Oonthonglang, 2002).

In Australia, many States and Territories have accepted Interstate Certification Assurance (ICA) arrangements for domestic trade of several horticultural commodities that are susceptible hosts to *B. tryoni* (Queensland fruit fly) infestations. ICA-13 allows interstate movement of approved fruits, including mangosteen, based on the requirement for mature fruit with unbroken skin.

Mangosteen fruits for import into Australia will be required to be harvested at the mature stage and to have an unbroken skin. Fruit is to comply with the following two requirements:

Mature	means mature fruit harvested at the pink to maroon stage.
Unbroken skin	means the skin has no pre-harvest crack, puncture, pulled stem or other break that penetrates through to the flesh and has not healed with callus tissue.

The objective of this measure is to remove fresh mangosteen fruit with pre-harvest cracks, stings, puncture or other breaks in the skin (indicating a potential wound site through which the fruit flies may deposit eggs within the fruit) from the export pathway.

Additional risk management measures described in part [3] of this section will ensure that operational procedures are in place to maintain and verify the integrity of this measure.

[2] Cleaning for the removal of mealybugs and black ants

Mealybugs (*Dysmicoccus neobrevipes* and *Pseudococcus cryptus*) and black ants (*Dolichoderus* spp. and *Technomyrmex butteli*) were assessed to have an unrestricted risk estimate of low; therefore measures are required to mitigate that risk. As these pests can hide beneath the fruit calyx, visual inspection alone is not considered to be an appropriate risk management option. If infested fruit was not detected at inspection, these mealybugs and ants may enter, establish and spread.

Other postharvest chemical disinfestation treatments (e.g. methyl bromide fumigation and insecticide dip) were identified as in-principle options for these pests but were considered to be no more effective and clearly more costly than cleaning, which is the current measure used by Thailand for mangosteen exports to Japan and Taiwan.

All fruit are to be individually cleaned of mealybugs and black ants on the surface and underneath the calyx using physical or mechanical means, such as washing, pressurised air blast, high-pressure water jet blast, or a combination of these methods. Each sepal of the calyx is to be lifted carefully and cleaned underneath to ensure the removal of mealybugs, ants and nesting material and any other contaminants. Washing, air or water blasting is to be conducted in a designated area of the packinghouse where all soil, insects, debris and trash are removed in a manner that will ensure that pests are not able to reinfest fruit or packaging. This must be completed in packinghouses that are registered with, and audited by, ARD (see measure 3B).

Cleaning by air blasting is standard practice in Thailand for fruit that is exported to Japan and Taiwan. A gun/nozzle connected to the hose from an electrically driven air compressor is used in Thailand to blast air under the calyces of mangosteens. This activity involves examination and cleaning of every piece of fruit by an operator.

This method was observed by Australian scientists during a visit to Thailand in 2002 and found to be very successful in dislodging mealybugs, ants, thrips and plant debris from beneath the fruit calyx.

Cleaning of all fruit using washing and/or a pressurised air or water blast will reduce the likelihood of introduction of mealybugs, ants, other insect pests, soil and admixed organic matter by physically removing them from the fruit surface and beneath the fruit calyx.

Additional risk management measures described in part [3] of this section will ensure that operational procedures are in place to maintain and verify the integrity of this measure.

[3] Operational maintenance and verification of phytosanitary status

It is necessary to have a system of operational procedures in place to ensure that the phytosanitary status of fresh mangosteen from Thailand is maintained and verified during the process of production and export to Australia. This is to ensure that the objectives of the risk mitigation measures previously identified have been met and are being maintained.

The system of operational procedures for the production and export of fresh mangosteen from Thailand to Australia consists of:

- Registration of export orchards,
- Packinghouse registration and auditing of procedures,
- Packaging and labelling compliance,
- Pre-export inspection by ARD,
- Phytosanitary certification by ARD,
- Specific conditions for storage and movement of produce,
- On-arrival quarantine clearance by AQIS.

[3A] Registration of export orchards

All mangosteens for export to Australia must be sourced from export orchards registered with Thailand's ARD. Copies of the registration records must be made available to AQIS if requested. The ARD is required to register export orchards prior to commencement of exports.

All export orchards are expected to produce mangosteens under standard commercial cultivation, harvesting and packing activities, for example, in-field hygiene and management of pests (e.g. orchard control program), cleaning and hygiene during packing and commercial quality control activities. Orchards are expected to be kept clean and free of weeds and other trash.

The objective of this procedure is to ensure that orchards from which mangosteens are sourced can be identified. This is to allow trace back to individual orchards in the event of non-compliance. For example, if live pests are intercepted during on arrival inspection, the ability to identify a specific orchard allows the investigation and corrective action to be targeted rather than applying to all contributing orchards.

[3B] Packinghouse registration and auditing of procedures

All packinghouses involved in the export of mangosteen fruit to Australia must be registered with ARD. The cleaning for management of mealybugs and black ants is to be done within the registered packinghouses.

Packinghouses will be required to identify the individual orchard with a numbering system and identify fruit from individual orchards by marking cartons or pallets with the unique orchard number. The list of registered packinghouses must be kept by ARD and provided to AQIS if requested, with updates provided should packinghouses be added or removed from the list.

Registration of orchards and packinghouses is to include an audit program by ARD to ensure that packinghouses are suitably equipped to carry out the specified phytosanitary treatments. An audit is to be conducted prior to registration and then done at least annually.

The objective of this procedure is to ensure that packinghouses at which the cleaning of fruit is to be done can be identified. This is to allow trace back to individual packinghouses and orchards in the event of non-compliance.

[3C] Packing and labelling

All packages of mangosteen for export will be free from contaminated plant materials including trash and weed seeds and will meet Australia's general import conditions for fresh fruits and vegetables (C6000 General Requirements for All Fruit and Vegetables, available at http://www.aqis.gov.au/icon/). Trash refers to soil, splinters, twigs, leaves and other plant materials. Inspected and treated fruits would be required to be packed in new cartons. Packing material must be synthetic or highly processed if of plant origin. No unprocessed packing material of plant origin, such as straw, will be allowed. All wood material used in packaging of mangosteen must comply with the AQIS conditions (e.g. those in "Cargo containers: Quarantine aspects and procedures" (AQIS, 2003)).

All boxes will be labelled with the orchard registration number and packinghouse registration number for the purposes of trace back in the event that this is necessary. The pallets should be securely strapped only after phytosanitary inspection has been carried out following mandatory postharvest treatments. Palletised product is to be identified by attaching a uniquely numbered pallet card to each pallet or part pallet to enable trace back to registered orchards.

The objectives of this procedure are to ensure that:

- The mangosteens exported to Australia are not contaminated by weeds or trash.
- Unprocessed packing material (which may vector pests identified as not on the pathway and pests not known to be associated with mangosteen) is not imported with the mangosteens.
- The packaged mangosteens are labelled in such a way as to identify the orchard and packinghouse (see measure 3A).

[3D] Targeted pre-export inspection by ARD

ARD will inspect all consignments in accordance with official procedures for all visually detectable quarantine pests, weed seeds and trash, including soil, using sampling procedures developed by ARD in consultation with Biosecurity Australia/AQIS.

For individual fruit, sheltered sites such as the calyx and any indented areas are to be inspected carefully. During inspection, the fruit is to be examined directly with a lens, and any pests, trash or weed seeds are to be brushed onto a sheet of white paper for enhanced inspection with a lens or microscope and the pests identified.

Records of any interceptions made during these inspections (live or dead pests, and trash) are to be maintained by ARD and made available to Biosecurity Australia as requested. This information will assist in future reviews of this import pathway and consideration of the appropriateness of the phytosanitary measures that have been applied.

The objective of this targeted procedure is to ensure that mangosteens exported to Australia do not contain quarantine pests or trash on the surface of the fruit and underneath the fruit calyx, and comply with packing and labelling requirements.

[3E] Phytosanitary certification by ARD

ARD is required to issue a Phytosanitary Certificate for each consignment upon completion of pre-export inspection and treatment. The objective of this procedure is to provide formal documentation to AQIS verifying that the relevant measures have been done offshore. Each Phytosanitary Certificate is to contain the following information:

Additional declarations

"The mangosteens in this consignment have been produced in Thailand in accordance with the conditions governing entry of fresh mangosteen fruits to Australia."

Distinguishing marks

The orchard registration number, packinghouse registration number, number of cartons per consignment, and container and seal numbers (as appropriate); (to ensure trace back to the orchard in the event that this is necessary).

A consignment is the quantity of mangosteen fruits covered by one Phytosanitary Certificate that arrives at one port in one shipment. All consignments would need to be shipped directly from one port or city in Thailand to a designated port or city in Australia.

[3F] Specific conditions for storage and movement of produce

Packed product and packaging is to be protected from pest contamination during and after packing, during storage and during movement between locations (e.g. packing house to cool storage/depot, to inspection point, to export point).

Product for export to Australia that has been inspected and certified by ARD must be maintained in secure conditions that will prevent mixing with fruit for export to other destinations or the domestic market and kept in storage until export.

Security of the consignment is to be maintained until release from quarantine in Australia.

The objective of this procedure is to ensure that the phytosanitary status of the product is maintained during storage and movement.

[3G] On-arrival quarantine clearance by AQIS

On arrival, each consignment will be inspected by AQIS and documentation examined for consignment verification purposes at the port of entry in Australia prior to release from quarantine. Fruit from each consignment will be randomly sampled for inspection. The sampling methodology will provide 95% confidence that there is not more than 0.5% infestation in a consignment.

For individual fruit, sheltered sites such as the calyx and any indented areas are to be inspected carefully. During inspection, the fruit is to be examined directly with a lens, and any pests, trash or weed seeds are to be brushed onto a sheet of white paper for enhanced inspection with a lens or microscope and the pests identified.

The objective of this procedure is to verify that the required measures have been undertaken.

Where consignments are found to be non-compliant with requirements on-arrival, the importer will be given the option to treat (if suitable treatments for the pests detected can be applied), re-export or destroy the consignment. If product continually fails inspection, Biosecurity Australia/AQIS reserves the right to conduct an audit of the Thai mangosteen risk management systems and ensure that appropriate corrective action has been taken.

Uncategorised pests

If an organism is detected on mangosteens from Thailand that has not been categorised, it will require assessment to determine its quarantine status and if phytosanitary action is required. The detection of any pests of quarantine concern not already identified in the analysis may result in a review of trade to ensure that the existing measures continue to provide the appropriate level of phytosanitary protection for Australia.

IMPORT CONDITIONS

The import conditions described below are based on the conclusions of the pest risk analysis contained in this final IRA report. Specifically, they are based on the risk management measures described in the previous section. Each risk management measure is covered in more detail below including the options of how they could be implemented.

The components of the import conditions are summarised in dot point format below. The risk management measure that links with each component is given in brackets ( ).

- Import Condition 1. Registration of export orchards (links with risk management measure 3A)
- Import Condition 2. Packinghouse registration and auditing of procedures (3B)
- Import Condition 3. Harvesting of mature fruit with unbroken skin for freedom from fruit flies (1)
- Import Condition 4. Cleaning for removal of mealybugs and black ants (2)
- Import Condition 5. Packing and labelling (3C)
- Import Condition 6. Targeted pre-export inspection by ARD (3D)
- Import Condition 7. Phytosanitary certification by ARD (3E)
- Import Condition 8. Storage (3F)
- Import Condition 9. On-arrival quarantine clearance by AQIS (3G)
- Import Condition 10. Audit and review of policy.

IMPORT CONDITION 1. REGISTRATION OF EXPORT ORCHARDS

All mangosteens for export to Australia must be sourced from export orchards registered with Thailand's ARD. Copies of the registration records must be made available to AQIS if requested. The ARD is required to register export orchards prior to commencement of exports.

All export orchards are expected to produce mangosteens under standard commercial cultivation, harvesting and packing activities, for example, in-field hygiene and management of pests (e.g. orchard control program), cleaning and hygiene during packing and commercial quality control activities. Orchards are expected to be kept clean and free of weeds and other trash.

IMPORT CONDITION 2. PACKINGHOUSE REGISTRATION AND AUDITING OF PROCEDURES

All packinghouses involved in the export of mangosteen fruit to Australia must be registered with ARD. The cleaning for management of mealybugs and black ants is to be done within the registered packinghouses. Biosecurity Australia understands these measures are consistent with current practices in Thailand for export fruit.

Packinghouses will be required to identify the individual orchard with a numbering system and identify fruit from individual orchards by marking cartons or pallets with the unique orchard number. The list of registered packinghouses must be kept by ARD and provided to AQIS if requested, with updates provided should packinghouses be added or removed from the list.

Registration of orchards and packinghouses is to include an audit program by ARD to ensure that packinghouses are suitably equipped to carry out the specified phytosanitary treatments. An audit is to be conducted prior to registration and then done at least annually.

IMPORT CONDITION 3. HARVESTING OF MATURE FRUIT WITH UNBROKEN SKIN FOR FREEDOM FROM FRUIT FLIES

Mangosteen fruits for export to Australia will be required to be harvested at the mature stage (pink to maroon). Fruit is to comply with the following two requirements:

Mature	means mature fruit harvested at the pink to maroon stage.
Unbroken skin	means the skin has no pre-harvest crack, puncture, pulled stem or other break that penetrates through to the flesh and has not healed with callus tissue.

IMPORT CONDITION 4. CLEANING FOR REMOVAL OF MEALYBUGS AND BLACK ANTS

All fruit are to be individually cleaned of mealybugs and black ants on the surface and underneath the calyx using physical or mechanical means, such as washing, pressurised air blast, high-pressure water jet blast, or a combination of these methods. Each sepal of the calyx is to be lifted carefully and cleaned underneath to ensure the removal of mealybugs, ants and any other contaminants. Washing, air or water blasting is to be conducted in a designated area of the packinghouse where all soil, insects, debris and trash are removed in a manner that will ensure that pests are not able to reinfest fruit or packaging. This must be completed in packinghouses that are registered with and audited by ARD. This measure is consistent with current practices in Thailand for mangosteen fruit exported to Japan and Taiwan.

IMPORT CONDITION 5. PACKING AND LABELLING

All packages of mangosteen for export must be free from contaminated plant materials including trash and weed seeds and must meet Australia's general import conditions for fresh fruits and vegetables (C6000 General Requirements for All Fruit and Vegetables, available at http://www.aqis.gov.au/icon/). Trash refers to soil, splinters, twigs, leaves and other plant materials. Inspected and treated fruits will be required to be packed in new cartons. Packing material must be synthetic or highly processed if of plant origin. No unprocessed packing material of plant origin, such as straw, will be allowed. All wood material used in packaging of mangosteen must comply with the AQIS conditions (e.g. those in "Cargo containers: Quarantine aspects and procedures" (AQIS, 2003).

All boxes will be labelled with the orchard registration number and packinghouse registration number for the purposes of trace back in the event that this is necessary. The pallets should be securely strapped only after phytosanitary inspection has been carried out following mandatory postharvest treatments. Palletised product is to be identified by attaching a uniquely numbered pallet card to each pallet or part pallet to enable trace back to registered orchards.

IMPORT CONDITION 6. TARGETED PRE-EXPORT INSPECTION BY ARD

ARD will inspect all consignments in accordance with official procedures for all visually detectable quarantine pests and trash using sampling procedures developed by ARD in consultation with Biosecurity Australia/AQIS.

The targeted inspection procedures will ensure that mangosteen fruit is free from pests of quarantine concern to Australia, has no broken skin, is free of any contaminant plant material (leaves, twigs, seed, etc.), weed seeds and soil, and is clean on the surface and underneath the calyx.

For individual fruit, sheltered sites such as the calyx and any indented areas are to be inspected carefully. During inspection, the fruit is to be examined directly with a lens, and any pests, trash or weed seeds are to be brushed onto a sheet of white paper for enhanced inspection with a lens or microscope and the pests identified.

Records of the interceptions made during these inspections (live or dead pests, and trash) are to be maintained by ARD and made available to Biosecurity Australia as requested.

This information will assist in future reviews of this import pathway and consideration of the appropriateness of the phytosanitary measures that have been applied.

Consignments that do not comply with the above requirements will be rejected for export to Australia.

IMPORT CONDITION 7. PHYTOSANITARY CERTIFICATION BY ARD

ARD is required to issue a Phytosanitary Certificate for each consignment upon completion of pre-export inspection and treatment. Each Phytosanitary Certificate is to contain the following information/declarations:

Additional declarations

"The mangosteens in this consignment have been produced in Thailand in accordance with the conditions governing entry of fresh mangosteen fruits to Australia."

Distinguishing marks

The orchard registration number, packinghouse registration number, number of cartons per consignment, and container and seal numbers (as appropriate); (to ensure trace back to orchard in the event that this is necessary).

A consignment is the quantity of mangosteen fruit covered by one Phytosanitary Certificate that arrives at one port in one shipment. All consignments would need to be shipped directly from one port or city in Thailand to a designated port or city in Australia.

IMPORT CONDITION 8. STORAGE

Packed product and packaging is to be protected from pest contamination during and after packing, during storage and during movement between locations (e.g. packing house to cool storage/depot, to inspection point, to export point).

Product for export to Australia that has been inspected and certified by ARD must be maintained in secure conditions that will prevent mixing with fruit for export to other destinations or the domestic market and kept in storage until export. For example, segregation of product for export to Australia in separate storage facilities, shrink-wrapping pallets in plastic, placing product in low temperature cold storage or directly transferring the packed product at the packinghouse into a shipping container, which would be sealed and not opened until the container reached Australia.

