Import risk analysis: Fresh Coconut (*Cocos nucifera*) from Tuvalu

FINAL

ISBN 978-0-478-33832-4 (P)
ISBN 978-0-478-33833-1 (O)

15 January 2009

Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

MAF Biosecurity New Zealand
Pastoral House
25 The Terrace
PO Box 2526
Wellington 6140
New Zealand

Tel: 64 4 894 0100
Fax: 64 4 894 0731

Policy and Risk
MAF Biosecurity New Zealand

Import risk analysis:
Fresh Coconut (*Cocos nucifera*) from Tuvalu

FINAL

15 January 2009

ISBN 978-0-478-33832-4 (P)
ISBN 978-0-478-33833-1 (O)

Approved for general release

Christine Reed
Manager, Risk Analysis
Biosecurity New Zealand

Contributors to this risk analysis

1. Primary author

Charlotte Hardy	Adviser Plants Risk Analysis	MAF Biosecurity New Zealand Wellington

2. Secondary contributors

Deb Anthony	Adviser Plants Risk Analysis	MAF Biosecurity New Zealand Wellington
Dr Shiroma Sathyapala	Team Manager Plants Risk Analysis	MAF Biosecurity New Zealand Wellington

3. External review

Dr Phillip Lester	Senior Lecturer School of Biological Sciences	Victoria University Wellington
Dr Priyanthie Fernando	Principal Officer Crop Protection Division	Coconut Research Institute Sri Lanka
Roy Masamdu	Biosecurity & Trade Facilitator Land Resources Division	Secretariat for the Pacific Community Fiji

Executive summary

Tuvalu has requested market access for the export of fresh coconuts to New Zealand. Market access was granted historically and has continued for other Pacific Island countries to the present. Previously coconuts were considered under general Import requirements for fresh produce. This risk analysis examines the biosecurity risks posed by their importation.

The draft risk analysis was released for public consultation on 28 November 2008. No submissions were received from stakeholders. Minor changes of wording were made to the document, but the conclusions presented in the draft risk analysis were unchanged from the draft of 28 November 2008.

The coconut palm (*Cocos nucifera*) is a member of the Family Arecaceae (palm family). It is the only species in the genus *Cocos*, and is a large palm, growing up to 30m tall. The term *coconut* refers to the nut of the coconut palm, which is actually a fibrous drupe, and is considered a true fruit. Green coconuts are those which are used for drinking. They are not fully mature and contain a substantial amount of liquid inside. The outer husk is green. Brown coconuts are fully mature most often dehusked, and utilised for the hard flesh inside the nut and the water. The coconut apple is the growing embryo inside the nut. It will commonly appear dehusked with the growing roots and stems cut off. It is considered a delicacy among Pacific Island people. Coconuts of all three types are assumed to be sourced from three of the Islands in the Tuvalu group – Nanumanga, Niutoa and Vaitapu.

In this risk analysis pests and pathogens are grouped according to their biology and members of the same genus are considered within one pest risk assessment. Species within a genus often have similar life history traits which are comparable. The groups include mealybugs and scales, termites, stick insects, ants and pathogens. A total of 40 pests were researched of which 22 were further assessed in the risk analysis. Thirteen are considered hazards and management options for these species discussed and reviewed. Of the 13 organisms requiring mitigation 6 have a likely association with green and mature coconuts and coconut apples when they are in their natural environment. The remaining 7 ant species are evaluated as hitchhikers on the pathway. Hitchhiker species do not require the commodity to complete any part of their life cycle, and are most likely contaminating the commodity after harvest. Although tritrophic interactions between plants, honeydew producing insects and ants are considered in individual risk analyses where appropriate.

The risk analysis concluded there was a non-negligible risk for organisms listed in Table 1 and that phytosanitary measures were justified. Management options reflect the two types of pests considered in the analysis; host associated and hitchhiker species. A systems approach with good post harvest hygiene, washing and brushing for green coconuts, baiting to reduce ant populations prior to export, cold storage and a container hygiene system are outlined. Waxing of remaining fresh shoot and root material on coconut apple is also covered.

The remaining 18 organisms were not considered potential hazards because there was no supporting literature or evidence for their direct and likely association with the commodity, or they already occurred in New Zealand. Because of its unusual and unique characteristics coconut sits somewhere between an inanimate pathway commodity such as scrap metal, and other fresh produce like taro and papaya exported to New Zealand from the Pacific. Its structural appearance provides a surface like that of an inanimate object, without supplying any nutritional value to an organism. Opportunistic hitchhiker species utilise this structure

in a different way to host associated organisms. For this reason it is proposed that coconuts be considered in future management frameworks as intermediate between an inanimate and a fresh produce commodity.