Security of the consignment is to be maintained until release from quarantine in Australia.

IMPORT CONDITION 9. TARGETED ON-ARRIVAL QUARANTINE CLEARANCE BY AQIS

On arrival, each consignment will be inspected by AQIS and documentation examined for consignment verification purposes at the port of entry in Australia prior to release from quarantine. Sampling methodology would provide 95% confidence that there is not more than 0.5% infestation in a consignment.

An example of a sampling size for inspection of mangosteens is given below:

Consignment size (Units)	Sample size (Units)
For 'consignments' of fruit of less than 1000 units	either 450 units or 100% of consignment (whichever is smaller)
For 'consignments' of fruit of greater than or equal to 1000 units	600 units

Unit = one individual mangosteen fruit

For individual fruit, sheltered sites such as the calyx and any indented areas are to be inspected carefully. During inspection, the fruit is to be examined directly with a lens, and any pests, trash or weed seeds are to be brushed onto a sheet of white paper for enhanced inspection with a lens or microscope and the pests identified.

Where consignments are found to be non-compliant with requirements on-arrival, the importer will be given the option to treat (if suitable treatments for the pests detected can be applied), re-export or destroy the consignment. If product continually fails inspection, AQIS reserves the right to conduct an audit of the Thai mangosteen risk management systems and ensure that appropriate corrective action has been taken.

Uncategorised pests

If an organism is detected on mangosteens from Thailand that has not been categorised, it will require assessment to determine its quarantine status and if phytosanitary action is required. The detection of any pests of quarantine concern not already identified in the analysis may result in a review of trade to ensure that the existing measures continue to provide the appropriate level of phytosanitary protection for Australia.

IMPORT CONDITION 10. AUDIT AND REVIEW OF POLICY

Biosecurity Australia reserves the right to review the adopted policy at any time after significant trade has occurred or where there is reason to believe the phytosanitary status of the exporting country has changed.

CONCLUSIONS

The findings of this final IRA report are based on a comprehensive analysis of relevant scientific literature.

Biosecurity Australia considers that the risk management measures described in this final IRA report will provide an appropriate level of protection against the pests identified in the risk assessment.

FURTHER STEPS IN THE IMPORT RISK ANALYSIS PROCESS[5]

This final IRA report has now been released to stakeholders, together with a Plant Biosecurity Policy Memorandum (PBPM) containing the Executive Manager's recommendation for a policy determination.

The IRA process will now proceed through the following steps:

- Stakeholders have 30 days from the publication of this document to lodge an appeal in writing
  - – With determination of appeals, if required
- Final policy determination by the Director of Animal and Plant Quarantine and public notification
  - – Notification being made to the proponent/applicant, registered stakeholders and the WTO
  - – Notification being made to AQIS and liaison with AQIS on the implementation

Stakeholders will be advised of any significant variations to this process.

[5] The process described here differs from that in *The AQIS Import Risk Analysis Process Handbook*. This is the new process as outlined in Biosecurity Australia's *Import Risk Analysis Handbook* 2003.

STAKEHOLDER COMMENTS ON THE DRAFT IRA REPORT AND RESPONSE FROM BIOSECURITY AUSTRALIA

A synopsis of the stakeholder comments and the response from Biosecurity Australia is given below. All stakeholder comments and Biosecurity Australia's response to the comments have been placed on the Public File for this IRA.

Biosecurity Australia circulated the draft import risk analysis report in August 2003 and stakeholders were requested to provide comments within 60 days of release. Biosecurity Australia received written responses from Australian State Departments of Agriculture (Victoria, Western Australia), Apple & Pear Australia Limited, two written responses from the Rambutan and Tropical Exotic Growers Association Inc. (RTEGA), and many written responses from individual growers of RTEGA, who each submitted a similar set of comments. Stakeholder comments were considered and incorporated into the final import risk analysis report where appropriate and relevant.

GENERAL COMMENTS

Lack of completeness of pest list

Stakeholder comment: There could be numerous scientific gaps in any literature review conducted for this IRA following the statement from Lim and Sangchote (2003), "Compared with other tropical fruits, the pests and diseases that attack mangosteen have been studied and documented less extensively."

Biosecurity Australia's response: Mangosteen is affected by fewer pests and diseases than other tropical fruit crops (Yaacob *et al*. 1995; Ooi *et al*. 2002). The relatively thick skin of the fruit and leathery texture of the mature leaves are characteristics that deter both insects and fungi from the crop (Yaacob *et al*., 1995). Biosecurity Australia has compiled the Thailand mangosteen pest list using available technical information and published scientific literature.

Stakeholder comment: Biosecurity Australia has deleted the four post-harvest fungi, Siam weed and the 10 foliage insect pests from consideration in the pest list.

Biosecurity Australia's response: Biosecurity Australia has considered the four postharvest fungi, *Gliocephalotrichum bulbilium*, *Phomopsis* sp., *Graphium* sp. and *Pestalotiopsis flagisetula* and the ten foliage insect pests in this IRA (Appendix 1). However, these pests are not considered to be quarantine pests, so no risk management measures are required.

The draft IRA report provided a reason for the removal of all weed species from the pest list for mangosteens from Thailand (p. 43). However, in response to stakeholders' comments, all weed species listed in the technical issues paper have been included in Appendix 1 of the final IRA report.

References and citations

Stakeholder comment: The DOA (2000) reference used by Biosecurity Australia in support for the exclusion of mangosteen thrips from the pest list is simply a table reference without a link to any scientific reference.

Biosecurity Australia's response: Biosecurity Australia has obtained further information on pests of mangosteens from the Department of Agriculture, Thailand, sourced from their departmental records and publications in the Thai language. Biosecurity Australia has amended the references for *Scirtothrips oligochaetus* (mangosteen thrips) accordingly in the final IRA report.

Thai mangosteen exports

Stakeholder comment: This is the first time that mangosteens have been exported from Thailand to another tropical environment. The USA does not allow imports of mangosteens from Thailand.

Biosecurity Australia's response: Mangosteens are exported to Japan, Taiwan, Canada, Europe, and the United Kingdom, as well as a number of tropical countries including Hong Kong, Singapore, Brunei and Middle Eastern countries.

The United States Department of Agriculture (USDA) is considering Thailand's request, according to their pest risk assessment process.

Linkages with CER-FTA between Thailand and Australia

Stakeholder comment: There are obvious linkages to the pending Closer Economic Relations Free Trade Agreement (CER-FTA) between Thailand and Australia.

Biosecurity Australia's response: Thailand first requested access for mangosteens to Australia in July 2000, before the initiation of the CER-FTA discussions. As such, the mangosteen IRA and the CER-FTA between Australia and Thailand are unrelated.

Review of draft IRA report

Stakeholder comments: Biosecurity Australia should revise the current draft IRA and present a second draft IRA report to stakeholders. The second draft IRA report should be peer reviewed by CSIRO and QDPI staff not involved in the IRA process as per the requirements of Item 15, page 16, *Import Risk Analysis Handbook*. Every scientific reference used by Biosecurity Australia should be verified to prevent misuse of references.

Biosecurity Australia's response: Biosecurity Australia has considered stakeholders' comments, and where appropriate and relevant, has incorporated them into this final IRA report.

There is not sufficient new published evidence or scientific information that warrants the publication of a second draft. Biosecurity Australia has reassessed published literature and other information and has made amendments in the final IRA where necessary.

IRA reports are already peer reviewed internally by Biosecurity Australia and DAFF. This IRA report will be peer reviewed by external experts if deemed necessary by the Executive Manager of Biosecurity Australia.

Biosecurity Australia is committed to ensuring that all IRAs are scientifically sound. This includes checking and verifying all scientific references.

Consultation with stakeholders

Stakeholder comments: Biosecurity Australia has not investigated, consulted or advised stakeholders of the outcomes of the issues raised at the initial consultation with growers in July 2002 and on the technical issues paper (TIP).

Biosecurity Australia's response: The issues raised by stakeholders at the workshops held in Cairns and Darwin in July 2002 were considered by Biosecurity Australia during the preparation of the draft IRA. PBPM 2002/36 advised stakeholders of the Action Items (i.e. summary of issues raised) from the workshops and Biosecurity Australia's response. Where appropriate and relevant, stakeholder comments were considered and incorporated into the TIP and draft IRA report. For example, risk assessments were conducted for fruit fly species in the draft IRA report, and stakeholder concerns regarding weeds, soil and ants on mangosteen fruit were also considered. Biosecurity Australia has actively consulted with industry throughout the IRA process and has held stakeholder workshops to discuss industry's comments and concerns.

Biosecurity Australia has considered additional relevant scientific information provided in response to queries raised by stakeholders for inclusion in the final IRA. Industry's comments and Biosecurity Australia's response are included on page 73 of the Draft IRA Report and are also available on the Public File.

Maintenance of Australia's pest and disease free status for our domestic and export markets

Stakeholder comments: Australia must maintain its present pest and disease free status for our domestic and export markets. Failure to accept stakeholder recommendations would place Australia at extreme risk of the entry, establishment and spread of exotic pests, and Australia's ALOP would be under threat as any quarantine breach will affect our environment, market access for exports and horticultural commodities.

Biosecurity Australia's response: Biosecurity Australia is committed to ensuring that Australia maintains its present pest and disease free status for our domestic and export markets. The IRA for mangosteens from Thailand ensures that Australia's ALOP is maintained through the described phytosanitary measures for pests of quarantine concern. Biosecurity Australia considers that the risk management options proposed in the draft IRA appropriately mitigate the risk of pests and diseases associated with imports of fresh mangosteen fruit from Thailand.

Biosecurity Australia has considered all stakeholders' comments and where appropriate, has incorporated them in this final IRA report.

IRA PROCESS

Stakeholder comment: The process of thorough investigation into controlling/preventing the spread of pests, and setting up import/export protocols could pave the way for our own export industry in the future. This would only be the case if the science behind it were adequate and correct, with all risks effectively controlled.

Biosecurity Australia's response: Biosecurity Australia utilises a structured, science-based approach (IRA process) to developing quarantine policies and considers relevant scientific data when considering the potential risks associated with import access requests.

The IRA identifies pests that pose an unacceptable risk and proposes phytosanitary measures to mitigate these risks to ensure that pests and diseases do not affect Australian industries. The economic and environmental consequences of control of a pest or disease are considered as part of the risk assessment.

Interpretation of ISPM guidelines

Stakeholder comment: ISPM guidelines on pest risk analysis for quarantine pests including analysis of environmental risks (FAO, 2003) indicate that a list of pests likely to be associated with the pathway should be considered, not only a list of pests reported from the *importing country* to be present on the pathway. Yunus and Ho (1980) report on pests from West (Peninsular) Malaysia which borders Thailand; the draft has indicated that mangosteen production in Thailand occurs south to the Malaysian border, suggesting that a similar suite of pest species would be likely in these two areas.

Biosecurity Australia's response: The pathway is defined as the commodity produced in an area and exported from that area. Therefore, Biosecurity Australia cannot include all pest species that attack mangosteen fruit in mangosteen growing areas in the world for assessing mangosteen from Thailand. Similarly, other countries cannot assess pests and diseases not actually present in Australia when considering access for Australian exports.

Furthermore, mangosteen production areas in southern Thailand are not contiguous with mangosteen production areas in Malaysia, as they are separated by vast expanses of tropical rainforest.

PESTS

Exotic pests, soil and weed seeds under the fruit calyces

Stakeholder comments: The fruit calyx is the perfect vehicle to allow exotic pests, soil and weed seeds into Australia, so contamination by soil on the fruit should be considered and checked microscopically.

Biosecurity Australia's response: Biosecurity Australia agrees that there is a risk of contaminants such as pests and soil being present under the calyx and has proposed risk management measures to mitigate this risk.

Biosecurity Australia requires that all consignments of mangosteen fruit for export to Australia must be free from contaminated plant materials including trash (i.e. soil, splinters, twigs, leaves and other plant materials) and weed seeds. Consignments found to be non-compliant with pre-export and on-arrival inspection requirements, including the above-mentioned condition, will be rejected.

Biosecurity Australia has proposed cleaning for the removal of mealybugs, black ants, trash (including soil) and weed seeds from the calyx. Biosecurity Australia considers that the risk management options proposed in the draft IRA appropriately mitigate the risk of pests and diseases and trash associated with imports of fresh mangosteen fruit from Thailand.

In Thailand, the mangosteen canopy of mature trees does not touch the ground and fruit are individually harvested into bins and do not come into contact with the ground. This harvesting practice reduces the risk of soil, weed seeds or ground dwelling insects being present beneath the fruit calyces.

In response to stakeholder concerns, Biosecurity Australia has specified enhanced visual inspection using a lens or microscope, both pre-export and on-arrival, to ensure that pests, soil and other contaminants will be detected on fruit.

Ants

Stakeholder comments: Even with the practice of individual harvesting, ant nests are regularly found on and under the calyx. Soil particles are carried by ants to the calyx for nest building.

Biosecurity Australia's response: In response to industry's concerns about ant nests and soil under the calyx, Biosecurity Australia has done further research and contacted scientific experts to obtain additional information on ant species associated with mangosteens.

Biosecurity Australia has clarified the information on the nesting behaviour of black ants from various sources and has concluded that there is a possibility that black ants may nest in soil underneath the mangosteen fruit calyx. Biosecurity Australia has amended the risk assessment for black ants accordingly, and as such has determined that the unrestricted risk estimate is Low, which is above Australia's ALOP. Therefore, risk mitigation measures are required for these pests.

Biosecurity Australia has proposed the use of cleaning using washing and/or a pressurised air or water blast to remove black ants and their nesting material from beneath the calyces of mangosteen fruit. This treatment was observed to be efficacious against black ants during a visit to Thailand by Biosecurity Australia and NSW Agriculture officers. In addition, Biosecurity Australia has proposed enhanced pre-export and on-arrival inspections, which will ensure that any ants present on fruit will be detected.

Mangosteen thrips

Stakeholder comment: Ripe fruit ready for harvest and immature fruit are located on the same tree. How will the mangosteen thrips know that as the fruit is bound for Australia, they must stay away from the mature fruit?

Biosecurity Australia's response: There is very scant published scientific literature and studies on *Scirtothrips oligochaetus* (mangosteen thrips) because of its rare occurrence on mangosteen in Thailand and its lack of economic significance. This indicates that the pest does not fit the definition of a quarantine pest.

Thai plant quarantine officers have reported that in Thailand, only young, developing fruits are attacked. Thrips are only present within or upon mangosteens at flowering and immature fruit development stages. By the time the fruit has matured, thrips are unable to lay eggs within the thick skin of the mangosteen (refer to p.53 of the TIP). However, if any thrips are present on mature mangosteens, they will be removed by the mandatory cleaning, or will be detected during visual inspection.

S. oligochaetus shares similar biology to *S. dorsalis* and other *Scirtothrips* spp. (CABI/EPPO, 1997). CABI/EPPO (1997) has reported that only seedlings or cuttings with young growing leaf buds are liable to carry these pests.

Stakeholder comment: Mangosteen thrips is similar to red-banded thrips in Australia as most of the feeding damage is carried out in the early stages of fruit development. Even though thrips do not lay in the mature fruit skin at the mature fruit stage, eggs are laid in and under the fruit calyx, and all stages of this pest have been recorded in mature fruit in Australia.

Biosecurity Australia's response: The comment on feeding damage to mangosteens refers specifically to *Selenothrips rubrocinctus* (red-banded thrips) and not *Scirtothrips oligochaetus* (mangosteen thrips). There is no published scientific evidence to show that the damage caused by mangosteen thrips is the same as by red-banded thrips. Biosecurity Australia welcomes any additional scientific information from stakeholders on mangosteen thrips (*Scirtothrips oligochaetus*).

Inclusion of pests *Oecophylla smaragdina*, *Carpophilus dimidiatus* and *Thrips florum*

Stakeholder comments: The reason for the exclusion of *Oecophylla smaragdina*, *Carpophilus dimidiatus* and *Thrips florum* is not consistent when compared to other pests in this and recent IRAs e.g. *Bactrocera carambolae* and *B. papayae* have both been considered further in the IRA. However, neither of these two pests has been associated with mangosteens in Thailand. It appears as though these pests have been considered further as they have been reported to be associated with mangosteens elsewhere and are known to be present in Thailand. *Carpophilus dimidiatus* and *Thrips florum* are known to occur in Thailand and have been recorded on mangosteens. *Carpophilus dimidiatus*, *Thrips florum* and *Oecophylla smaragdina* should be considered for further assessment to improve the scientific rigour and transparency of the document.

Biosecurity Australia's response: *Oecophylla smaragdina* has been reported on mangosteen in Queensland but has not been reported on mangosteen fruit in Thailand or Malaysia. Therefore, Biosecurity Australia has not included this in the pest list for mangosteens from Thailand. *Oecophylla smaragdina* is present on other crops in both countries.

Carpophilus dimidiatus and *Thrips florum* have not been reported on mangosteen in Thailand, although they are both present in Thailand. Both species have been reported once in Malaysia, on mangosteen leaves by Yunus and Ho (1980). Neither has been reported infesting mangosteen fruit in Thailand and so were not considered in this IRA.

B. carambolae (carambola fruit fly) and *B. papayae* (papaya fruit fly) have been considered further in the IRA as they are present in southern Thailand where mangosteens are grown, although they have not been reported attacking mature, intact mangosteen fruit in Thailand. However, there are reports of these fruit fly species attacking mangosteen fruits in Malaysia.

Inclusion and consideration of *Vinsonia stellifera* (stellate scale)

Stakeholder comment: *Vinsonia stellifera* should be included in the pest list and considered further as it occurs in Thailand and is associated with mangosteens (Hodges, 2003).

Biosecurity Australia's response: *Vinsonia stellifera* (stellate scale) does occur in Thailand and Malaysia (Ben-Dov, 2002; Hodges, 2003), but has never been recorded on mangosteen in these two countries. Hodges (2003) did not specifically say in which country this pest occurs on mangosteen in his article, or which part of the plant this pest infests.

Yunus and Ho (1980) did not mention the occurrence of this pest on mangosteen, or its occurrence on crops in Malaysia. After reviewing available literature on the pest, *V. stellifera* has been recorded on the foliage of fruit trees and ornamentals like orchids and palms.

Consideration of biocontrol agents on the fruit pathway

Stakeholder comment: Consideration should be given to supplying a list of biocontrol agents such as predatory mites and parasitic wasps that may be associated with the fruit pathway. Biocontrol agents have the potential to be present on the fruit pathway if their target host is associated with the fruit pathway. Examples of this can be found in interception records (AQIS, 2001) for stone fruit from New Zealand where many biocontrol agents such as mites have been intercepted. The pathway association of biocontrol agents should be reviewed to take into consideration the interception records on imported fruit.

Biosecurity Australia's response: Biosecurity Australia would review the pathway association of biocontrol agents intercepted on commodities that currently have access into Australia such as stone fruit. There is no record of any interception of natural biocontrol agents on fresh mangosteen fruit into Australia as no fruit have entered under current conditions. Biosecurity Australia would consider biological control agents that are deliberately used commercially to control insect pests, as in the case of glasshouse production of tomatoes. Assessing all possible and potential biocontrol agents on the mangosteen fruit pathway at this stage would be trade restrictive.

Pathway analysis for *Aspidiotus destructor*, *Coccus viridis* or *Planococcus minor*

Stakeholder comment: The pathway analysis for *Aspidiotus destructor*, *Coccus viridis* or *Planococcus minor* should be verified as it appears the draft IRA has misinterpreted information regarding the pathway analysis of these species. Yunus and Ho (1980) make no reference to the presence of *A. destructor*, *C. viridis* or *P. minor* on leaves or fruit of mangosteen, nor do Ooi *et al*. (2002) refer to the presence of *P. minor* on leaves or fruit of mangosteen.

Biosecurity Australia's response: Biosecurity Australia has verified the status of *Aspidiotus destructor*, *Coccus viridis* and *Planococcus minor* on the mangosteen pathway and agree that *C. viridis* and *P. minor* should be excluded. *Aspidiotus destructor* forms colonies on the lower surface of mangosteen leaves (Yaacob *et al*., 1995), so should not be considered further in the IRA. The appropriate amendments have been made in this final IRA report.

Consequence assessment for fruit flies

Stakeholder comment: The environmental consequences for fruit flies should be re-assessed as they may present threats to Australia's natural ecosystems. Consequences should also be reassessed to provide consistency between IRAs.

Biosecurity Australia's response: Environmental consequences of fruit flies (*B. carambolae*, *B. dorsalis* and *B. papayae*), including their impact on natural ecosystems, were considered in the assessment of overall consequences in accordance with ISPM guidelines No. 11 Pest risk analysis for quarantine pests including analysis of environmental risks. Consistency between IRAs is an ongoing process, as is the refinement of the application of risk analysis methodology. Therefore, differences between IRAs may exist. In addition, the fruit fly species considered differ between the IRAs and the assessment of consequences has taken account of these differences.

Probability of importation for mealybugs

Stakeholder comment: The probability of importation appears not to have taken into consideration that the mandatory issuance of a phytosanitary certification for all fresh fruit exported to Australia is dependent upon inspection at some level by the exporting NPPO, which would reduce the probability of importation to at least a rating of "very low". The probability of importation should be reassessed due to the lack of data on the occurrence of the two quarantine mealybug species on mangosteen fruit following the standard cultivation, harvesting and packing activities involved in the commercial production of mangosteen fruit and the impact of mandatory pre-export inspections by exporting NPPOs.

Biosecurity Australia's response: When assessing the probability of introduction and spread, the unrestricted or unmitigated risk of that pest must be considered. Inspection and phytosanitary certification are not considered in the probability of importation assessment as they are regarded as risk mitigation measures as well as verification safeguards. The use of inspection and phytosanitary certification contribute further in reducing the overall risk of mealybugs.

Biosecurity Australia has consistently rated the overall risk of mealybugs as low in all IRAs and therefore, risk mitigation measures are required. A rating of "very low" would meet our ALOP and would therefore not require any risk mitigation measures, including inspection. Due to the manner of infestation on mangosteen by mealybugs (i.e. hide beneath the calyces), Biosecurity Australia has proposed cleaning as a mandatory treatment to mitigate the risk of mealybugs. The use of targeted pre-export inspection, on-arrival inspection and other phytosanitary safeguards will collectively ensure that the risk of entry of mealybugs is reduced to an acceptable level. No single measure is relied upon to completely mitigate the risk.

DISEASES

Consideration of four post-harvest fungi as quarantine pests

Stakeholder comment: The four post-harvest fungi should not have been removed from the pest list as Lim and Sangchote (2003) have stated that, "Many of the pathogens that attack mangosteen are widespread and attack other tropical fruits". The four post-harvest fungi are not simply weak secondary organisms but fruit rots that could have a severe impact on other horticultural crops in Australia. At least one of these post-harvest fungi is known to affect apples and so is of concern. These pathogens can infect Thai mangosteen fruit through field infection, damage in the harvest and packing procedures, high humidity and temperatures during packaging, storage and transport, and time required to reach their destination. There is abundant evidence that *Gliocephalotrichum bulbilium* is a significant fruit rotting pathogen of mangosteen and other tropical fruit crops such as rambutan and durian, on which it causes a latent field infection. As it is on the pathway and there are no records of the fungus in Australia, it should be treated as a quarantine pest.

Biosecurity Australia's response: Fungi can be pathogens but are not necessarily quarantine pests. Postharvest secondary pathogens such as *G. bulbilium*, *Phomopsis* sp., *Graphium* sp. and *Pestalotiopsis flagisetula* do not fit the definition of a quarantine pest as they are not considered to be of economic or environmental significance to the PRA area.

Biosecurity Australia's assessment of the pathogens associated with mangosteens is supported by substantial scientific literature, which is detailed in the Draft IRA Report (Appendix 2). *G. bulbilium*, *Phomopsis* sp., *Graphium* sp. (only on mangosteen) and *Pestalotiopsis flagisetula* are associated with causing postharvest storage rots together with other fungi on many fruits such as mangosteen (Sangchote and Pongpisutta, 1998), rambutan (Visarathanonth and Ilag, 1987), and related durian species, *Durio kutejensis* and *D. graveolens* (Sivapalan *et al*., 1998). They have not been reported on durian *Durio zibethinus*. These fungi are weak pathogens or secondary invaders (Sivapalan *et al*., 1998), and cause postharvest problems related to latent field infection or injuries caused during harvesting, processing and high humidity and temperatures during packaging, storage and transport (Visarathanonth and Ilag, 1987).

In a survey of rambutan fruit in Bangkok markets, about 30% of the postharvest diseases were identified as being caused by *Colletotrichum* spp., 10% by *G. bulbilium*, and 5% by *Botryodiplodia theobromae* (Visarathanonth and Ilag, 1987). Weak postharvest secondary rots are widely recognised as not being of quarantine significance and do not fit the definition of a quarantine pest. Therefore, no risk mitigation measures are required for these fungi. This fact has been recognised by Australia's trading partners and also applies to Australian exports.

Sangchote and Pongpisutta (1998) reported that *G. bulbilium* is a postharvest fruit rot of mangosteen that is only present in two of the eight mangosteen production areas in Thailand. This fungus is of minor economic significance and is more important as a postharvest rot of rambutans than mangosteen (Visaranthanonth and Ilag, 1987). Furthermore, this disease is easily detected on mangosteen, as the epidermal tissues of affected fruit become swollen, light pink and lumpy in appearance (Lim and Sangchote, 2003). As *G. bulbilium* is visually conspicuous, infected fruit would be culled during commercial quality control activities. Therefore, Biosecurity Australia considers that this fungus does not pose a threat to the Australian apple industry.

One of the import conditions proposed by Biosecurity Australia is that damaged or bruised fruit must not be packed for export to Australia. The packinghouse procedures will remove any damaged or rotting mangosteen fruit. Also, pre-export inspection by Thailand's ARD and on-arrival inspection by AQIS will provide further safeguards.

Pathogen status of *Corticium koleroga* and *Helminthosporium quaciniae* in Australia

Stakeholder comment: The Chacko *et al*. (1995) reference implies that *Corticium koleroga* and *Helminthosporium quaciniae* are present in Australia, but does not provide any scientific references to support the presence of these pathogens. Literature and Internet searches could not find any information to suggest that these pathogens are present in Australia.

Biosecurity Australia's response: After checking pathogen records in all the states, Biosecurity Australia confirms that both fungi have not been reported in Australia. Biosecurity Australia has amended the list accordingly in this final IRA report.

Further consideration of *Corticium koleroga*

Stakeholder comment: This pathogen is not known to occur in Western Australia and is associated with mangosteen fruit. However, further consideration of this pathogen has not occurred. This may be an oversight as other pathogens with the same status, such as *Gliocephalotrichum bulbilium*, have been given further consideration.

Biosecurity Australia's response: In Thailand, *Corticium koleroga* (Cooke) Honel (Syn. = *Pellicularia koleroga* Cke; *Koleroga noxia noxia* Donk; *Ceratobasidium anceps* (Bres. & Syd.) Jackson) has been reported to attack foliage and leaves and not fruit. Therefore, Biosecurity Australia considered that this fungus was not on the pathway. There was a remark by Morton (1987) (not a pathologist) that mangosteen fruit in Puerto Rico can be infested. An examination of scientific literature has shown that this species infests foliage, twigs and branches causing thread blight of trees and also black rot of trees in coffee (Bhat and Govindarajan, 1992; Duarte and Albuquerque, 2000; Lawrence *et al*., 1991). The disease is easily recognised by a fine white thread on stems, branches, leaves and spikes. On the under surface of the leaves the pathogen mycelium shows a fan shape growth. These threads are white but turn light brown at old age. Dead leaves remain attached to branches by mycelial strands, with texture resembling vellum. Heavy infections may cause defoliation and death of stems and branches.

WEEDS

Consideration of additional weed species, including *Chromolaena odorata*

Stakeholder comments: The technical issues paper (TIP) recognised that *Chromolaena odorata* (Siam weed) may be a contaminant and would be considered further in the IRA. Further consideration of this species did not occur in the draft IRA nor was a suitable explanation provided for its exclusion. This species should be considered for the potential for seeds to attach to the fruit calyx or the potential for contamination of packaging etc.

Biosecurity Australia's response: All of the weed species reported to be associated with mangosteen in Thailand were considered and listed in the TIP. After further consideration only one species, *Chromolaena odorata* (Siam weed) was determined to be of quarantine significance. However, further analysis of scientific literature has shown that seeds of this species have structures for wind dissemination and are not carried by insects, so are unlikely to become lodged beneath the fruit calyces. The draft IRA report provided a reason for the removal of all weed species from the pest list for mangosteens from Thailand (p. 43). However, in response to stakeholders' comments, all weed species listed in the technical issues paper have been included in Appendix 1 of the final IRA report.

Following stakeholder comments on the draft IRA, Biosecurity Australia requested further information on Siam weed in Thailand from the Department of Agriculture (DOA) Thailand. DOA informed Biosecurity Australia that Siam weed is commonly found along roadsides and wastelands in Thailand, and is not associated with mangosteen production. The weed seeds are not associated with mangosteen fruit for export during the harvesting and packing process (DOA, 2004, pers. comm.). Siam weed is not listed as a primary serious weed in mangosteen (CABI, 2002).

Siam weed produces glabrous seeds (achenes) with silky pappus that aid in wind dispersal (CABI, 2002). The seeds have tiny barbs that stick to clothing, footwear, animals, vehicles and machinery (NRM, 2001). However, mangosteen fruits are smooth, so there is a very low likelihood that Siam weed seeds will stick to the smooth skin or become lodged under the fruit calyces. Siam weed seeds would need to be carried by crawling insects to become lodged beneath the calyces.

In Thailand, mangosteen fruit is manually and individually harvested using a harvesting aid and placed directly into bins without contacting the ground (see Appendices 1 and 2 in the Technical Issues Paper). This practice reduces the risk of weed seeds and soil adhering to the fruit. The mandatory cleaning treatment will also further reduce the risk of weed seeds on the fruit. Biosecurity Australia has consulted with in-house weed experts and concluded that Siam weed is unlikely to enter Australia with fresh mangosteen fruit from Thailand. Therefore, this weed is not considered to be of quarantine concern in this IRA.

However, as a safeguard, Biosecurity Australia has specified as a condition of registration of export orchards that mangosteen orchards must be kept clean and free of weeds and other trash. If any weed seeds are present on the fruit, they will be removed during the cleaning process, or will be detected during visual inspection.

VERTEBRATE PESTS

Stakeholder comment: Vertebrate pests such as geckoes and frogs could be present in consignments.

Biosecurity Australia's response: The risks posed by hitchhikers such as vertebrate pests were considered, particularly where there are known or recorded associations with the fruit importation pathway.

Furthermore, inspection of consignments is undertaken by AQIS for all quarantine risks, contaminants and associated hitchhikers. Appropriate action such as treatment, re-export or destruction of the consignment is taken if any non-compliance is found.

PHYTOSANITARY/ IMPORT CONDITIONS

Air/water blasting treatment

Stakeholder comments: There is no supporting scientific efficacy data to show the effectiveness of air/water blasting of the calyx in removing Thai mealybugs and ants. The air applied would simply be deflected off the convex exterior of the calyx, so would be ineffective. Air/water blasting is simply an attempt to move the quarantine pest off the fruit and the calyx and to another area of the packing shed, where they could recontaminate fruit and packaging. Biosecurity Australia should provide details of the specific operational PSI pressures to be used.

Biosecurity Australia's response: In response to stakeholder concerns, Biosecurity Australia requested the Department of Agriculture, Thailand to conduct a trial to determine the efficacy of air blasting for the removal of mealybugs from mangosteens. The air pressure used in this trial was 3-5 Kilo Pascals. The results of the trial showed 100% efficacy in removing mealybugs from beneath the calyx (DOA, 2003b).

Air blasting was proven to be efficacious for removing pests, soil and other organic matter during a visit to Thailand by NSW Agriculture and Biosecurity Australia officers. The trip reports from this visit stated that air blasting was effective in dislodging and removing insects such as thrips, ants and mealybugs from the calyx. This practice is used by Thailand to clean all mangosteen fruit of foreign material for export to other countries such as Japan and Taiwan. Biosecurity Australia considers that air and water blasting are equivalent measures.

The air/water blasting treatment physically removes the mealybugs and ants from the calyx. The procedure takes place in a designated area of the packhouse where all soil, insects, debris and trash are blasted into a metal trough filled with water to ensure the pests are not able to reinfest fruit packed for export. In this final IRA report, Biosecurity Australia has specified that the cleaning must be done in a manner that ensures that recontamination does not occur.

Thailand's ARD will supervise and audit the postharvest procedures, conduct pre-export inspections and provide phytosanitary certification for all mangosteen exports to Australia to ensure that consignments are free from quarantine pests, contaminated plant materials including trash (i.e. soil, splinters, twigs, leaves and other plant materials) and weed seeds.

An appropriate protocol will be implemented to ensure the effectiveness of this measure.

Stakeholder comment: The proposed risk mitigation measure of air/water blast treatment under the calyx of each piece of fruit is extremely labour intensive and difficult to audit and review records. Although consignments will undergo pre-export inspections by ARD, the importance of inspections based on AQIS inspection procedures to minimise the risk of this pest being present in a consignment must be emphasised.

Biosecurity Australia's response: Thailand's ARD will audit registered packinghouses where the pressurised air/water blasting will occur.

Mangosteen consignments will be inspected pre-export by ARD using an agreed sampling plan. The agreed sampling methodology must provide 95% confidence that there is not more than 0.5% infestation in a consignment.

The calyx

Stakeholder comment: In other IRAs e.g. global pineapple, the crown is removed as part of the protocol. This should also be applied to mangosteen with the removal of the calyx. The removal of the calyx to ensure soil, dust particles and weed seeds do not enter Australia is an insignificant and responsible quarantine measure. It is not trade restrictive but is cost-effective, feasible and is non-discriminatory of exporting countries with equal phytosanitary status.

Biosecurity Australia's response: Biosecurity Australia requires the removal of pineapple crowns as interception records from New Zealand have shown that they are a receptacle for weed seeds. De-crowning is considered to be the most appropriate measure to mitigate the risk associated with weed seeds on pineapples.

In the case of mangosteens, there is no available data to show that mangosteens are a receptacle for weed seeds. Unlike the pineapple, the structure of mangosteens allows physical cleaning beneath the calyx, which would effectively remove any weed seeds that were present, so the removal of the calyx is unnecessary. For this reason, Biosecurity Australia has specified the phytosanitary measure of cleaning beneath the calyx for removal of pests, trash and weed seeds.