Table 1: Management options to mitigate the risks of hazard organisms

Coconut stage	Organism associations	Management options
Green coconut: with husk	*Hemiptera* (scales/mealybugs) *Aspidiotus destructor, Chrysomphalus aonidum, Chrysomphalus dictyospermi, Dysmicoccus brevipes, Ferissia virgata* *Hymenoptera* (ants) *Anoplolepis gracilipes, Monomorium destructor, Paratrechina bourbonica, Paratrechina longicornis, Paratrechina vaga, Tetramorium similimum, Wasmannia auropunctata* *Pathogen* (Oomycete) *Phytophthora palmivora*	* Washing and brushing to remove surface pests. * Waxing to prevent recontamination. * Ant baiting to reduce populations around storage facilities. * Cold storage in transit * Good container hygiene practice.
Mature coconut: dehusked	*Hymenoptera* (ants) *Anoplolepis gracilipes, Monomorium destructor, Paratrechina bourbonica, Paratrechina longicornis, Paratrechina vaga, Tetramorium similimum, Wasmannia auropunctata*	* Ant baiting to reduce populations around storage facilities. * Cold storage in transit * Good container hygiene practice
Coconut apple: dehusked	*Hemiptera* (scales/mealybugs) *Aspidiostus destructor,Chrysomphalus aonidum, Chrysomphalus dictyospermi, Dysmicoccus brevipes, Ferissia virgata* *Hymenoptera* (ants) *Anoplolepis gracilipes, Monomorium destructor, Paratrechina bourbonica, Paratrechina longicornis, Paratrechina vaga, Tetramorium similimum, Wasmannia auropunctata* *Pathogen* (Oomycete) *Phytophthora palmivora*	* Dehusking is essential * Waxing to prevent recontamination and maintain coconut apple quality * Ant baiting to reduce populations around storage facilities * Cold storage in transit * Good container hygiene practice

Contents Page

List of tables **Page**

List of figures **Page**

List of plates **Page**

1. Project background and process

1.1. Background

There is currently no import health standard for coconut from Tuvalu. But import health standards do exist for coconut from the Philippines and for other Pacific Islands under general fresh produce import requirements (MAF 2010). The objective of this project is to conduct an import risk analysis, using current standards and methodology (MAFBNZ risk analysis proceedures 2006). The analysis will be used for the development of an import health standard for coconut fresh produce from Tuvalu. In addition the analysis will contribute to the review of existing generic import requirements for importation of coconut fresh produce from other Pacific countries as required.

1.2. Scope of the risk analysis

The scope of this risk analysis is the assessment of the risk posed by potential hazard organisms and diseases associated with fresh coconut imported from Tuvalu and identify risk management options. For the purposes of this analysis fresh coconut means the nut either with the husk or dehusked, not including any calyx material. No measures were requested, as this is the first import of a fresh product for export from Tuvalu to New Zealand so a range of management options are reviewed. These include visual inspection, washing/brushing of the commodity, site hygiene, ant baiting, cold storage and container hygiene systems.

1.3. Risk analysis process and methodology

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

1.3.1. Commodity and pathway description

The first step in the risk analysis process is to describe the entry pathway of the commodity. This includes relevant information on:

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

1.3.2. Hazard identification

Hazard identification is the essential step conducted prior to a risk assessment. Unwanted organisms or diseases which could be introduced by the risk goods into New Zealand and are capable of, or potentially capable of, causing unwanted harm, must be identified. This process begins with the collation of a list of organisms that might be associated with the commodity in the country of origin. This list is further refined and species removed or added to the list depending on the strength of the association and the information available about its biology and life cycle. Each pest or pathogen is assessed mainly on its biological characteristics and its likely interaction with the New Zealand environment and climate.

Hitch-hiker organisms sometimes associated with a commodity but that don't feed on it or specifically depend on that commodity in some other way are also included in the analysis. This is because the potential for economic consequences can outweigh the low likelihood of the organism being associated with the commodity.