Stakeholder comment: Mangosteen fruit is often found with its calyx locked onto the pericarp of the fruit. Fruit with the locked-down calyx will need to be prised upwards to allow air to be applied. This often results in the breaking of the calyx and the removal of these damaged leaves.

Biosecurity Australia's response: The calyx of mature mangosteen fruit is not tightly adpressed to the fruit surface. Discussions with Biosecurity Australia and NSW Agriculture officers have indicated that they did not observe any breaking of the calyx during demonstrations of the air/water blasting treatment during their visit to commercial mangosteen packing houses in Thailand.

The calyx is tough and flexible enough to allow an operator to apply the air/water blasting treatment to remove pests and trash/debris from underneath the calyx. The NSW Agriculture officer explained that that the operator handles the mangosteen fruit with the left hand and uses the left thumb to lift up one of the calyces. The air/water blast nozzle is then inserted under the lifted calyx, and the fruit is rotated as the air/water blast is applied under all calyces. The calyces are bent backwards in shape, but none of the calyces were broken or showed signs of weeping (Jessup, 2003, pers. comm.).

Inspection

Stakeholder comment: The draft IRA should include details of the inspection sampling plan and how mangosteens are inspected.

Biosecurity Australia's response: Mangosteen consignments will be inspected pre-export by ARD and on-arrival by AQIS using an agreed sampling plan. The sampling methodology used for the on-arrival inspection by AQIS will provide 95% confidence that there is not more than 0.5% infestation in a consignment. The usual sampling rate used by AQIS is given under 'On-arrival quarantine clearance by AQIS' in the 'Import Conditions' section of this final IRA report.

AQIS inspections are conducted under minimum 600 lux light and on a white laminate table. Standard inspection procedures are performed by AQIS and include the following:

- Scanning the surface of fruits for obvious signs of insect infestation or disease symptoms;
- Examination of inside surfaces of packaging, and entire surface of the fruit, in particular, the ends of the fruit e.g. sepals, calyx, etc.; and
- Further examination of any suspect, damaged or deformed fruit.

Biosecurity Australia has also specified that sheltered sites such as the calyx and any indented areas are to be inspected carefully. During inspection, the fruit is to be examined directly with a lens and any pests, trash or weed seeds are to be brushed onto a sheet of white paper for enhanced inspection with a lens or microscope.

Stakeholder comment: Biosecurity Australia has proposed three visual inspections in this draft IRA i.e. the first is in the Thai packing shed for exotic fruit flies, the second for mealybugs, ants, soil and weed seeds in the packing shed, the third is the on-arrival inspection by AQIS in Australia. Page 57 of the draft IRA report states that, "Visual inspection alone is not considered to be an appropriate risk management option in view of the level of risk identified because clear visual external signs of infestation (particularly in recently infested fruit) may not be present". Assumptions have no basis in science where Australia's pest and disease free status is concerned.

Biosecurity Australia's response: Inspection for any contaminated plant materials including trash (i.e. soil, splinters, twigs, leaves and other plant materials), weed seeds and quarantine pests (including fruit flies, mealybugs and ants) occurs during the pre-export inspection by ARD and on-arrival quarantine clearance by AQIS.

The quote from page 57 of the draft IRA report refers to the reasoning as to why visual inspection alone is not considered to be an appropriate risk management option for exotic fruit flies, *Bactrocera carambola*, *B. dorsalis* and *B. papayae* on susceptible host species.

Adult fruit flies oviposit eggs under the surface of susceptible host fruit and larvae develop in the fruit (Koyama, 1989). Infested fruit can show some necrosis around the puncture mark ('sting') following oviposition, which causes decomposition of the fruit that appears as black or brown lesions. However, scientific studies have proven that mangosteen is a conditional non-host for these fruit fly species.

Adoption of a systems approach protocol

Stakeholder comments: The option of a systems approach should be added to the unbroken skin requirement for exotic fruit flies. The proposed systems approach consists of, in sequential order:

- Removal of 4 leaflets from fruit calyx
- Water blast for soil and weed seeds

- Methyl bromide for Thai mealybugs, thrips and ants as per DOA recommendations and preference
- Fungicide dip for 4 Thai post-harvest fungi
- On-arrival inspection by AQIS.

Biosecurity Australia's response: Based on scientific data, Biosecurity Australia considers that the unbroken skin requirement is appropriate to manage the risk of exotic fruit flies.

Biosecurity Australia has received efficacy data to show that cleaning by air blasting effectively removes mealybugs from beneath the calyx of mangosteen fruit (DOA, 2003b). This measure is recognised and accepted by Thailand's trading partners to remove insects, soil, weeds etc. from under the fruit calyces. Therefore, additional measures, such as the removal of the calyx, are unnecessary. Methyl bromide fumigation will only be used if any live quarantine pests are detected on consignments of mangosteens from Thailand during targeted on-arrival inspection by AQIS.

Consideration of fungicidal treatment for post-harvest fungi

Stakeholder comment: Biosecurity Australia has failed to include any fungicidal treatment in the draft IRA report.

Biosecurity Australia's response: Fungicidal treatment is not necessary as *G. bulbilium*, *Phomopsis* sp., *Graphium* sp. and *Pestalotiopsis flagisetula* are not considered to pose any quarantine risk. Please refer to previous comments on post-harvest fungi on pp. 86-87.

Consideration of other postharvest treatments – methyl bromide fumigation and oil treatment dips

Stakeholder comments: Biosecurity Australia should consider methyl bromide fumigation and oil treatment dips for mealybugs.

Biosecurity Australia's response: Postharvest disinfestation treatments such as chemical (oil) dips and methyl bromide fumigation were identified as in-principle options for the management of mealybugs and fruit flies, as discussed on pages 57 and 58 of the Draft IRA Report. However, these measures were considered to be no more effective and clearly more costly than cleaning, which is the current measure used by Thailand for mangosteen exports to Japan and Taiwan.

Consideration of AQIS import conditions for entry of soil and foliage into Australia for mangosteen fruit imports

Stakeholder comment: AQIS has import conditions for entry of soil and foliage into Australia that should also apply to imports of mangosteen from Thailand.

Biosecurity Australia's response: All consignments of mangosteen fruit for export to Australia must be free from contaminated plant materials including trash (i.e. soil, splinters, twigs, leaves and other plant materials) and weed seeds and meet Australia's general import requirements for fresh fruit and vegetables (C6000 General Requirements for All Fruit and Vegetables). That is, shipments must be free of soil and other debris and packed in clean new packages.

Consignments found to be non-compliant with pre-export or on arrival inspection requirements, including the above-mentioned condition, will be rejected. Biosecurity Australia considers that these import conditions will ensure that consignments of mangosteen fruit from Thailand will be free of soil.

Quarantine treatment for soil removal

Stakeholder comment: Air blasting is not an appropriate quarantine treatment for soil removal. Water is required to dissolve the soil and move it off the product. This was demonstrated by Anon (1998) in a quarantine protocol developed to allow the movement of farm machinery from the Ord River sugar producing region in WA to the sugar producing regions of eastern Australia following the smut outbreak in WA in 1998. The application of air to soil on any other product simply causes the soil to roll and smudge and is completely ineffective. Therefore, the removal of the calyx followed by the application of high pressure water and brushing is recommended to assist with the removal of the soil and possible weed seeds.

Biosecurity Australia's response: The protocol described by Anon. (1998) refers to interstate quarantine conditions to prevent the spread of smut disease in Western Australia to sugar producing regions of eastern Australia via the entry of farm machinery. In the case of the mangosteen IRA, any import conditions must apply only to the fruit.

Biosecurity Australia has proposed cleaning on the surface and beneath the calyx for the removal of mealybugs, ants, trash, soil and weed seeds. Biosecurity Australia and NSW Agriculture officers observed that the use of air blasting is efficacious for removing debris, soil and insects from the fruit during a visit to Thailand in 2002. Other countries, including Japan and Taiwan, also accept this measure. Biosecurity Australia considers that the risk management options proposed in the draft IRA appropriately mitigate the risk of pests and diseases associated with imports of fresh mangosteen fruit from Thailand.

Use of recommendations/protocols used by cool climate countries

Stakeholder comment: Biosecurity Australia is using recommendations/protocols used by cool climate countries such as Japan and Canada to make decisions about importing fruit into Australia. Tropical pests that do not survive long enough to spread in cold climates are less of an issue for these countries.

Biosecurity Australia's response: Cool climate countries such as China, Japan, Korea and USA have their own set of protocols to import fruit from both tropical and temperate countries, including Australia.

Under the SPS Agreement, member countries have the right to take sanitary and phytosanitary measures necessary for the protection of human, animal and plant life or health, provided that the measure is applied only to the extent necessary, is based on scientific principles and is not more trade restrictive than necessary.

Phytosanitary measures are not dependent on factors such as the climate, they must relate to the mitigation of the quarantine pest(s) irrespective of the climate of the country.

Domestic arrangements for ICA-13

Stakeholder comment: Western Australia does not accept ICA-13 for mangosteen fruits. Western Australia regulations (for *Bactrocera tryoni*, *B. neohumeralis* and *B. musae*) stipulate that mangosteen fruit is to be '*certified as having been harvested in a green mature condition*' or that fruit is '*in a green mature condition on arrival in Western Australia*'. In relation to mangosteen fruit, green mature condition means '*that the fruit has no purplish black colouring*'. However, these conditions will be reviewed, pending finalisation of the national IRA for the importation of mangosteen fruit from Thailand.

Biosecurity Australia's response: ICA-13 has defined mangosteen flesh as the pith of the shell as well as the flesh that is usually eaten. There is no reference to any colour of the mangosteen fruit. Biosecurity Australia has defined mature to mean mature fruit harvested at the pink to maroon stage. Our main concern is broken skin, which is defined as any pre-harvest crack, puncture, pulled stem or other break that penetrates through to the flesh and has not healed with callus tissue.

Biosecurity Australia and AQIS recognise ICA-13 for domestic trade of mangosteen from Queensland and the Northern Territory. There is sufficient evidence by scientists in Queensland and Thailand that demonstrates that mangosteen is a conditional non-host of Oriental fruit fly (*Bactrocera dorsalis*) (Unahawutti and Oonthonglang, 2002), papaya fruit fly (*B. papayae*) (Leach, 1997) and Queensland fruit fly (*B. tryoni*) (Leach, 2003, pers. comm.), when the mature fruit are harvested intact, undamaged and non-bruised.

Pre-export inspection by ARD

Stakeholder comments: How will this proposed risk management measure 'ensure' that mangosteen fruit exported to Australian do not contain quarantine pests or trash. Is it proposed to thoroughly inspect every fruit? What sampling rate, infestation level and confidence levels will be required? Assuming the Australian inspection parameters will apply, the inspection may only provide a 95% confidence that the infestation level does not exceed 0.5%.

Biosecurity Australia's response: Pre-export inspection is used in combination with the other specified quarantine measures to reduce risk to an acceptable level. Commercial orchard practices of monitoring and spraying when pests are detected, harvesting and processing practices which include grading, sorting, cleaning and checking of fruit for the export requirements in the packinghouses will also help to reduce the risk of pests and contaminants on the fruit.

Biosecurity Australia has specified that sheltered sites such as the calyx and any indented areas are to be inspected carefully. During inspection, the fruit is to be examined directly with a lens or microscope, or any pests or debris are to be brushed onto a sheet of white paper for enhanced inspection with a lens or microscope.

It is not proposed that Thailand's ARD will inspect every fruit to ensure that the consignment is free of quarantine pests, trash, soil, etc. as required. However, during targeted pre-export inspection using sampling procedures recommended by AQIS, any fruit found to harbour trash, soil, weed seeds or live pests will result in the whole consignment from that registered source being rejected. Rejected consignments would not be allowed to be exported and are traceable by their orchard registration number. Furthermore, in the packinghouse, every fruit has to be cleaned by air/water blasting.

Biosecurity Australia and the Department of Agriculture, Thailand will ensure that an appropriate sampling methodology is implemented for pre-export inspection.

Uncategorised pests

Stakeholder comment: The process for categorising pests should be included as part of the document as there are inevitably significant numbers of pests detected that are not identified by the analysis. If a pest that is detected during inspection that has not been identified in the analysis and is not present in the State of Western Australia, will that State be notified?

Biosecurity Australia's response: The term uncategorised pest refers to pests that could be present on the fruit pathway that has not been reported and assessed previously. This could include hitchhikers or contaminants. Any new pests would be assessed via the same three-step process of pest categorisation as described in all the IRA documents to determine whether a pest is categorised as a quarantine pest in accordance with FAO's ISPM definition of a quarantine pest.

Any unidentified pests detected during inspection are sent for identification. If a new pest is detected and found to be of quarantine concern, the importer has the option of treatment (if available), destruction or re-export. Quarantine status is assessed in accordance with Australia's international obligations. All pests found are recorded in the AQIS 'Incidents' database.

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APPENDICES

APPENDIX 1: PEST CATEGORISATION FOR MANGOSTEENS FROM THAILAND

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
ARTHROPODA					
Acari [mites]					
Brevipalpus californicus (Banks, 1904) [Acarina: Tenuipalpidae]	Citrus flat mite	Yes (CAB International, 2002)	Yes (Astridge *et al.*, 2000a; Halliday, 1998; ICDB, 2002)		No
Tetranychus urticae Koch [Acarina: Tetranychidae]	Two-spotted spider mite	Yes (IIE, 1996; Waterhouse, 1993)	Yes (Astridge & Fay, 2000; ICDB, 2002; IIE, 1996)		No
Diptera [flies]					
Bactrocera carambolae (Drew & Hancock) [Diptera: Tephritidae]	Carambola fruit fly	Yes (CAB International, 2002), but not on mangosteen	No (CAB International, 2002)	Yes (CAB International, 2002)	**Yes**
Bactrocera dorsalis (Hendel, 1912) [Diptera:	Oriental fruit fly	Yes	No	Yes	**Yes**

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
Tephritidae]		(Burikam *et al*., 1991; IIE, 1994; Waterhouse, 1993)	(Evenhuis, 1989)	(Burikam *et al*., 1991)	
Bactrocera papayae (Drew & Hancock) [Diptera: Tephritidae]	Papaya fruit fly	Yes (CAB International, 2002; Drew & Romig, 1996)	No – Eradicated (CAB International, 2002)	Yes (CAB International, 2002); only on damaged fruit (Leach, 1997)	**Yes**
Drosophila (*Sophophora*) *melanogaster* [Diptera: Drosophilidae]	Vinegar fly	Yes (Okada, 1977)	Yes (Anderson & Gibson, 1985; Davidson, 1990; ICDB, 2002; Worthen, 1996)		No
Hemiptera [aphids, leafhoppers, mealybugs, psyllids, scales, whiteflies]					
Aspidiotus destructor Signoret, 1869 [Hemiptera: Diaspididae]	Coconut scale	Yes (APPPC, 1987; CIE, 1966; Waterhouse, 1993)	Yes (Astridge & Fay, 2000; CIE, 1966) Not present in WA (AgWA, 2003)	No leaf (Yaacob *et al*., 1995)	No
Dysmicoccus neobrevipes Beardsley, 1959 [Hemiptera: Pseudococcidae]	Gray pineapple mealybug	Yes (Waterhouse, 1993)	No (Williams, 1985)	No? (Anon., 2000)	**Yes**
Greenidea sp. [Hemiptera: Aphididae]	Aphid	Yes (DOA, 2000)	? – Genus is present in Australia	No (DOA, 2000)	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
			(Carver, 2002) Not present in WA (AgWA, 2003)		
Icerya seychellarum (Westwood, 1855) [Hemiptera: Margarodidae]	Seychelles scale	Yes (CIE, 1955; Waterhouse, 1993)	Yes (CAB International, 2002) Not present in WA (AgWA, 2003)	No (CAB International, 2002)	No
Planococcus citri (Risso, 1813) [Hemiptera: Pseudococcidae]	Citrus mealybug	Yes (CABI/EPPO, 1999; Waterhouse, 1993)	Yes (Astridge, 2000; Chay-Prove *et al*., 2000; ICDB, 2002; Smith *et al*., 1997)		No
Pseudococcus cryptus Hempel, 1918 [Hemiptera: Pseudococcidae]	Cryptic mealybug	Yes (Anon., 2000)	No (Ben-Dov, 1994)	Yes (Anon., 2000)	**Yes**
Toxoptera aurantii (Boyer de Fonscolombe, 1841)	Camellia aphid	Yes (APPPC, 1987; Waterhouse, 1993)	Yes (Berlandier, 1999; CIE, 1961; Smith *et al*., 1997)		No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
Hymenoptera [ants, bees]					
Dolichoderus sp. [Hymenoptera: Formicidae]	Black ant	Yes (Sudhi-Aromna, 2002)	? – Genus is present in Australia (Shattuck & Barnett, 2001) Not present in WA (AgWA, 2003)	Yes (Sudhi-Aromna, 2002)	**Yes**
Technomyrmex butteli Forel [Hymenoptera: Formicidae]	Black ant	Yes (Sudhi-Aromna, 2002)	No (Shattuck & Barnett, 2001)	Yes (Sudhi-Aromna, 2002)	**Yes**
Lepidoptera [butterflies, moths]					
Acrocercops sp. [Lepidoptera: Gracillariidae]	Leaf miner	Yes (Anon., 2002)	? – Genus is present in Australia (Nielsen *et al*., 1996) Not present in WA (AgWA, 2003)	No (Anon., 2002)	No
Adoxophyes privatana Walker [Lepidoptera: Tortricidae]	Apple leaf-curling moth	Yes (DOA, 2000)	No (Nielsen *et al*., 1996)	No (DOA, 2000)	No
Aetholix flavibasalis (Guenée, 1854) [Lepidoptera: Pyralidae]	Leaf roller	Yes (DOA, 2000)	Yes (Nielsen *et al*., 1996) Not known if present in WA (AgWA, 2003)	No DOA (2000)	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
Archips micaceanus (Walker) [Lepidoptera: Tortricidae]	Soyabean leaf roller	Yes (DOA, 2000; Waterhouse, 1993)	No (Nielsen *et al*., 1996)	No (CAB International, 2002; DOA, 2000)	No
Dudua aprobola (Meyrick, 1886) [Lepidoptera: Tortricidae]	Leaf roller	Yes (DOA, 2000)	Yes (Nielsen *et al*., 1996) Not present in WA (AgWA, 2003)	No (DOA, 2000)	No
Eudocima fullonia (Clerck, 1764) [Lepidoptera: Noctuidae]	Fruit-piercing moth	Yes (Anon., 2000)	Yes (Common, 1990; Nielsen *et al*., 1996)		No
Gatesclarkeana idia Diakonoff, 1973 [Lepidoptera: Tortricidae]	Moth	Yes (DOA, 2000)	No (Nielsen *et al*., 1996)	No (DOA, 2000)	No
Homona difficilis Meyrick [Lepidoptera: Tortricidae]	Leaf roller	Yes (DOA, 2000)	No (Nielsen *et al*., 1996)	No (DOA, 2000)	No
Hyposidra talaca (Walker, 1860) [Lepidoptera: Geometridae]	Leaf-eating looper	Yes (DOA, 2000)	Yes (Common, 1990; Nielsen *et al*., 1996)		No
Lobesia genialis Meyrick [Lepidoptera: Tortricidae]	Moth	Yes (DOA, 2000)	No (Nielsen *et al*., 1996)	No (DOA, 2000)	No
Orgyia postica (Walker, 1855) [Lepidoptera: Lymantriidae]	Cocoa tussock moth	Yes (CAB International,	No (CAB International,	No (CAB International,	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
		2002; Waterhouse, 1993)	2002)	2002; Waterhouse, 1993)	
Phyllocnistis citrella Stainton, 1856 [Lepidoptera: Gracillariidae]	Citrus leaf miner	Yes (IIE, 1995; Waterhouse, 1993)	Yes (Smith *et al*., 1997; Wilson, 1991; Woods, 1995)		No
Stictoptera columba (Walker) [Lepidoptera: Noctuidae]	Leaf-eating caterpillar	Yes (DOA, 2000; Jumroenma *et al*., 2000)	Yes (Nielsen *et al*., 1996) Not present in WA (AgWA, 2003)	No (DOA, 2000)	No
Stictoptera cucullioides Guenée, 1852 [Lepidoptera: Noctuidae]	Leaf-eating caterpillar	Yes (Jumroenma *et al*., 2000)	Yes (Nielsen *et al*., 1996) Not present in WA (AgWA, 2003)	No (Ooi *et al*., 2002)	No
Stictoptera signifera Walker [Lepidoptera: Noctuidae]	Leaf-eating caterpillar	Yes (Jumroenma *et al*., 2000)	No (Nielsen *et al*., 1996)	No (Jumroenma *et al*., 2000)	No
Thysanoptera [thrips]					
Megalurothrips usitatus (Bagnall, 1913) [Thysanoptera: Thripidae]	Bean flower thrips	Yes (Reyes, 1994; Waterhouse, 1993)	Yes (Miyasaki *et al*., 1984; Mound, 1996) Not present in WA	No (CAB International, 2002)	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
			(AgWA, 2003)		
Scirtothrips dorsalis Hood, 1919 [Thysanoptera: Thripidae]	Castor thrips	Yes (DOA, 2000; IIE, 1986; Waterhouse, 1993)	Yes (Moulden, 2002; Mound, 1996)		No
Scirtothrips oligochaetus Karny [Thysanoptera: Thripidae]	Mangosteen thrips	Yes (Anon., 2002; Sririnee, 1992)	No (Mound, 1996)	No – only recorded on immature fruit and foliage (Anon., 2002; Sririnee, 1992)	No
Selenothrips rubrocinctus Giard, 1901 [Thysanoptera: Thripidae]	Red-banded thrips	Yes (Strassen & Harten, 1984)	Yes (Astridge, 2000; Astridge *et al*., 2000b; Johnson & Parr, 1999; Mound, 1996)		No
NEMATODA					
Tylenchulus semipenetrans Cobb, 1913 [Tylenchida: Tylenchulidae]	Citrus root nematode	Yes (Chunram, 1972)	Yes (Anderson, 1965; Colbran, 1955; Meagher, 1969; McLeod *et al*., 1994)		No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
ALGAE					
Cephaleuros virescens Künze [Protista]	Algal leaf spot	Yes (Lim & Sangchote, 2003)	Yes (Lim & Sangchote, 2003) No records in WA	No – only associated with foliage (Lim & Sangchote, 2003)	No
FUNGI					
Botryodiplodia theobromae Pat. [Mitosporic fungi: Coelomycetes]	Fruit rot	Yes (Banjerdcherdchu & Shana, 1991; Lim & Sangchote, 2003; Wisalthanon & Jermsiri, 1998)	Yes (CMI, 1985; Shivas, 1989)		No
Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. [Phyllachorales: Phyllachoraceae]	Anthracnose	Yes (Giatgong, 1980; Khanmalee, 1965; Lim & Sangchote, 2003; Wisalthanon & Jermsiri, 1998)	Yes (CAB International, 2002; Cameron *et al*., 1989; Chakraborty *et al*., 1996; Sweetingham *et al*., 1995)		No
Colletotrichum sp. [Phyllachorales: Phyllachoraceae]	Anthracnose; leaf blight	Yes (Khanmalee, 1965; Wisalthanon & Jermsiri, 1998)	? – Genus is present in Australia (CAB International, 2002)	No (DOA, 2000)	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
Corticium koleroga (Cooke) Höhnel [Polyporales: Corticiaceae]	Thread blight	Yes (Wisalthanon & Jermsiri, 1998)	No (APPD, 2003)	No branch, leaf, stem, twig (Bhat & Govindarajan, 1992; Duarte & Albuquerque, 2000; Lawrence *et al*., 1991)	No
Corticium salmonicolor (Berk. & Broome) [Polyporales: Corticiaceae]	Pink disease	Yes (IMI, 1996)	Yes (IMI, 1996) No records found for WA (AgWA, 2003)	No (CAB International, 2002)	No
Gliocephalotrichum bulbilium Ellis & Hesseltine [Hypocreales: Nectriaceae]	Fruit rot	Yes (Sangchote & Pongpisutta, 1998)	No (APDD, 2002) No records found for WA (AgWA, 2003)	Yes (Sangchote & Pongpisutta, 1998)	**Yes**
Graphium sp. [Mitosporic fungi: Deuteromycetes]	Fruit rot	Yes (Pienpuck & Choobumroong, 1988)	? – Genus is present in Australia (CAB International, 2002) No records found for WA (AgWA, 2003)	Yes (DOA, 2000)	**Yes**
Helminthosporium quaciniae [Mitosporic fungi: Hyphomycetes]	Leaf spot	Yes (Wisalthanon & Jermsiri, 1998)	No (APPD, 2003)	No (DOA, 2000)	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
Pestalotiopsis flagisetulai Guba [Mitosporic fungi]	Leaf spot	Yes (Giatgong, 1980; Lim & Sangchote, 2003; Wisalthanon & Jermsiri, 1998)	No (APDD, 2002) No records found for WA (AgWA, 2003)	Yes (Wisalthanon & Jermsiri, 1998)	**Yes**
Phomopsis sp. [Mitosporic fungi]	White pulp rot	Yes (Banjerdcherdchu & Shana, 1991; Lim & Sangchote, 2003)	? – Genus is present in Australia (CAB International, 2002) Genus present in WA (AgWA, 2003)	Yes (DOA, 2000)	**Yes**
WEEDS					
Brachiaria mutica (Forsk.) Stapf. [Poaceae]	Para grass; buffalo grass	Yes (DOA, 2000)	Yes (APNI, 2001) Not present in WA (Hussey *et al*., 1997)	No DOA (2000)	No
Chromolaena odorata (L.) R.M. King & H. Robbins [Asteraceae]	Siam weed; bitter-bush	Yes (DOA, 2000)	No – incursion eradicated (APNI, 2001; Hnatiuk, 1990; Holm *et al*., 1979)	No Seeds are wind dispersed and therefore unable to be lodged beneath the calyx (CABI, 2002). Not associated with	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
				mangosteen production in Thailand (DOA, 2004; CABI, 2002). Not considered able to contaminate mangosteen fruit or packaging (DOA, 2004).	
Commelina benghalensis L. [Commelinaceae]	Benghal dayflower; tropical spider wort	Yes (DOA, 2000)	Yes (APNI, 2001; Hnatiuk, 1990; Holm *et al*., 1979; Hussey *et al*., 1997)		No
Cynodon dactylon (L.) Pers. [Poaceae]	Bahama grass; Bermuda grass; couch grass; devil grass; dog's tooth grass; quick grass; star grass	Yes (DOA, 2000)	Yes (APNI, 2001; Hnatiuk, 1990; Hussey *et al*., 1997)		No
Cyperus rotundus L. [Cyperaceae]	Purple nutsedge; coco sedge; nut grass	Yes (DOA, 2000)	Yes (APNI, 2001; Hnatiuk, 1990; Holm *et al*., 1979; Hussey *et al*., 1997)		No
Digitaria ciliaris (Retz.) Koeler [Poaceae]	Finger grass; southern crab grass; tropical crab grass	Yes (DOA, 2000)	Yes (APNI, 2001; Hnatiuk, 1990;		No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
			Hussey *et al*., 1997)		
Echinochloa colona (L.) Link [Poaceae]	Awnless barnyard grass; birds rice; jungle rice grass	Yes (DOA, 2000)	Yes (APNI, 2001; Hnatiuk, 1990; Hussey *et al*., 1997)		No
Imperata cylindrica (L.) P. Beauv. [Poaceae]	Bedding grass; blady grass; cogon grass; silver spike; spear grass; sword grass; thatch grass	Yes (DOA, 2000)	Yes (APNI, 2001) Not present in WA (Hussey *et al*., 1997)	No Seeds are wind dispersed and therefore unable to be lodged beneath the calyx (CABI, 2002).	No
Paspalum conjugatum Berg. [Poaceae]	Hilo grass, sour grass	Yes (DOA, 2000)	Yes (APNI, 2001; Hussey *et al*., 1997)		No
Pennisetum polystachyon Shult. [Poaceae]	Feather pennisetum; mission grass; thin napier grass	Yes DOA (2000)	Yes (APNI, 2001; Hussey *et al*., 1997)		No

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APPENDIX 2: POTENTIAL FOR ENTRY, ESTABLISHMENT OR SPREAD AND CONSEQUENCES

Scientific name	Common name	Potential for entry[1], establishment or spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
ARTHROPODS						
Diptera [flies]						
Bactrocera carambolae (Drew & Hancock) [Diptera: Tephritidae]	Carambola fruit fly	Feasible	Wide host range (Allwood *et al*., 1999). Dispersed by infected fruit and adult flight (Fletcher, 1989). Strong flyer – adults can fly up to 50-100 km (Fletcher, 1989).	Significant	Primary economic impact would result from quarantine restrictions imposed by important domestic and foreign export markets, rather than from direct yield losses from infested fruit.	**Yes**
Bactrocera dorsalis (Hendel) [Diptera: Tephritidae]	Oriental fruit fly	Feasible	Wide host range (Allwood *et al*., 1999; Tsuruta *et al*., 1997). Dispersed by infected fruit and adult flight (Fletcher, 1989). Strong flyer – adults can fly up to 50-100 km (Fletcher, 1989).	Significant	Primary economic impact would result from quarantine restrictions imposed by important domestic and foreign export markets, rather than from direct yield losses from infested fruit.	**Yes**
Bactrocera papayae (Drew & Hancock) [Diptera: Tephritidae]	Papaya fruit fly	Feasible	Wide host range (Allwood *et al*., 1999). Dispersed by infected fruit and adult flight (Fletcher, 1989). Strong flyer – adults can fly up to 50-100 km (Fletcher, 1989).	Significant	Primary economic impact would result from quarantine restrictions imposed by important domestic and foreign export markets, rather than from direct yield losses from infested fruit.	**Yes**

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[1] Association of the pest with the mangosteen fruit pathway (see Appendix 1) was considered to be sufficient evidence of feasibe potential for entry.

Scientific name	Common name	Potential for entry[1], establishment or spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
Hemiptera [aphids, leafhoppers, mealybugs, psyllids, scales, whiteflies]						
Dysmicoccus neobrevipes Beardsley [Hemiptera: Pseudococcidae]	Gray pineapple mealybug	Feasible	Wide host range (Ben-Dov, 1994) and high reproductive rates (Kessing & Mau, 1992). Adults females live an average length of 95-148 days (Ito, 1938; Kessing & Mau, 1992).	Significant	Can infest a wide range of plant species. Therefore, has potential to cause economic damage if introduced. Vector of green spot disease on pineapple leaves (Beardsley, 1993; Kessing & Mau, 1992).	**Yes**
Pseudococcus cryptus Hempel [Hemiptera: Pseudococcidae]	Cryptic mealybug	Feasible	Wide host range (Ben-Dov, 1994).	Significant	Can infest a wide range of plant species. Therefore, has potential to cause economic damage if introduced.	**Yes**
Hymenoptera [ants, bees]						
Dolichoderus sp. [Hymenoptera: Formicidae]	Black ant	Feasible	This species can establish and spread in the PRA area, as other species in the genus are present in Australia (Shattuck & Barnett, 2001). This species is highly adaptive, competitive and a general scavenger.	Significant	This species will compete for resources with native species. Can cause indirect damage through proliferation of honeydew secreting pests, leading to reduction of photosynthesis as a result of sooty mould development.	**Yes**
Technomyrmex butteli Forel [Hymenoptera: Formicidae]	Black ant	Feasible	This species can establish and spread in the PRA area, as other species in the genus are present in Australia (Shattuck & Barnett, 2001). This species is highly adaptive, competitive and a general scavenger.	Significant	This species will compete for resources with native species. Can cause indirect damage through proliferation of honeydew secreting pests, leading to reduction of photosynthesis as a result of sooty mould development.	**Yes**

Scientific name	Common name	Potential for entry[1], establishment or spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
FUNGI						
Gliocephalotrichum bulbilium Ellis & Hesseltine [Hypocreales: Nectriaceae]	Fruit rot	Feasible	Wood rotting fungus commonly found in woody substrates, plant debris, soil, manure, and polluted water (Anon., 2002).	Not significant	Weak pathogen or secondary invader (Sivapalan *et al*., 1998), causing postharvest problems related to injuries caused during harvesting, processing and high humidity and temperatures during packaging, storage and transport (Visarathanonth & Ilag, 1987).	No
Graphium sp. [Mitosporic fungi: Deuteromycetes]	Fruit rot	Feasible	This species can establish and spread in the PRA area, as other species in the genus are present in Australia (CAB International, 2002).	Not significant	Causes postharvest problems related to injuries caused during harvesting, processing and high humidity and temperatures during packaging, storage and transport (Visarathanonth & Ilag, 1987). The fact that this species has not been identified to species level and has only been reported once in a list of mangosteen diseases indicates its lack of economic importance.	No
Pestalotiopsis flagisetulai Guba [Mitosporic fungi]	Leaf spot	Feasible	This species can establish and spread in the PRA area, as susceptible hosts are present in Australia.	Not significant	Weak pathogen or secondary invader (Sivapalan *et al*., 1998), causing postharvest storage rots. Causes postharvest problems related to injuries caused during harvesting, processing and high humidity and temperatures	No

Scientific name	Common name	Potential for entry[1], establishment or spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
					during packaging, storage and transport (Visarathanonth & Ilag, 1987).	
Phomopsis sp. [Mitosporic fungi]	White pulp rot	Feasible	This species can establish and spread in the PRA area as the genus is present in Australia (CAB International, 2002).	Not significant	Weak pathogen or secondary invader (Sivapalan *et al*., 1998), causing postharvest problems related to injuries caused during harvesting, processing and high humidity and temperatures during packaging, storage and transport (Visarathanonth & Ilag, 1987).	No

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APPENDIX 3: DATASHEETS FOR PESTS OF QUARANTINE CONCERN

3.1 *Bactrocera carambolae* (Drew & Hancock) [Diptera: Tephritidae]

Synonyms and changes in combination: *Bactrocera* sp. near *dorsalis* (A) (Hendel)

Common name(s): Carambola fruit fly.

Host(s): *Bactrocera carambolae* is a serious pest of *Averrhoa carambola* (carambola), however its total host list is extensive. This species is present in Thailand (Drew and Romig, 1996), but has not been reported to infest mangosteen in Thailand, although mangosteen has been reported to be a host by CAB International (2002).