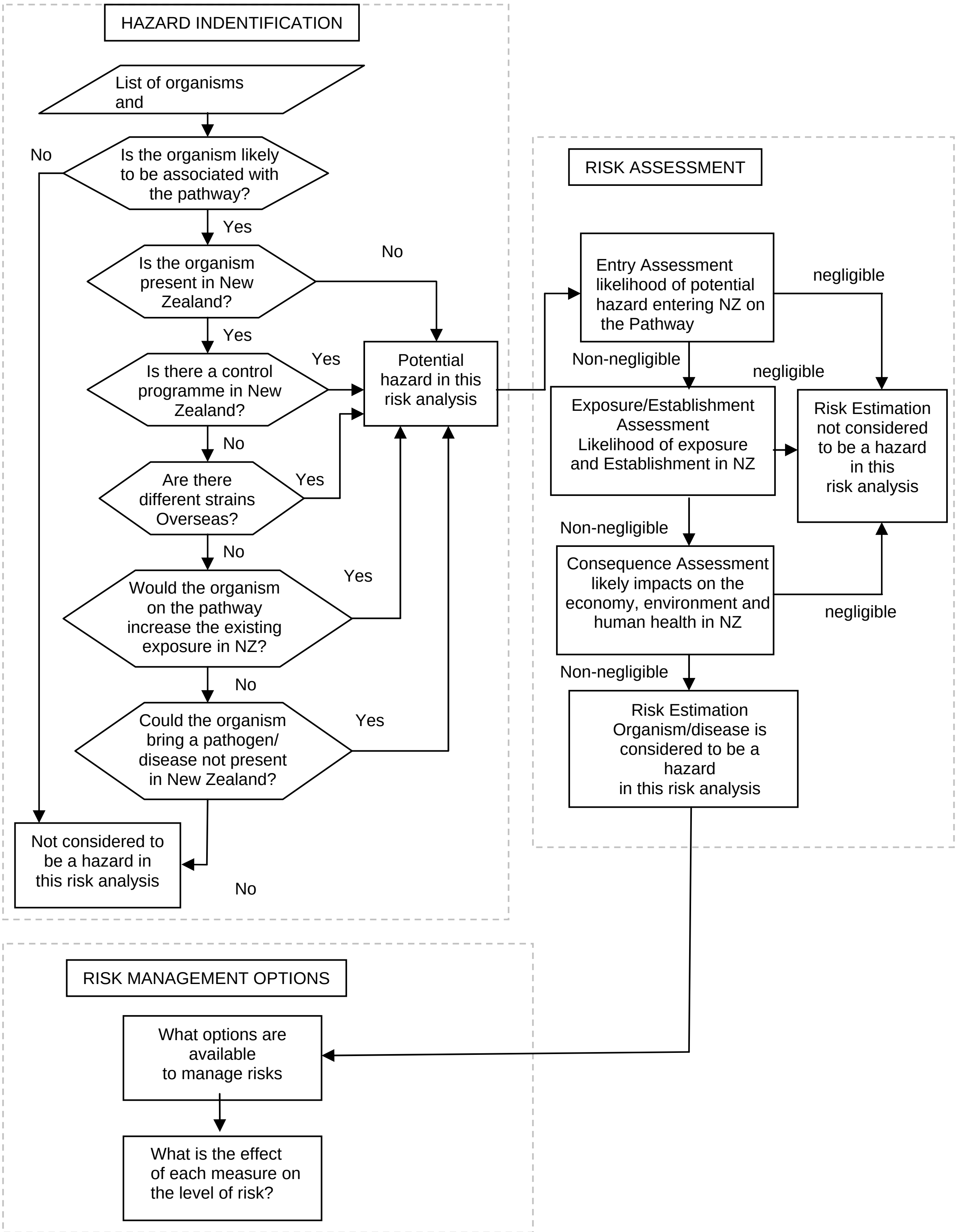
1.3.3. Risk assessment of potential hazards

Risk assessment is the evaluation of the likelihood of entry, exposure and establishment of a potential hazard, and the environmental, economic, human and animal health consequences of the entry within New Zealand. The aim of risk assessment is to identify hazards which present an unacceptable level of risk, for which risk management measures are required. A risk assessment consists of four inter-related steps:

- Assessment of likelihood of entry
- Assessment of likelihood of exposure and establishment
- Assessment of consequences
- Risk estimation.

In this risk analysis hazards have been grouped to avoid unnecessary duplication of effort in the assessment stage of the project. Where there is more than one species in a genus for example, the most common or potentially damaging species is researched and analysed in detail and used as an example to cover major biological traits within the group. Any specific differences between congeners are highlighted in individual analyses.
Figure 1 below illustrates the risk analysis process.

Figure 1: Diagram of the risk analysis process. The three main aspects of analysis include: hazard identification, risk assessment, and risk management



1.3.4. Assessment of uncertainties

The purpose of this section is to summarise the uncertainties and assumptions identified during the preceding hazard identification and risk assessment stages. An analysis of these uncertainties and assumptions can then be completed to identify which are critical to the outcomes of the risk analysis. Critical uncertainties or assumptions are considered for further research with the aim of reducing uncertainty or removing the assumption.

Where there is significant uncertainty in the estimated risk, a precautionary approach to managing risk may be adopted. In these circumstances the measures should be consistent with other measures where equivalent uncertainties exist and be reviewed as soon as additional information becomes available.

1.3.5. Analysis of measures to mitigate biosecurity risks

Risk management in the context of risk analysis is the process of deciding measures to effectively manage the risks posed by the hazard(s) associated with the commodity or organisms under consideration. It is not acceptable to identify a range of measures that might reduce the risks. There must be a reasoned relationship between the measures chosen and the risk assessment so that the results of the risk assessment support the measure(s).

Since zero-risk is not a reasonable option, the guiding principle for risk management should be to manage risk to achieve the required level of protection that can be justified and is feasible within the limits of available options and resources. Risk management identifies ways to react to a risk, evaluating the efficacy of these actions, and presenting the most appropriate options.