Other recorded commercial hosts are: *Anacardium occidentale* (cashew), *Annona muricata* (soursop), *Arenga pinnata* (sugar palm), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Artocarpus integer* (chempedak), *Averrhoa bilimbi* (bilimbi), *Capsicum annuum* (bell pepper, capsicum), *Carica papaya* (pawpaw), *Chrysophyllum cainito* (star-apple), *Citrus aurantiifolia* (lime), *Citrus maxima* (pummelo), *Citrus limon* (lemon), *Citrus reticulata* (mandarin), *Citrus sinensis* (navel orange), *Citrus* × *paradisi* (grapefruit), *Eugenia uniflora* (Brazil cherry), *Fortunella margarita* (oval kumquat), *Garcinia mangostana* (mangosteen), *Lycopersicon esculentum* (tomato), *Malpighia glabra* (acerola), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Mimusops elengi* (Asian bulletwood), *Persea americana* (avocado), *Pouteria campechiana* (yellow sapote), *Psidium cattleianum* (strawberry guava), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Rhizophora* sp., *Rollinia pulchrinervis*, *Syzygium aqueum* (water apple), *Syzygium jambos* (rose apple), *Syzygium malaccense* (Malay apple), *Syzygium samarangense* (wax apple), *Terminalia catappa* (beach almond), *Thevetia peruviana* (yellow oleander) and *Ziziphus jujuba* (jujube) (Allwood *et al*., 1999; CAB International, 2002; Ranganath and Veenakumari, 1995; Ranganath *et al*., 1997; Yong, 1994).

Plant part(s) affected: Fruit (CAB International, 2002).

Distribution: *B. carambolae* is widely distributed throughout Asia and is present in the Thai/Malay peninsular area. It is found in India (Drew and Hancock, 1994); Indonesia (Drew and Hancock, 1994; White and Hancock, 1997); Malaysia (Drew and Hancock, 1994; White and Hancock, 1997); Singapore (Drew and Hancock, 1994) and Thailand (Drew and Hancock, 1994). In the Western Hemisphere, this species has been recorded from French Guiana (Drew and Hancock, 1994); Guyana (IIE, 1994) and Suriname (Drew and Hancock, 1994).

Biology: The eggs of *B. oleae* were described in detail by Margaritis (1985) and those of other species are probably very similar. They are 0.8 mm long, 0.2 mm wide, and white to yellow-white in colour (Margaritis, 1985). Eggs of species related to *B. carambolae* are laid below the skin of the host fruit. They hatch within a day (although this can be delayed up to 20 days in cool conditions) and the larvae feed for another 6-35 days, depending on the season. Eggs are visible to the naked eye (CAB International, 2002). Third instar larvae of *B. carambolae* are medium-sized, 7.5-9.5 mm long and 1.5-2 mm wide (White and Elson-Harris, 1994).

Pupariation is in the soil under the host plant for 10-12 days but may be delayed for up to 90 days under cool conditions (Christenson and Foote, 1960). Pupae are barrel-shaped with most larval features unrecognisable. Puparium are usually about 60-80% length of larva. Fruits and growing media are liable to carry pupae of this fruit fly in trade/transport (CAB International, 2002). Pupae can be found in the growing medium, accompanying plants, and are also visible to the naked eye, being white to yellow-brown in colour. Other plant parts are not known to carry the pest in trade/transport (CAB International, 2002).

Adults are predominantly black or dark fuscous, or a balanced mixture of black and yellow. When viewed dorsally, the thorax is predominantly dark with lateral yellow stripes before turning yellow posteriorly. The abdomen is oval in shape or parallel sided, tergites are separate with medial dark stripes (Carroll *et al*., 2002). Adults occur throughout the year and begin mating after about 8-12 days, they may live 1-3 months depending on temperature (up to 12 months in cool conditions) (Christenson and Foote, 1960).

The major means of movement and dispersal are adult flight and transportation of infected fruit (Fletcher, 1989). Many *Bactrocera* spp. can fly 50-100 km (Fletcher, 1989).

Little information is available on the attack time for most fruits but few *Bactrocera* spp. attack prior to ripening (CAB International, 2002). Fruit show the following symptoms of infestation, some necrosis around the puncture mark ('sting') following oviposition, which causes decomposition of the fruit that appears as black or brown lesions. Premature drop from trees can occur (CAB International, 2002).

Control: Fruits (locally grown or samples of fruit imports) should be inspected for puncture marks and any associated necrosis. Suspect fruits should be cut open and checked for larvae. Larval identification is difficult, so if time allows, mature larvae should be transferred to saw dust (or similar dry medium) to allow pupariation. Upon emergence, adult flies must be fed with sugar and water for several days to allow hardening and full colour to develop, before they can be identified (CAB International, 2002). One of the most effective control techniques against fruit flies in general is to wrap fruit, either in newspaper, a paper bag, or in the case of long/thin fruits, a polythene sleeve. This is a simple physical barrier to oviposition but it has to be applied well before the fruit is attacked.

Larvae of *Bactrocera* spp. can be attacked either by parasitoids or by vertebrates eating fruit (either on the tree or as fallen fruit). Parasitoids appear to have little effect on the populations of most fruit flies and Fletcher (1987) noted that 0-30% levels of parasitism are typical. Mortality due to vertebrate fruit consumption can be very high as can puparial mortality in the soil, either due to predation or environmental mortality (White and Elson-Harris, 1994). To date, there are no records of biological control success for any *Bactrocera* or *Dacus* spp. (Wharton, 1989).

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3.2 *Bactrocera dorsalis* (Hendel, 1912) [Diptera: Tephritidae]

Synonyms and changes in combination: *Bactrocera conformis* Doleschall, 1858; *Bactrocera ferrugineus* Fabricius; *Chaetodacus dorsalis* Hendel; *Chaetodacus ferrugineus* Fabricius; *Chaetodacus ferrugineus dorsalis* Hendel; *Chaetodacus ferrugineus okinawanus* Shiraki, 1933; *Dacus dorsalis* Hendel, 1912; *Dacus ferrugineus* Fabricius; *Dacus ferrugineus dorsalis* Fabricius; *Dacus ferrugineus okinawanus* Shiraki; *Dacus ferrugineus* var. *dorsalis* Fabricius; *Musca ferruginea* Fabricius, 1794; *Strumeta dorsalis* Hendel; *Strumeta ferrugineus* Fabricius.

Common name(s): Oriental fruit fly.

Host(s): *Bactrocera dorsalis* is a very serious pest of a wide variety of fruits and vegetables throughout its range and damage levels can be anything up to 100% of unprotected fruit. In China, where the pest populations are definitely the true *B. dorsalis*, the major hosts are apple, guava, mango, peach and pear (*Pyrus communis*) (X.-J. Wang, unpublished data, 1988, as reported in White and Elson-Harris, 1994). Due to the confusion between *B. dorsalis* and related species in the Oriental fruit fly species complex (some 52 species that are found in the Oriental region, and a further 16 species native to Australasia), there are very few published host records which definitely refer to true *B. dorsalis* (CAB International, 2002).

Mangosteen has not been listed as a primary or secondary host of *B. dorsalis* in CAB International (2002). No host plant survey has yet been carried out to show which hosts are of particular importance within the Asian range of true *B. dorsalis*. However, in the Californian Department of Food and Agriculture Exotic Fruit Fly Regulatory Response Manual, mangosteen is listed as a typical host of *B. dorsalis* (Hillard and Jordan, 2001).

Recorded commercial hosts are: *Aegle marmelos* (bael fruit), *Anacardium occidentale* (cashew nut), *Annona reticulata* (bullock's heart), *Annona squamosa* (sugar apple), *Areca catechu* (betelnut palm), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Capsicum annuum* (bell pepper), *Chrysophyllum cainito* (caimito), *Citrus maxima* (pummelo), *Citrus reticulata* (mandarin), *Coffea arabica* (arabica coffee), *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Dimocarpus longan* (longan), *Ficus racemosa* (cluster fig), *Litchi chinensis* (lychee), *Malus pumila* (apple), *Mangifera foetida* (bachang mango), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Mimusops elengi* (Asian bulletwood), *Momordica charantia* (bitter gourd), *Muntingia calabura* (Jamaica cherry), *Musa* sp. (banana), *Nephelium lappaceum* (rambutan), *Persea americana* (avocado), *Prunus armeniaca* (apricot), *Prunus avium* (gean), *Prunus cerasus* (sour cherry), *Prunus domestica* (plum, prune), *Prunus mume* (Japanese apricot), *Prunus persica* (peach), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Pyrus communis* (European pear), *Syzygium aqueum* (water apple), *Syzygium aromaticum* (clove), *Syzygium cumini* (jambolan), *Syzygium jambos* (rose apple), *Syzygium malaccense* (Malay apple), *Syzygium samarangense* (wax apple), *Terminalia catappa* (beach almond), *Ziziphus jujuba* (jujube) and *Ziziphus mauritiana* (Chinese date) (Allwood *et al*., 1999; Tsuruta *et al*., 1997).

Plant part(s) affected: Fruit (CAB International, 2002).

Distribution: The true *Bactrocera dorsalis* is restricted to mainland Asia (except the peninsula of southern Thailand and West Malaysia), as well as Taiwan and its adventive population in Hawaii (Drew and Hancock, 1994). CAB International (2002) also includes California and Florida, USA, in the distribution because the fly is repeatedly trapped there in small numbers. The distribution of *B. dorsalis* was mapped by IIE (1994). This species is a serious pest of a wide range of fruit crops in Taiwan, southern Japan, China and in the northern areas of the Indian subcontinent, and it has also been established in the Hawaiian Islands since about 1945 (Pemberton, 1946).

In Asia, *B. dorsalis* is recorded from Bangladesh (IIE, 1994); Bhutan (Drew and Hancock, 1994); Cambodia (Drew and Hancock, 1994; Waterhouse, 1993); China (Drew and Hancock, 1994); Guam (Waterhouse, 1993); Hawaii (Drew and Hancock, 1994); Laos (Drew and Hancock, 1994); Myanmar (Drew and Hancock, 1994); Nauru (Waterhouse, 1993) Nepal (Drew and Hancock, 1994); Pakistan (Drew and Hancock, 1994); Sri Lanka (Drew and Hancock, 1994); Thailand (Drew and Hancock, 1994; Waterhouse, 1993) and Vietnam (Drew and Hancock, 1994).

Biology: The eggs of *B. oleae* were described in detail by Margaritis (1985) and those of other species are probably very similar. They are 0.8 mm long, 0.2 mm wide, and white to yellow-white in colour (Margaritis, 1985). Females lay a number of eggs per fruit. Clutch sizes of 3-30 eggs have been recorded for *B. dorsalis* (Fletcher, 1989). Eggs of *B. dorsalis* are laid below the skin of the host fruit. These hatch within a day (although this can be delayed up to 20 days in cool conditions) and the larvae feed for another 6-35 days, depending on the season. Eggs are visible to the naked eye (CAB International, 2002). Third instar larvae of *B. dorsalis* are medium-sized, length 7.5-10 mm; width 1.5-2 mm (White and Elson-Harris, 1994).

Pupariation is in the soil under the host plant for 10-12 days but may be delayed for up to 90 days under cool conditions (Christenson and Foote, 1960). Pupae are barrel-shaped with most larval features unrecognisable. Puparium are usually about 60-80% length of larva. Pupae can be found in the growing medium, accompanying plants, and are also visible to the naked eye, being white to yellow-brown in colour. Other plant parts are not known to carry the pest in trade/transport (CAB International, 2002). Fruits and growing media are liable to carry pupae of this fruit fly in trade/transport (CAB International, 2002).

Adults are predominantly black or dark fuscous, or a balanced mixture of black and yellow. When the thorax is viewed dorsally, there are a number of pale whitish to yellow lateral stripes over the anterior plates. In addition, the posterior thoracic plates are black with orange to red-brown areas, or black. The abdomen is oval or parallel sided with a mediolateral dark stripe running most of its length (Carroll *et al*., 2002). Adults occur throughout the year and begin mating after about 8-12 days, and may live 1-3 months depending on temperature (up to 12 months in cool conditions) (Christenson and Foote, 1960). Adults may live for many months and in laboratory studies, the potential fecundity of females of *B. dorsalis* is well over 1000 eggs (Fletcher, 1989).

The major means of movement and dispersal are transportation of infected fruit and adult flight (Fletcher, 1989). Many *Bactrocera* spp. can fly 50-100 km (Fletcher, 1989).

Little information is available on the attack time for most fruits but few *Bactrocera* spp. attack prior to ripening (CAB International, 2002). Fruit show the following symptoms of infestation, some necrosis around the puncture mark (‘sting’) following oviposition, which causes decomposition of the fruit that appears as black or brown lesions. Premature drop from trees can occur (CAB International, 2002).

Control: Fruits (locally grown or samples of fruit imports) should be inspected for puncture marks and any associated necrosis. Suspect fruits should be cut open and checked for larvae. Larval identification is difficult, so if time allows, mature larvae should be transferred to saw dust (or similar dry medium) to allow pupation. Upon emergence, adult flies must be fed with sugar and water for several days to allow hardening and full colour to develop, before they can be identified (CAB International, 2002). One of the most effective control techniques against fruit flies in general is to wrap fruit, either in newspaper, a paper bag, or in the case of long/thin fruits, a polythene sleeve. This is a simple physical barrier to oviposition but it has to be applied well before the fruit is attacked.

Larvae of *Bactrocera* spp. can be attacked either by parasitoids or by vertebrates eating fruit (either on the tree or as fallen fruit). Parasitoids appear to have little effect on the populations of most fruit flies and Fletcher (1987) noted that 0-30% levels of parasitism are typical. Mortality due to vertebrate fruit consumption can be very high as can puparial mortality in the soil, either due to predation or environmental mortality (White and Elson-Harris, 1994). To date, there are no records of biological control success for any *Bactrocera* or *Dacus* spp. (Wharton, 1989). However, Clausen (1978) reviewed the numerous releases that have taken place in Hawaii and these are listed under natural enemies. Clausen (1978) noted that any benefit was almost entirely due to *Fopius arisanus* (as *Opius oophilus*) and gave the example of guava fruit attack being reduced from 100 to 22% as a result of reduction in *B. dorsalis* populations through the effects of parasitism. A number of parasitoids were also released in Guam against *B. dorsalis* (Waterhouse, 1993).

Due to difficulties in verifying the identifications of both parasitoids and (in some cases) the fruit fly hosts, no attempt has been made to catalogue all natural enemy records (CAB International, 2002). Major sources are listed in White and Elson-Harris (1994).

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3.3 *Bactrocera papayae* (Drew & Hancock) [Diptera: Tephritidae]

Synonyms and changes in combination: *Bactrocera conformis* Doleschall; *Bactrocera* sp. "Malaysian B".

Common name(s): Papaya fruit fly; Asian papaya fruit fly.

Host(s): In Malaysia, this species is a pest of papaya and it also caused heavy attack on mango and ripe (not green) banana (R.A.I. Drew, unpublished data, 1990, as reported by White and Elson-Harris, 1994). This species is present in Thailand (Drew and Romig, 1996), but has not been reported to infest mangosteen in Thailand, although mangosteen has been reported to be a host by CAB International (2002).

Other recorded commercial hosts are: *Anacardium occidentale* (cashew), *Annona glabra* (pond apple), *Annona muricata* (soursop), *Annona reticulata* (bullock's heart), *Annona squamosa* (sugar apple), *Areca catechu* (betelnut palm), *Arenga pinnata* (sugar palm), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Artocarpus integer* (chempedak), *Averrhoa bilimbi* (bilimbi), *Averrhoa carambola* (carambola), *Borassus flabellifer* (fan palm), *Calophyllum inophyllum* (Alexandrian laurel), *Capsicum annuum* (bell pepper, capsicum), *Carica papaya* (pawpaw), *Castanopsis* sp., *Chrysophyllum cainito* (star-apple), *Citrus aurantifolia* (lime), *Citrus limon* (lemon), *Citrus madurensis* (calamondin), *Citrus maxima* (pummelo), *Citrus reticulata* (mandarin), *Citrus sinensis* (navel orange), *Citrus × paradisi* (grapefruit), *Clausena lansium* (wampi), C*offea arabica* (arabica coffee), *Coffea canephora* (robusta coffee), *Cucumis sativus* (cucumber), *Diospyros blancoi* (velvet apple), *Eriobotrya japonica* (loquat), *Eugenia uniflora* (Brazil cherry), *Ficus benjamina* (Benjamina fig), *Ficus microcarpa* (Indian laurel tree), *Flacourtia rukam* (rukam), *Fortunella japonica* (round kumquat), *Fortunella margarita* (oval kumquat), *Garcinia mangostana* (mangosteen), *Lycopersicon esculentum* (tomato), *Malpighia glabra* (acerola), *Mangifera foetida* (bachang mango), *Mangifera indica* (mango), *Mangifera odorata*, *Manilkara zapota* (sapodilla), *Mimusops elengi* (Asian bulletwood), *Momordica charantia* (balsam apple), *Morinda citrifolia* (Indian mulberry), *Morus alba* (white mulberry), *Muntingia calabura* (Jamaica cherry), *Musa acuminata* (dwarf banana tree), *Musa balbisiana*, *Musa paradisiaca* (banana, plantain), *Nephelium lappaceum* (rambutan), *Passiflora edulis* (passionfruit), *Passiflora quadrangularis* (giant granadilla), *Passiflora suberosa* (Corky passionflower), *Persea americana* (avocado), *Phaseolus vulgaris* (bean), *Pouteria campechiana* (yellow sapote), *Prunus persica* (peach), *Psidium cattleianum* (strawberry guava), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Rhizophora* sp., *Rollinia pulchrinervis*, *Solanum incanum* (bitter apple), *Solanum melongena* (aubergine), *Solanum torvum* (devil's fig), *Spondias cytherea* (ambarella), *Syzygium aqueum* (water apple), *Syzygium jambos* (rose apple), *Syzygium malaccense* (Malay apple), *Syzygium samarangense* (wax apple), *Terminalia catappa* (beach almond), *Theobroma cacao* (cocoa), *Thevetia peruviana* (yellow oleander), *Ziziphus jujuba* (jujube) and *Ziziphus mauritiana* (Chinese date) (Allwood *et al*., 1999; CAB International, 2002; Drew and Hancock, 1994; Hancock *et al*., 2000; Yong, 1994).

Plant part(s) affected: Fruit (CAB International, 2002).

Distribution: *Bactrocera papayae* is a very serious pest in Malaysia and the recent outbreak in north Queensland, Australia caused considerable concern (now eradicated). *B. papayae* is found in Malaysia, the southern (peninsular) area of Thailand and throughout western Indonesia. The distribution of *B. papayae* was mapped by IIE (1994). In Asia, *B. papayae* is recorded from Brunei Darussalam (CAB International, 2002), Christmas Island (Drew and Hancock, 1994); Indonesia (Drew and Hancock, 1994); Malaysia (Drew and Hancock, 1994); Papua New Guinea (CAB International, 2002); Singapore (Drew and Hancock, 1994) and Thailand (Drew and Hancock, 1994).

Biology: No specific details on the biology of *B. papayae* are available.

The eggs of *B. oleae* were described in detail by Margaritis (1985) and those of other species are probably very similar. They are 0.8 mm long, 0.2 mm wide, and white to yellow-white in colour (Margaritis, 1985). Eggs of related species are laid below the skin of the host fruit. These hatch within a day (although delayed up to 20 days in cool conditions) and the larvae feed for another 6-35 days, depending on the season. Eggs are visible to the naked eye (CAB International, 2002). Third instar larvae of *B. papayae* are medium-sized, 7-9 mm long and 1.5-1.8 mm wide (White and Elson-Harris, 1994).

Pupariation is in the soil under the host plant for 10-12 days but may be delayed for up to 90 days under cool conditions (Christenson and Foote, 1960). Pupae are barrel-shaped with most larval features unrecognisable. Puparium are usually about 60-80% length of larva. Fruits and growing media are liable to carry pupae of this fruit fly in trade/transport (CAB International, 2002). Pupae can be found in the growing medium, accompanying plants, and are also visible to the naked eye, being white to yellow-brown in colour. Other plant parts are not known to carry the pest in trade/transport (CAB International, 2002).

Adults are predominantly black or dark fuscous, or a balanced mixture of black and yellow. When the thorax is viewed dorsally, there are a number of pale whitish to yellow lateral stripes over the anterior plates (similar to *B. dorsalis*). The abdomen is oval or parallel sided with a mediolateral dark stripe running most of its length (similar to *B. dorsalis*) (Carroll *et al*., 2002). Adults occur throughout the year and begin mating after about 8-12 days, and may live 1-3 months depending on temperature (up to 12 months in cool conditions) (Christenson and Foote, 1960).

The major means of movement and dispersal are transportation of infected fruit and adult flight (Fletcher, 1989). Many *Bactrocera* spp. can fly 50-100 km (Fletcher, 1989).

Little information is available on the attack time for most fruits but few *Bactrocera* spp. attack prior to ripening (CAB International, 2002). Fruit show the following symptoms of infestation, some necrosis around the puncture mark ('sting') following oviposition, which causes decomposition of the fruit that appears as black or brown lesions. Premature drop from trees can occur (CAB International, 2002).

Control: Fruits (locally grown or samples of fruit imports) should be inspected for puncture marks and any associated necrosis. Suspect fruits should be cut open and checked for larvae. Larval identification is difficult, so if time allows, mature larvae should be transferred to saw dust (or similar dry medium) to allow pupariation. Upon emergence, adult flies must be fed with sugar and water for several days to allow hardening and full colour to develop, before they can be identified (CAB International, 2002). One of the most effective control techniques against fruit flies in general is to wrap fruit, either in newspaper, a paper bag, or in the case of long/thin fruits, a polythene sleeve. This is a simple physical barrier to oviposition but it has to be applied well before the fruit is attacked.

Larvae of *Bactrocera* spp. can be attacked either by parasitoids or by vertebrates eating fruit (either on the tree or as fallen fruit). Parasitoids appear to have little effect on the populations of most fruit flies and Fletcher (1987) noted that 0-30% levels of parasitism are typical. Mortality due to vertebrate fruit consumption can be very high as can puparial mortality in the soil, either due to predation or environmental mortality (White and Elson-Harris, 1994). To date, there are no records of biological control success for any *Bactrocera* or *Dacus* spp. (Wharton, 1989). Laboratory studies have indicated that *B. papayae* can be attacked by the braconid *Diachasmimorpha longicaudata* Ashmead (Petcharat, 1997a) and some field trial of this as a possible biocontrol agent have also been carried out in Thailand (Petcharat, 1997b).

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3.4 *Dolichoderus* sp. (Lund, 1831) [Hymenoptera: Formicidae]

Synonyms and changes in combination for genus: *Hypoclinea* sp. Mayr, 1855; *Acanthoclinea* sp. Wheeler, 1935; *Diceratoclinea* sp. Wheeler, 1935.

Common name(s): Black ant.

Host(s): *Dolichoderus* sp. is found in forested areas, from dry savannah woodlands through mallee, dry sclerophyll and wet sclerophyll, and into rainforests (Shattuck and Barnett, 2001). Host species include *Cordia alliodora* (Longino, 1996); *Garcinia mangostana* (mangosteen) (Sudhi-Aromna, 2002); Fabaceae, *Dioclea* sp., *Goupia glabra*, *Philodendron* sp., *Vochysia* sp., *Xylopia* sp. (Blüthgen *et al*., 2000b); *Guzmania lingulata*, *Tillandsia adpressiflora* (crazy pineapple), *Vriesea procera* and *Vriesea rubra* (Blüthgen *et al*., 2000a).

Plant part(s) affected: *Dolichoderus* sp. roam all over plants in search of honeydew secreted by mealybugs and extra floral nectaries from the plant itself (Delabie, 2001). They are also generalist inhabitants of dead stems and nodes (Longino, 1996).

Distribution: *Dolichoderus* sp. is distributed worldwide except for the Afrotropics and Madagascar (Lund, 1831). The 142 described species and subspecies of *Dolichoderus* occur in southern North America, northern South America, Europe east to the Black Sea, and from India east to Japan, and south to Australia (Shattuck, 1992). Within Australia, there are 22 described species and subspecies. These occur in eastern Queensland from

Cape York Peninsula south through eastern New South Wales, Victoria, southern South Australia and southern Western Australia. The only known Tasmanian population is apparently introduced (Shattuck and Barnett, 2001).

Biology: *Dolichoderus* sp. are medium sized black ants, the worker body length is 3-5 mm. They can be identified by the presence of a weak to well-developed flange (that is sometimes tooth-like) on the underside of the head near the base of the mouthparts. The body is often strongly sculptured and the plates on the underside of the body above the front legs (visible only when the front legs are removed) are expanded and overlapping along the centre-line of the body (Shattuck and Barnett, 2001).

Dolichoderus sp. are often found in small numbers foraging in columns on the ground or on low vegetation and trees. Nesting occurs either in the soil or in the trees. Sometimes plant fibres are used to form coverings over the nest area during construction. During warm weather, some species will move their larvae to the surface of the ground for warmth. Workers generally scavenge and tend Hemiptera in order to collect honeydew as nutrients (Shattuck and Barnett, 2001). Honeydew-producing 'Homoptera' can be seen as an ecological equivalent of plant extra floral nectaries, and the presence of both ants and sap-sucking insects should be understood as a mechanism beneficial to the plant, if trophobiont density remains low (Cushman and Addicott, 1991; Way, 1963; Wood, 1982).

Ants play a vital role in rainforest ecology. They have developed mutual relationships with many types of trees and other plants, some so important that without one another they would not be able to survive. By developing these relationships, both the ants and the plants create an optimal environment for each other in which they can avoid predation, provide protection, and cycle nutrients and waste products with each other. Some plants have even developed ways to provide a habitat and nutrients for ants, which live on them. In turn, the ants protect the plant from herbivores and from certain types of plant diseases (Peck, 2001). Some mobile Homoptera provide an example. The honeydew they secrete collects on the plants surface and generally promotes the formation of large spots of the fungus sooty mould (Carter, 1962; Gullan, 1997; Way, 1963). This can damage the foliage of the plant and reduce the amount of photosynthesis possible. However, the ants that are in a mutualistic relationship with the Homoptera clean up the honeydew and in addition scavenge other sap-sucking insects that could cause further damage to the plant (Paulson, 1998).

Following are examples of *Dolichoderus* species along with their interactions with plants and/or Homopterans. *D. thoracicus* is commonly used throughout Southeast Asia to help control major insect pests of cocoa (Chong, 2001), which include the mirid *Helopeltis theivora* (Khoo and Ho, 1992), the moth *Conopomorpha cramerella* (See and Khoo, 1996) and the fruit borer *Alophia* sp. (Paul *et al*., 1999). *D. thoracicus* has a mutualistic relationship with the mealybug *Cataenococcus hispidus* on the cocoa plant. The ants protect the mealybugs from predators in exchange for nutrients in the form of honeydew, which the mealybugs secrete (Ho and Khoo, 1997). Trophobiosis between *D. bidens* (L.) and the mealybug *Planococcus citri* (Risso) on a cocoa pod occurs at Bahia in Brazil (Delabie, 2001). Several species of the genus *Dolichoderus* living in the Malaysian Peninsula are known as herdsmen ants because they spend all their life as nomads, migrating together with symbiotic Allomyrmococcini mealybugs, and occasionally tending some Coccidae or Membracidae (Hölldobler and Wilson, 1990; Maschwitz and Dill, 1998; Maschwitz and Hänel, 1985).

Many of the mealybugs tended by *Dolichoderus* sp. are economic pests of crops. For example, *Planococcus citri* is a citrus pest that is also a vector of cocoa swollen shoot virus and has been implicated with the transmission of grapevine leafroll associated virus 3 (GLRaV-3) (Cabaleiro and Segura, 1997). It has also been reported, for the first time, as a vector of banana streak virus and cucumber mosaic virus infecting banana cultivars (*Musa* spp.) in Taiwan (Su *et al*., 1997).

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3.5 *Dysmicoccus neobrevipes* Beardsley, 1959 [Hemiptera: Pseudococcidae]

Synonyms and changes in combination: *Dysmicoccus brevipes* (grey form) (Ito, 1938).

Common name(s): Annona mealybug; gray pineapple mealybug; pineapple grey mealybug.

Host(s): *Acacia farnesiana* (sweet wattle) (Beardsley, 1959); *Acacia koa* (Hawaiian mahogany) (Beardsley, 1959); *Agave sisalana* (sisal agave) (Beardsley, 1959); *Aglaonema treubii* (arum) (Ben-Dov, 1994); *Alpinia purpurata* (red ginger) (Beardsley, 1959); *Ananas comosus* (pineapple) (Ben-Dov, 1994; Williams and Watson, 1988); *Annona muricata* (prickly custard apple) (Williams and Watson, 1988); *Annona reticulata* (custard apple) (Beardsley, 1965); *Arachis hypogaea* (peanut) (Ben-Dov, 1994); *Artocarpus altilis* (breadfruit) (Williams and Watson, 1988); *Barringtonia asiatica* (fish-killer tree) (Beardsley, 1965); *Basella* sp. (Anon., 1979); *Brassavola cordata* (Ben-Dov, 1994); *Cajanus cajan* (pigeon pea) (Ben-Dov, 1994); *Citrus aurantifolia* (lime) (Williams and Watson, 1988); *Citrus limon* (lemon) (Williams and Watson, 1988); *Citrus sinensis* (navel orange) (Ben-Dov, 1994); *Clerodendrum* sp. (fragrant clerodendron) (Ben-Dov, 1994); *Coccoloba* sp. (sea-grape) (Williams and Watson, 1988); *Coccoloba uvifera* (sea-grape) (Williams and Watson, 1988); *Cocos nucifera* (coconut) (Beardsley, 1965); *Codiaeum* sp. (croton) (Ben-Dov, 1994); *Coffea arabica* (arabica coffee) (Williams and Watson, 1988);

Coffea canephora (robusta coffee) (Williams and Watson, 1988); *Cordia alliodora* (Spanish elm) (Ben-Dov, 1994); *Crescentia alata* (Beardsley, 1965); *Cucurbita maxima* (giant pumpkin) (Williams and Watson, 1988); *Ficus* sp. (fig) (Anon., 1979); *Garcinia mangostana* (mangosteen) (Beardsley, 1965); *Gossypium* sp. (cotton) (Ben-Dov, 1994); *Guettarda speciosa* (Williams and Watson, 1988); *Heliconia latispatha* (Ben-Dov, 1994); *Lycopersicon esculentum* (tomato) (Williams and Watson, 1988); *Machaerium robinifolium* (Ben-Dov, 1994); *Mangifera* sp. (Anon., 1979); *Manilkara zapota* (sapodilla) (Beardsley, 1965); *Messerschmidia argentea* (Beardsley, 1959); *Musa × paradisiaca* (banana) (Beardsley, 1965; Williams and Watson, 1988); *Musa* sp. (banana, plantain) (Williams and Watson, 1988); *Nothopanax* sp. (Beardsley, 1959); *Opuntia megacantha* (mission prickly-pear) (Beardsley, 1959); *Pandanus* sp. (screw palm, screwpine) (Beardsley, 1959); *Phaseolus* sp. (bean) (Williams and Watson, 1988); *Philodendron* sp. (Ben-Dov, 1994); *Pipturus argentea* (Beardsley, 1965); *Piscidia piscipula* (fish-poison-tree) (Beardsley, 1965); *Pluchea* sp. (Anon., 1979); *Plumeria* sp. (frangipani) (Anon., 1979); *Polianthes tuberosa* (tuberose) (Beardsley, 1959); *Portulacaria* sp. (Anon., 1979); *Psidium* sp. (guava) (Anon., 1979); *Punica granatum* (pomegranate) (Ben-Dov, 1994); *Samanea saman* (French tamarind, monkeypod) (Beardsley, 1959); *Solanum melongena* (aubergine, eggplant) (Williams and Watson, 1988); *Tectona grandis* (teak) (Williams and Watson, 1988); *Theobroma cacao* (cocoa) (Williams and Watson, 1988); *Thespesia populnea* (Pacific rosewood, portia tree) (Beardsley, 1959); *Tournefortia argentea* (Williams and Watson, 1988); *Vigna unguiculata* subsp. *sesquipedalis* (asparagus bean, yard-long bean) (Williams and Watson, 1988); *Vitex* sp. (Anon., 1979); *Vitis* sp. (grape, grapevine) (Anon., 1979); *Yucca guatemalensis* (spineless yucca) (Ben-Dov, 1994); *Zea mays* (corn, maize) (Williams and Watson, 1988).

Plant part(s) affected: Developing fruit (pineapple) (Beardsley, 1993); leaf (pineapple) (Ito, 1938); aerial roots, flower, fruit, leaf, stem (Kessing and Mau, 1992).

Distribution: American Samoa (Ben-Dov, 1994; Williams and Watson, 1988); Antigua and Barbuda (Ben-Dov, 1994); Bahamas (Ben-Dov, 1994); Brazil (Ben-Dov, 1994); China (Taiwan (Rohrbach *et al*., 1988)); Colombia (Ben-Dov, 1994); Cook Islands (Williams and Watson, 1988); Costa Rica (Ben-Dov, 1994); Dominican Republic (Ben-Dov *et al*., 2001); Ecuador (Ben-Dov, 1994); El Salvador (Ben-Dov, 1994); Fiji (Beardsley, 1965); Guam (Beardsley, 1965); Guatemala (Ben-Dov, 1994); Haiti (Ben-Dov, 1994); Honduras (Ben-Dov, 1994); Italy (Sicily (Ben-Dov, 1994)); Jamaica (Beardsley, 1965); Kiribati (Williams and Watson, 1988) (Gilbert Islands (Beardsley, 1965)); Marshall Islands (Ben-Dov, 1994); Malaysia (Kessing and Mau, 1992); Mexico (Beardsley, 1965); Micronesia, Federated States of (Kessing and Mau, 1992); Northern Mariana Islands (Rota Island) (Beardsley, 1965); Panama (Ben-Dov, 1994); Peru (Ben-Dov, 1994); Philippines (Beardsley, 1965); Puerto Rico (Vieques Island (Ben-Dov, 1994)); Suriname (Ben-Dov, 1994); Trinidad and Tobago (Ben-Dov, 1994); United States (Florida (Anon., 1979), Hawaiian Islands (Beardsley, 1965)); United States Virgin Islands (Ben-Dov, 1994); Vietnam (Ben-Dov, 1994); Western Samoa (Williams and Watson, 1988).

Biology: *D. neobrevipes* reproduces sexually, and mating must occur for young to be produced (Beardsley, 1965; Ito, 1938; Rohrbach *et al*., 1988). No eggs are laid; the young emerge from the female as fully developed first instar larvae called crawlers. The crawler stage is the primary dispersal stage (Rohrbach *et al*., 1988). Crawlers move about actively for a short period of time, no more than a day, and may be dispersed onto other plants up to several hundred yards by wind (Rohrbach *et al*., 1988). Larvae only feed during the first instar and the early part of the second instar (Kessing and Mau, 1992).