The uncertainty noted in the assessments of economic consequences and probability of introduction should also be considered and included in the consideration of risk management options. Where there is significant uncertainty, a precautionary approach may be adopted. However, the measures selected must nevertheless be based on a risk assessment that takes account of the available scientific information. In these circumstances the measures should be reviewed as soon as additional information becomes available. It is not acceptable to simply conclude that, because there is significant uncertainty, measures will be selected on the basis of a precautionary approach. The rationale for selecting measures must be made apparent.

Each hazard or group of hazards will be dealt with separately using the following framework:

1.3.6. Risk evaluation

- If the risk estimate, determined in the risk assessment, is non-negligible, measures can be justified.

1.3.7. Option evaluation

a) Identify possible options, including measures identified by international standard setting bodies, where they are available.

b) Evaluate the likelihood of the entry, exposure, establishment or spread of the hazard according to the option(s) that might be applied.

1.3.8. Review and consultation

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

Once a risk analysis has been peer reviewed and the critiques addressed, the risk analysis is then published and released for public consultation. The period for public consultation is usually six weeks from the date of publication.

All submissions received from stakeholders are analysed and compiled into a review. Either a document will be developed containing the results of the review or recommended modifications to the risk analysis itself will be edited to comply with the modifications.

2. Commodity and pathway description

The following chapter provides information on the commodity and pathway that is relevant to the analysis of biosecurity risks and common to all organisms or diseases potentially associated with the pathway and commodity. Organism or disease-specific information is provided in subsequent chapters.

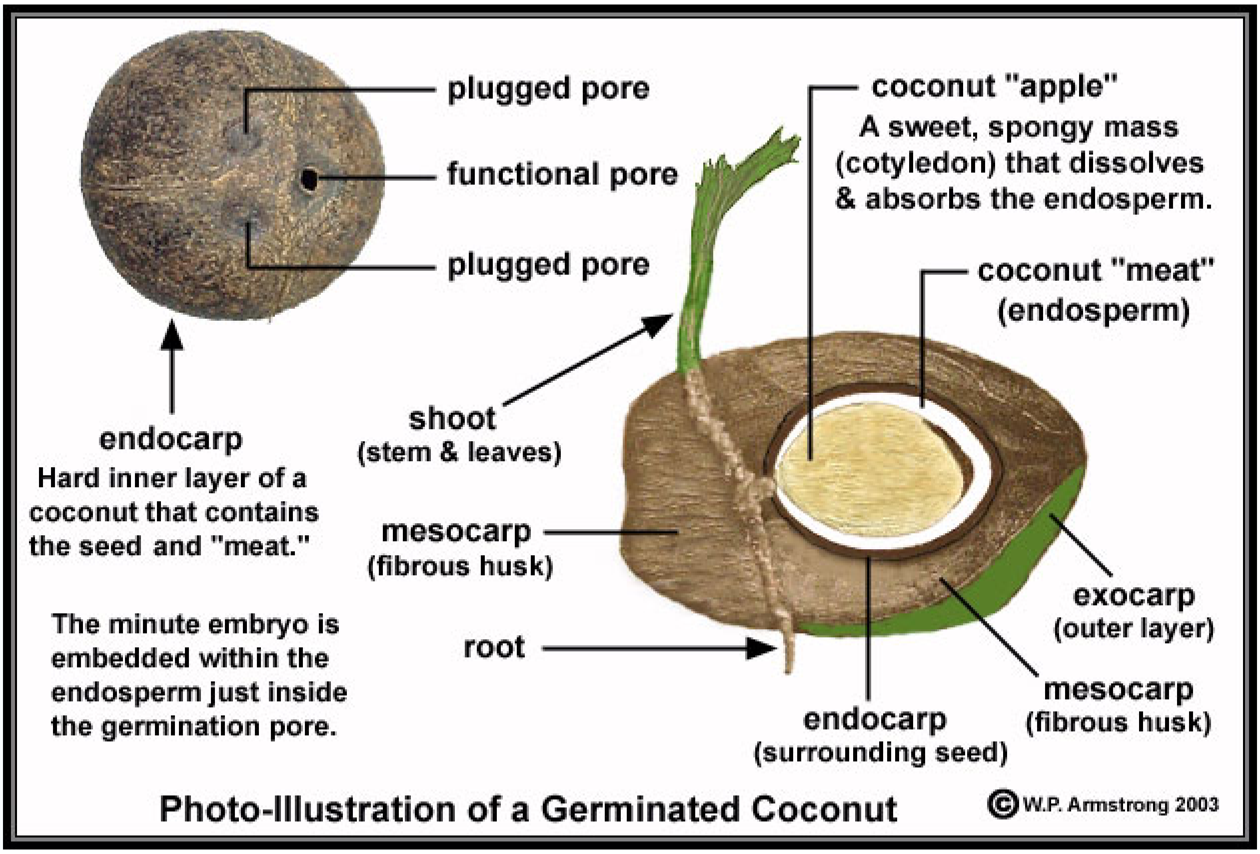
2.1. Commodity description - *Cocos nucifera*

The Coconut Palm (*Cocos nucifera*) is a member of the Family Arecaceae (palm family). It is the only species in the genus Cocos, and is a large palm, growing up to 30m tall, with pinnate leaves 4-6 m long, pinnae 60-90 cm long; old leaves break away cleanly leaving the trunk smooth. The term coconut refers to the fruit of the coconut palm. A coconut is a simple dry fruit known as a fibrous drupe (not a true nut). The husk (mesocarp) is composed of fibers called coir and there is an inner "stone" (the endocarp). This hard endocarp (the outside of the coconut as sold in the shops of non-tropical countries) has three germination pores that are clearly visible on the outside surface once the husk is removed. It is through one of these that the radicle emerges when the embryo germinates (see Figure 2). Adhering to the inside wall of the endocarp is the testa, with a thick albuminous endosperm (the coconut "meat"), the white and fleshy edible part of the seed. The endosperm surrounds a hollow interior space, filled with air and often a liquid referred to as coconut water, not to be confused with coconut milk.

Coconut milk is made by grating the endosperm and mixing it with (warm) water. This produces a thick, white liquid called coconut milk that is used in much cooking, for example, in curries. Coconut water from the unripe coconut, on the other hand, is drunk fresh as a refreshing drink. When the coconut is still green, the endosperm inside is thin and tender, often eaten as a snack. But the main reason to pick the fruit at this stage is to drink its water; a big fruit contains up to one litre. When the fruit has ripened and the outer husk has turned brown, a few months later, it will fall from the palm of its own accord. At that time the endosperm has thickened and hardened, while the coconut water has become somewhat bitter. When the fruit is still green the husk is very hard, but green fruits rarely fall, only when they have been attacked by moulds, etc. By the time the fruit naturally falls, the husk has become brown, the coir has become dryer and softer, and the fruit is less likely to cause damage when it drops

Inside the functional germination pore is a minute embryo embedded in the endosperm tissue. During germination, a spongy mass develops from the base of the embryo and fills the seed cavity. This mass of tissue is called the "coconut apple" and is essentially the functional cotyledon of the seed (see Figure 2). It dissolves and absorbs the nutrient-rich endosperm tissue to supply the developing shoot with sugars and minerals. Eventually, the developing palm becomes self sufficient, as its leaves produce sugars through photosynthesis and its roots absorb minerals from the soil. The coconut "apple" is rich in sugars and is a sweet delicacy in tropical countries (Retrieved from "http://en.wikipedia.org/wiki/Coconut").
A germinating nut is husked with the use of a sturdy, pointed metal stake or stick set about waist high in concrete. The germinating nut is struck onto the point nearer the pointed end and twisted. The process is repeated until the husk is loose and removed by hand. An experienced husker can husk a coconut in less than ten seconds.

Figure 2: Coconut dehusked (left), and with husk, showing coconut embryo, shoot and root (right).



For clarification of terminology used in this risk analysis green coconuts are those which are used for drinking. They are not fully mature and contain a substantial amount of liquid inside. The outer husk is green. Brown coconuts are fully mature most often dehusked, and utilised for the hard flesh inside the nut and the water. The coconut apple is the growing embryo inside the nut. It will commonly appear dehusked with the growing roots and stems cut off. There are seven varieties of coconuts grown in Tuvalu, they are Rennel tall (RT), Malayan dwarf (MD), RT & MD hybrid, Green dwarf (niu leka), and the 3 local varieties (Te kula (red), Te alava (light red), Te ui (green). Currently there is no treatment required for de-husked coconuts from anywhere in the Pacific. However methyl bromide fumigation is usually applied when live organisms are found.

2.2. Coconuts in New Zealand

Coconuts do not grow in New Zealand. Frequently in Northland (upper North Island) coconuts are found washed up on beaches after tropical storm systems bring material from Australia and the Pacific. These nuts don't germinate here, and there is no suitable climate anywhere in New Zealand for the establishment of the species.