Females undergo three larval stages (moults) before reaching maturity; each larval stage lasts for 11-23 days, 6-20 days and 7-28 days respectively (Kessing and Mau, 1992), or an average of 8-14 days (Ito, 1938). The total larval period varies from 26-52 days, averaging about 35 days (Kessing and Mau, 1992). When the adult female emerges, there is a period of about 25 days before it produces its first larvae (Kessing and Mau, 1992). During this period the female is mated by males. Further mating can take place at any time after the maturation of the female. The female then produces larvae for a period of about 30 days (Kessing and Mau, 1992). Females die about four days after they cease to produce young (Ito, 1938; Kessing and Mau, 1992). Each female can produce up to 350 larvae (Ito, 1938), but there are some that produce up to 1000 young (Kessing and Mau, 1992). Unmated females live for an average length of 148 days, while mated females an average of 95 days (Ito, 1938). Duration of female adult life varies from 48-72 days, averaging about 61 days (Kessing and Mau, 1992). In comparison, males are short lived and live for only 2-7 days (Kessing and Mau, 1992).

Males moult four times before reaching the winged, adult stage; each larval stage lasts for 11-19 days, 7-19 days, 2-7 days and 2-8 days respectively (Kessing and Mau, 1992), or an average of 3-13 days (Ito, 1938). The total larval period varies from 22-53 days (Kessing and Mau, 1992). Feeding is limited to the first and second stages, which together last for about 20 days. The second, third and fourth moults of the male take place inside a waxy cocoon, during a period of about 12 days. When the adult male emerges from this cocoon, it is a fragile insect about 1 mm long, with a pair of membranous wings. It has no mouthparts, and lives for only a few days (Ito, 1938). Winged adult males live for an average length of 37 days (Ito, 1938). The lifespan from first instar to adult death varies from 59-117 days, averaging 90 days (Kessing and Mau, 1992).

Adults appear predominantly grey in colour as their common name implies. In actuality their bodies are brown to greyish-orange, but take on a greyish appearance in combination with the waxy exudation that covers them (Kessing and Mau, 1992). The body is broadly oval and measures about 1/17 inch long by 1/25 inch wide. The back is heavily coated with tiny tufts of white mealy wax. Short filaments of wax extend from around the margin of the entire body. Lateral wax filaments are usually less than one fourth as long as the breadth of the body and those towards the back of the insect are one-half as long as the body.

In pineapple fields in Hawaii, mealybug populations were mostly confined to the actively growing portions of the plant, such as young leaves and developing fruit (Beardsley *et al*., 1982). They are normally found on the aerial parts of its hosts such as leaves, stems, aerial roots, and flower and fruit clusters (Kessing and Mau, 1992). However, mealybug populations declined rapidly as the fruits and foliage approached maturity (Beardsley *et al*., 1982). Following the harvest of the first fruit crop new shoot growth could again support large mealybug populations, and both mealybug and ant populations increased (Beardsley *et al*., 1982). Sustained heavy rain may also cause a decline in ant and mealybug populations, but pest populations can recover after the return of dry weather (Beardsley *et al*., 1982).

In pineapple fields in Hawaii, *D. neobrevipes* is tended by *Pheidole megacephala* (big-headed ant). This ant greatly encourages the mealybug by interfering with their natural enemies, and maintaining the health of the mealybug colony by removing excess honeydew (Beardsley *et al*., 1982). Ants move mealybugs from one plant to another, and control of mealybugs depends on control of the ants (Beardsley *et al*., 1982; Carter, 1973; McEwen *et al*., 1979). The ant that attends and encourages this mealybug, *Pheidole megacephala*, is common in eastern and northern Australia (Shattuck, 1999). However, in the absence of natural enemies and inclement weather, the ants do not move mealybugs from one plant to another and do not cause an increase in mealybug populations (Jahn and Beardsley, 1996). Attempts to use natural enemies to control mealybugs have been unsuccessful unless the ants were also controlled (Rohrbach *et al*., 1988). Infestations of mealybugs and their attendant ants originate along field margins and gradually move inwards. Mealybug wilt spreads from single infested plants to adjacent plants. Cultivation destroys ant populations, and newly-prepared fields are re-invaded slowly from adjacent infested fields. Pesticide treatment around the margins of new plantings would prevent the establishment of new ant populations, and hence prevent the establishment of mealybug populations (Beardsley *et al*., 1982).

D. neobrevipes is the principal vector of pineapple wilt disease (Beardsley, 1965; McEwen *et al*., 1979; Rohrbach *et al*., 1988), which appears to be caused by a virus (Carter, 1963). Pineapple wilt, or mealybug wilt, is the most serious type of damage and is the principal cause of crop failure in Hawaii (Kessing and Mau, 1992). It can cause complete loss of pineapple crops if not controlled (Beardsley, 1993). There are two types of wilt, “quick wilt” and “slow wilt”. Both types cause the collapse of roots by the invasion of saprophytic organisms or by drying up (Kessing and Mau, 1992). “Quick wilt” is produced by a short period of feeding by a large colony of mealybugs and is characterized by discolouration of leaves to yellows or reds and the loss of rigidity in leaves (Kessing and Mau, 1992). “Slow wilt” occurs after the development of a large colony of mealybugs and shows fewer colour changes (Kessing and Mau, 1992). Leaves will be covered with mealybug feeding sites, leaf tips are browned, outer leaves droop, and the leaf will be flaccid to the touch (Kessing and Mau, 1992). Pineapple wilt has also been called "edge wilt" because the margins of the field would be affected first and the infection would move inward as the mealybug infestation dispersed. Fortunately, this disease has been controlled for the last three decades by routine ant control (Kessing and Mau, 1992). However, it may once again become prevalent if mealybugs are not continually suppressed by limiting ant populations (Kessing and Mau, 1992).

D. neobrevipes is also implicated as a vector of green spot disease on pineapple leaves (Beardsley, 1993; Carter, 1933; Kessing and Mau, 1992). Green spotting is characterised by the production of welt-like simulations of galls. The galls are produced by a secretion of this mealybug that reacts with the plant tissues (Kessing and Mau, 1992).

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3.6 *Pseudococcus cryptus* (Hempel, 1918) [Hemiptera: Pseudococcidae]

Synonyms and changes in combination: *Dysmicoccus cryptus* Hempel, 1918; *Pseudococcus citriculus* Green, 1922.

Common name(s): Cryptic mealybug; citriculus mealybug.

Host(s): *Artocarpus altilis* (breadfruit) (Ben-Dov, 1994); *Artocarpus incisa* (breadfruit) (Ben-Dov, 1994); *Artocarpus odoratissimus* (tarap) (Lit, 1997); *Calophyllum inophyllum* (Alexandrian laurel) (Ben-Dov, 1994); *Citrus aurantifolia* (lime) (Ben-Dov, 1994); *Citrus aurantium* (bitter orange) (Ben-Dov, 1994); *Citrus maxima* (pummelo) (Ben-Dov, 1994); *Citrus limon* (lemon) (Ben-Dov, 1994); *Citrus* × *paradisi* (grapefruit) (Ben-Dov, 1994); *Citrus reticulata* (mandarin) (CAB International, 2002); *Citrus reticulata* (mandarin) (Ben-Dov, 1994); *Citrus sinensis* (sweet orange) (Ben-Dov, 1994); *Citrus unshiu* (Satsuma) (CAB International, 2002); *Citrus* sp. (Lit, 1997); *Cocos nucifera* (coconut)

(Ben-Dov, 1994); *Coffea arabica* (Arabian coffee) (Ben-Dov, 1994); *Coffea liberica* (Liberian coffee) (Williams and Watson, 1988); *Crinum asiaticum* (Asiatic poison lily) (Ben-Dov, 1994); *Dahlia* sp. (Williams and Granara de Willink, 1992); *Dillenia indica* (elephant-apple) (Ben-Dov, 1994); *Elaeis guineensis* (African oil palm) (Williams and Watson, 1988); *Erythrina* sp. (coral tree) (Ben-Dov, 1994); *Garcinia mangostana* (mangosteen) (Anon., 2000); *Gardenia* sp. (Ben-Dov, 1994); *Heliconia* sp. (Lit, 1997); *Hevea brasiliensis* (rubbertree) (Williams and Watson, 1988); *Ixora* sp. (Lit, 1997); *Mangifera indica* (mango) (Ben-Dov, 1994); *Ocotea pedalifolia* (Stout, 1979); *Osbornia ocdonta* (Lit, 1997); *Pandanus* sp. (screwpine) (Ben-Dov, 1994); *Pandanus upoluensis* (palm) (Ben-Dov, 1994); *Passiflora foetida* (wild passionfruit) (Williams and Watson, 1988); *Persea americana* (avocado) (Ben-Dov, 1994); *Piper methysticum* (kava) (Ben-Dov, 1994); *Plumeria* sp. (frangipani) (Ben-Dov, 1994); *Psidium guajava* (guava) (Williams and Watson, 1988); *Selaginella* sp. (spike moss) (Ben-Dov, 1994).

Plant part(s) affected: Roots of coffee (Santa Cecilia *et al*., 2002). Most mealybug species feed on foliage, flowers, fruits and stems, but some species e.g. *Rhizoecus* feed on roots (Drees and Jackman, 1999).

Distribution: *Pseudococcus cryptus* is widely distributed in South East Asia, tropical Africa, mideastern Mediterranean and South America. However, it is particularly a pest of citrus in Israel, into which it was inadvertently introduced in 1937 (Blumberg *et al*., 1999). Following importation of the encyrtid *Clausenia purpurea* Ishii, the pest was successfully controlled.

Afghanistan (Ben-Dov, 1994); American Samoa (Ben-Dov, 1994); Argentina (Williams and Granara de Willink, 1992); Bangladesh (Varshney, 1992); Brazil (Ben-Dov, 1994); British Indian Ocean Territories (Chagos Archipelago) (Ben-Dov, 1994); China (Hu *et al*., 1992); Costa Rica (Ben-Dov, 1994); El Salvador (Ben-Dov, 1994); India (West Bengal) (Nath, 1972); Iran (Kozár *et al*., 1996); Israel (Ben-Dov, 1994); Japan (Ben-Dov, 1994); Kenya (Ben-Dov, 1994); Mauritius (Ben-Dov, 1994); Micronesia, Federated States of (Ponape Island) (Ben-Dov, 1994); Paraguay (Williams and Granara de Willink, 1992); Philippines (Lit, 1997); Palau (Beardsley, 1966); Sri Lanka (Ben-Dov, 1994); Taiwan (Ben-Dov, 1994); United States (Hawaii) (Ben-Dov, 1994); United States Virgin Islands (Ben-Dov, 1994); Vietnam (Ben-Dov, 1994); Western Samoa (Williams and Watson, 1988); Zanzibar (Ben-Dov, 1994).

Biology: No specific details on the biology of *Pseudococcus cryptus* are available. However, life history of a similar species of mealybug, *Planococcus citri* (Risso), is outlined below.

Adult female mealybugs of *Planococcus citri* are white, about 3 mm long, and covered with a white, fluffy wax. White wax filaments surround the body margin, with the last pair up to ¼ the length of the female body. Males are tiny, gnat-like insects with one pair of fragile wings and non-functional mouthparts. They are short-lived (Smith *et al*., 1997).

Pale yellow eggs are laid in an elongated, loose, cottony egg sac extending beneath and behind the female. About 300-600 eggs are laid over 1-2 weeks, and these eggs hatch in about a week (Smith *et al*., 1997). Very young nymphs (crawlers) are flat, oval and yellow. They develop through several stages (instars) over several weeks before reaching sexual maturity. There are three moults for females and four for males. Winged males emerge from a tiny fluffy cocoon and fly to the female mealybug to mate (Drees and Jackman, 1999). The complete life cycle takes about 6 weeks during the summer and there are 3-6 generations per year (Smith *et al*., 1997).

During winter, citrus mealybugs shelter in cracks in the branches or trunk, or in leaf axils. Young mealybugs move onto citrus fruit in late spring and usually settle under the calyx or between touching fruit (Smith *et al*., 1997). From late summer, they also settle in the navel of oranges. Mealybugs produce honeydew, resulting in heavy growths of sooty mould (Smith *et al*., 1997).

Control: Following the introduction of *P. cryptus* into Israel in 1937, it was biologically controlled with the encyrtid *Clausenia purpurea* Ishii, prior to its recurrence in newer varieties of citrus (Blumberg *et al*., 1999). Other natural enemies which attack nymphs and adults include the following parasitoids: *Anagyrus pseudococci* (Moore, 1988); *Cryptanusia luzonica*; *Paraplatycerus citriculus* and *Promuscidea unfasciativentris*; and following predators: *Amblyseius swirskii*; *Brumoides suturalis*; *Chilocorus nigrita*; *Diadiplosis hirticornis*; and *Pseudoscymnus dwipakalpa* (CAB International, 2002).

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3.7 *Technomyrmex butteli* (Forel, 1913) [Hymenoptera: Formicidae]

Note: There is very little information regarding the hosts, effect, global distribution, biology and control of the species *Technomyrmex butteli*. Only one reference to this species was found in the literature apart from the work that described *T. butteli*. Wenseleers *et al*. (1998) surveyed many ant species, including *T. butteli*, for infection by the bacterium *Wolbachia*, which may represent a widespread and previously unrecognised party active in the conflicts of interest within social insect colonies.

Synonyms and changes in combination: Not known.

Common name(s): Black ant.

Host(s): *Garcinia mangostana* (mangosteen) (Sudhi-Aromna, 2002).

Workers of *Technomyrmex* sp. commonly forage in houses in search of food and water. They enter through small cracks and, on finding a suitable food source, form distinct trails with many workers travelling between their nest sites and the food source. In general they nest outdoors but will sometimes establish small nests in a suitable location indoors near a well-maintained food supply (Shattuck and Barnett, 2001).

Plant part(s) affected: Damage by ants to agricultural commodities is usually indirect. Mealybugs, aphids, soft scales and whiteflies secrete honeydew, which attracts ants. Ants feed on honeydew, driving away the natural enemies of aphids and scale insects. The pests multiply and inflict damage on the plants (Nechols and Seibert, 1985).

Distribution: *Technomyrmex butteli* was described by Forel from specimens collected in West Malaysia. It has also been found in West Java (Wenseleers *et al*., 1998).

The 89 known species and subspecies of *Technomyrmex* occur from Africa east through southern Asia to Australia, with a single species (with one subspecies) known from Panama. Within Australia, there are seven species and subspecies. These occur along the east coast from Torres Strait south through eastern Queensland, New South Wales, Victoria and Tasmania to Kangaroo Island, South Australia, as well as southern Western Australia and the upper Northern Territory. They are most common in moist, forested habitats (Shattuck and Barnett, 2001).

Biology: *Technomyrmex* workers are general scavengers, foraging on the ground, low vegetation and trees. They nest in the soil with or without a covering, in twigs or branches, under loose bark, and in nests constructed of plant fibres which are attached under leaves or to tree trunks. Some species are known to have worker-like males and queens (Terron, 1972).

Generally eggs of *Technomyrmex* are laid, usually by a queen, in the nest they are protected by workers. They may be fertilized or unfertilised. Eggs are approximately 0.5 mm, white or yellowish ovals (Wheeler, 1910). Young larvae are soft, legless, pale grubs shaped like crook-necked squash (fat and bulbous at the bottom and narrow and curled at the head). Adult ants lick the larvae, and the saliva makes them sticky and easily transported in groups when the colony is disturbed (Wheeler, 1910). Most ant species have four larval stages. The larvae are attended by adults, usually of the worker caste (Hölldobler and Wilson, 1990). Adults are polymorphic i.e. having different body types. Adults of one body type form a social unit called a caste, which is also defined by the role in the community. Queens are usually comparatively large and winged early in life. They are reproductives, laying fertile and unfertile eggs throughout their lives. Males are usually short-lived and function only in reproduction (Victoria and Arnold, 1992). *Technomyrmex* is known to have multiple queen colonies (Shattuck, 2003, pers. comm.). Mating flights are the primary means of colony propagation for *Technomyrmex*, secondarily, satellite nests (or budding) can occur in which a portion of a colony becomes an autonomous unit (Shattuck, 2003, pers. comm.).

Males of *T. albipes* lack wings and are very similar in appearance to workers, a condition in ants referred to as ergatomorphic (Wheeler, 1910). Adult workers are wingless, medium-sized, dull black ants 2-4 mm long (less than ¼-inch) (Huddleston and Fluker, 1968). Adults recently emerged from the pupal stage are paler (Wheeler, 1910). Workers are females, which tend all stages of juvenile ants, construct and maintain nests, and forage for food. Commonly, only individuals of the worker caste are encountered because they are the most numerous and the most likely to be found outside the nest (Victoria and Arnold, 1992).

In a study conducted in Guam, survival of mealybugs was significantly higher when *T. albipes* was present due to decreased parasitisation of the mealybugs by encyrtid wasps and decreased predation by other arthropods. Ants were observed chasing away parasitic wasps and attacking predatory coccinellids by grabbing the beetles's legs (Nechols and Seibert, 1985).

Control: Many external and internal insect and mite parasites of ants live in ant nests. These usually stunt development in the ant. Some wasps and flies lay eggs in worker ants (Wheeler, 1910). The major predators of ant species are often other ant species (Hölldobler and Wilson, 1990). Interspecific competition occurs for ants sharing the same habitat (McGregor and Moxon, 1985). Birds, reptiles, amphibians, arthropods, and mammals, including humans, consume ants (Wheeler, 1910).

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