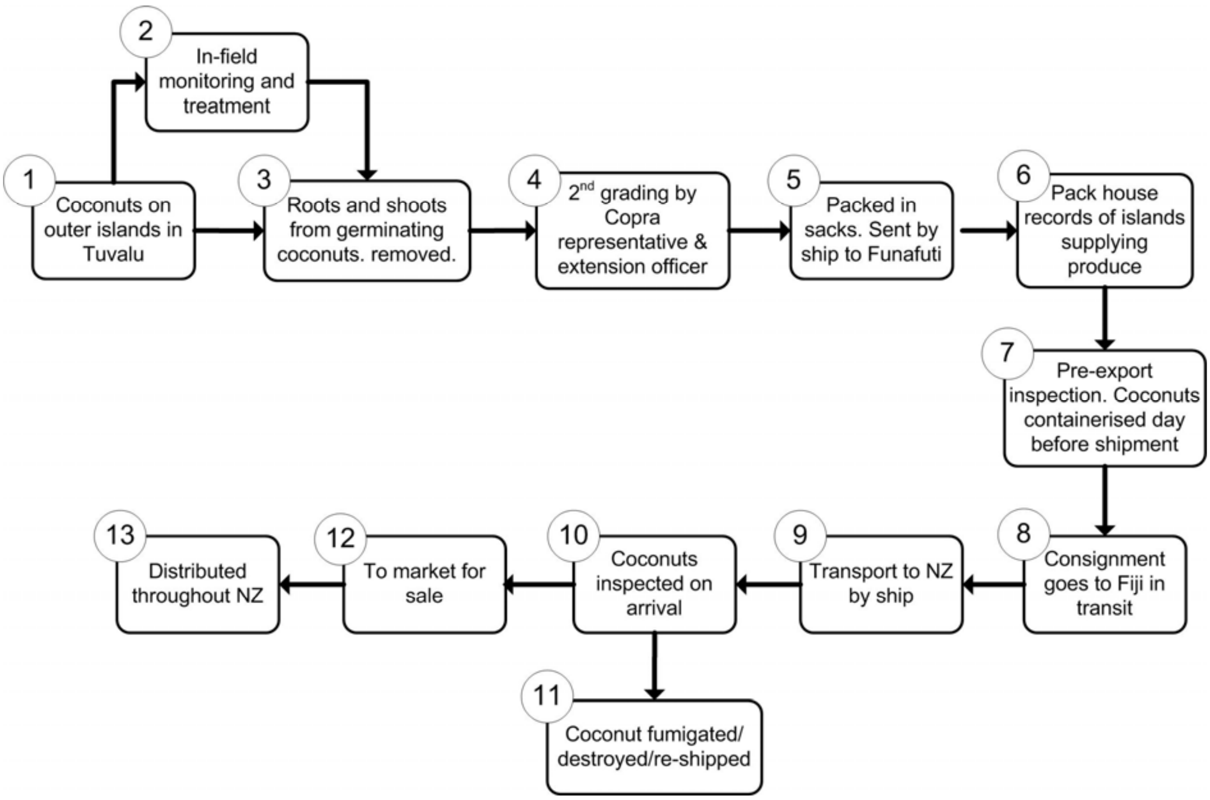
2.3. Description of the import pathway

For the purpose of this risk analysis, coconuts (green, brown and coconut apples) for import from Tuvalu are the fruit, dehusked without any roots or shoots in the case of coconut apple. Green coconuts for drinking may have the husk still on, but the calyx removed. Brown coconuts are fully mature and will have the husk and calyx removed. There will be a small

area of fresh stem material left after removal of the shoot and roots on coconut apple. But no husk will remain. Coconuts are presumed to be from the main growing areas in Tuvalu on the outer Islands of Niutao, Nanumanga, and Vaitupu, and the atolls of Nui, Nanumea and Nukufetau. Coconuts are not grown for commercial purposes on the main Island Funafuti, but are widespread as household food plants.
There are currently no requirements for treatment of de-husked coconut or coconuts with husks from any Pacific Island country. But management measures such as visual inspection before export are utilised to reduce likelihood of commodities arriving contaminated. This Risk Analysis will identify particular areas of biosecurity risk and mitigation options on the pathway.

Harvested coconuts would be sea freighted to New Zealand with a possible transit stop over in Fiji. If stopping in Fiji coconut sacks will either remain on board the ship, or be un-loaded then re-loaded onto ships bound for New Zealand. On arrival consignments will go to a holding facility and be inspected before being distributed to supermarkets, fruit and vegetable markets and shops for consumption. Figure 3 below illustrates the pathway of coconuts from the plantations in Tuvalu to New Zealand.

Figure 3: Steps in the coconut pathway from Tuvalu to New Zealand



Steps in the Pathway:

1) Coconuts in Tuvalu are growing in a plantation, as a single crop or beside breadfruit. Three main outer islands support plantations Niutao, Nanumanga, and Vaitupu

2) In field treatments for various pests such as scale insects.

3) Farmers collect germinating nuts from which roots and shoots are removed and then they are dehusked.

4) A second grade is made by a copra representative (from the TCTC) and an extension official.

5) Dehusked coconuts are packed in sacks and sent by boat to Funafuti

6) Registered packhouses maintain records of the islands supplying produce.

7) Pre-export inspection is made at wharf storage facilities and the consignment is placed in a container 1 day before shipment.

8) The consignment goes to Fiji in transit by ship

9) Transport to New Zealand by ship

10) Coconut inspected on arrival, accompanied by appropriate phytosanitary certificates.

11) Non complying coconut consignments will most often be fumigated, but could potentially be reshipped or destroyed.

12) Coconut goes to market for sale

13) And is distributed throughout New Zealand.

2.4. Tuvalu – description of climate and geography

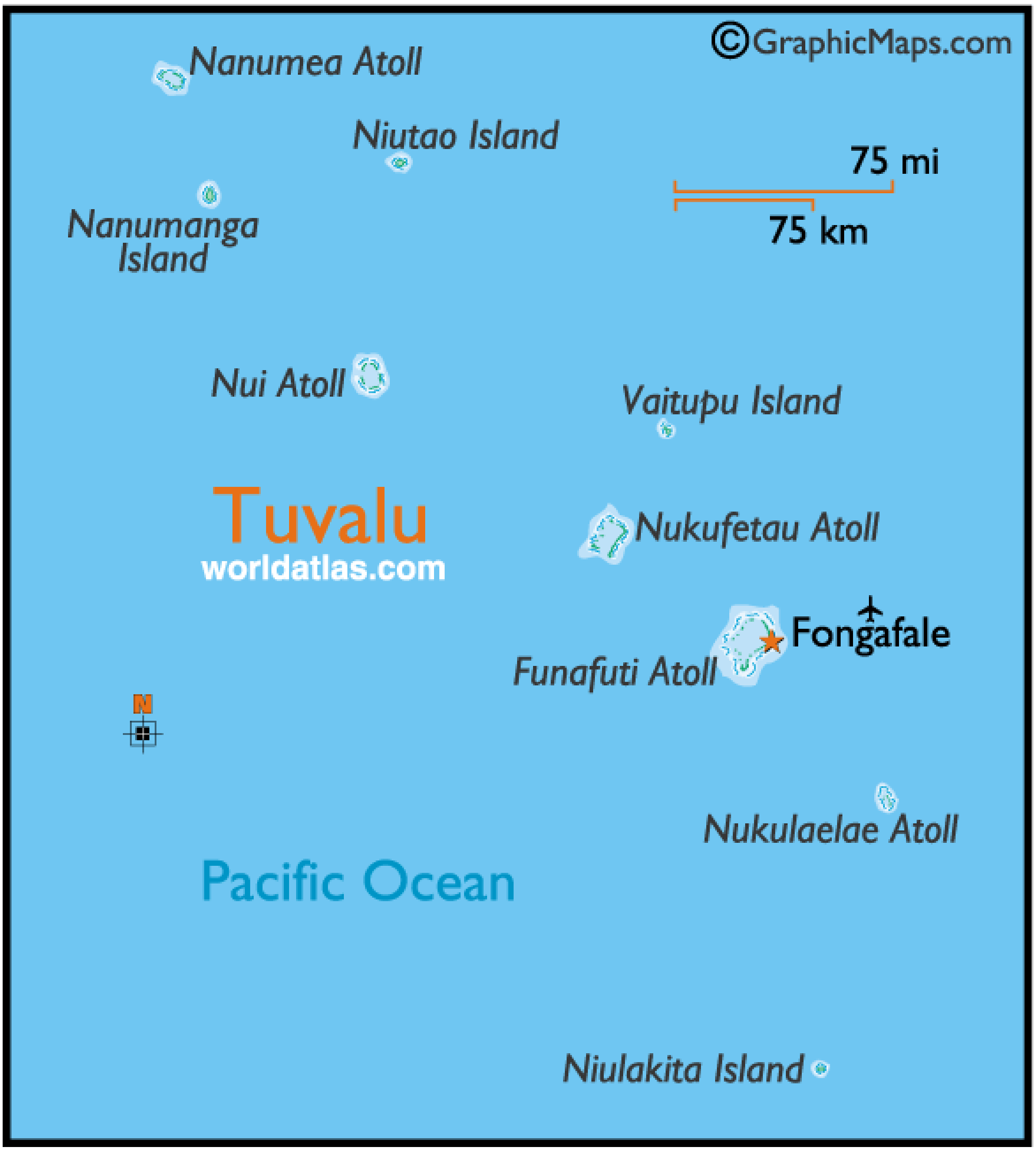
Tuvalu is to the north of the recognised hurricane belt in the southwest Pacific, but the islands have been struck on a number of occasions in modern times by severe cyclones (Maddison 1989) with three cyclones in 1997 (World Factbook). The climate is tropical with no marked wet and dry or hot and cold seasons. The temperature ranges from 20.6ºC-35.6 ºC, but the heat is moderated by trade winds that blow from an easterly direction much of the year. Annual rainfall ranges from 2,800-3,000mm, but can vary considerably, between islands and from year to year. The annual rainfall extends to 3000mm in the islands farthest south in an average year. The islands themselves are composed of coral reefs built on the outer arc of the ridges formed by pressure from the central Pacific plate against the ancient Australian landmass (Trewren 1986). It is one of the pacific nations that will be most affected by climate change if rising sea levels due to global warming increase. There are 5 atolls; Nanumea, Nukufetau, Nui, Funafuti and Nukulaelae and 4 islands; Niutao, Nanamanga, Vaitupu and Niulakita that make up the Tuvalu group (See Figure 4). Its previous name was the Ellice Islands.

2.5. Definition of tropical and subtropical climate

Climatic zones can be defined according to the geographical partitioning of the earth based on the way daylight is distributed across its surface during the year. Each part of the earth receives approximately the same number of daylight hours per year – at varying rates. The poles have half a year of darkness and then half a year of daylight. Near the equator daylight is evenly spread for half a day every single day of each year. At the mid latitudes daylight is delivered in greater or lesser amounts throughout the year (cseligman.com 2007). Regions near the poles receive only a fraction of the sunlight and heat per day that equatorial regions receive in just a few hours because the sun is on average closer to the horizon at the poles and higher overhead at the equator.

The boundaries of the region are defined according to the amount which the sun moves north and south in the sky during the planetary year which is equal to its axial inclination.
On earth the tilt is about 23.5º, so going from the poles, which are at 90º latitude, we define the position of the arctic and Antarctic circles as being 66.5 º North or South latitude. Going from the equator towards the poles, the Tropics of Cancer and Capricorn are 23.5 º North or South latitude (cseligman.com 2007). The tropical zone is marked by heavy rainfall. Water is abundant and temperatures remain relatively stable. There are seasons of heavier and less heavy rainfall but the region is not known to exhibit great swings in temperature. Generally it is wet and warm (cseligman.com 2007)

Figure 4: The islands and atolls making up the Tuvalu group



2.6. Tropical and subtropical pests

Many species of insects and mites occur principally in tropical/subtropical latitudes and can have a narrow band of temperature tolerance for their growth and development. They are often not recorded occurring outside a particular temperature range and may be characterised by fast generation rates and high reproductive output. Many in the context of this risk analysis are broad generalists while others have a specific association with coconut. Under current climatic conditions in New Zealand the probability of establishment of these "tropical/subtropical pests" here is very low given the very small area of the country with suitable subtropical climatic conditions.

Greenhouses and glasshouses are the exception to this generalisation, with conditions within these environments providing the humidity and temperatures required for such organisms to reproduce. The likelihood that coconuts available in supermarkets harbouring pests or pathogens would come into contact with either a greenhouse or the climatically suitable geographic areas for establishment is estimated to be very low or negligible. Greenhouse scenarios are therefore not discussed within the individual pest assessments as a potential risk, but where certain pests have established in greenhouses in temperate or boreal climate zone countries this is mentioned in the text.

2.7. New Zealand climate - general

New Zealand has a maritime climate which varies from warm subtropical in the far north to cool temperate in the far south, with severe alpine conditions in the mountainous areas. Mountain chains extending the length of New Zealand's South Island provide a barrier for the prevailing westerly winds, dividing the country into two separate climatic regions. The West Coast of the South Island is the wettest, whereas the area to the east of the mountains, just over 100 km away, is the driest (NIWA 2006).

Most parts of the country get between 600 and 1600 mm of rainfall annually, with a dry period during the summer. At four locations on the west coast of the South Island (Westport, Hokitika, Mt Cook and Milford Sound) mean annual rainfall was between 2200mm and 6800mm for the period 1971-2000 (NIWA 2006).Over the northern and central areas of New Zealand more rain falls in winter than summer, whereas for much of southern New Zealand, winter is the season of least rainfall.

Mean annual temperatures range from 10°C in the south to 16°C in the north. The coldest month is usually July and the warmest month is usually January or February. Generally there is little variation between summer and winter temperatures, although inland and to the east of the ranges the variation is greater (up to 14°C). Temperatures also drop about 0.7°C for every 100 m of altitude (NIWA 2006).

Sunshine hours are relatively high in places sheltered from the west and most of New Zealand would have at least 2000 hours annually. Most snow falls in the mountain areas. Snow rarely falls at the coast of the North Island and west of the South Island, although the east and south coasts of the South Island may experience some snow in winter. Frosts can occur anywhere, and usually form on cold nights with clear skies and little wind (NIWA 2006).

2.7.1. Northern New Zealand

The northern part of New Zealand is the most climatically suitable for the establishment of new pests and pathogens coming from a tropical country such as Tuvalu. The area includes Kaitaia, Kerikeri, Whangarei, Auckland – the largest city in New Zealand and Tauranga. The latter two cities both contain large active ports. Kerikeri is a well known orcharding town with many varieties of citrus fruit grown there. This is a sub-tropical climate zone, with warm humid summers and mild winters. Typical summer daytime maximum air temperatures range from 22°C to 26°C, but seldom exceed 30°C. Winter daytime maximum air temperatures range from 12°C to 17°C.

Annual sunshine hours average about 2000 per year in many areas, with Tauranga for example, experiencing at least 2200 hours. South westerly winds prevail for much of the year. Sea breezes often occur on warm summer days. Winter usually has more rain and is the most unsettled time of year. In summer and autumn, storms of tropical origin may bring high winds and heavy rainfall from the east or northeast (NIWA 2006).

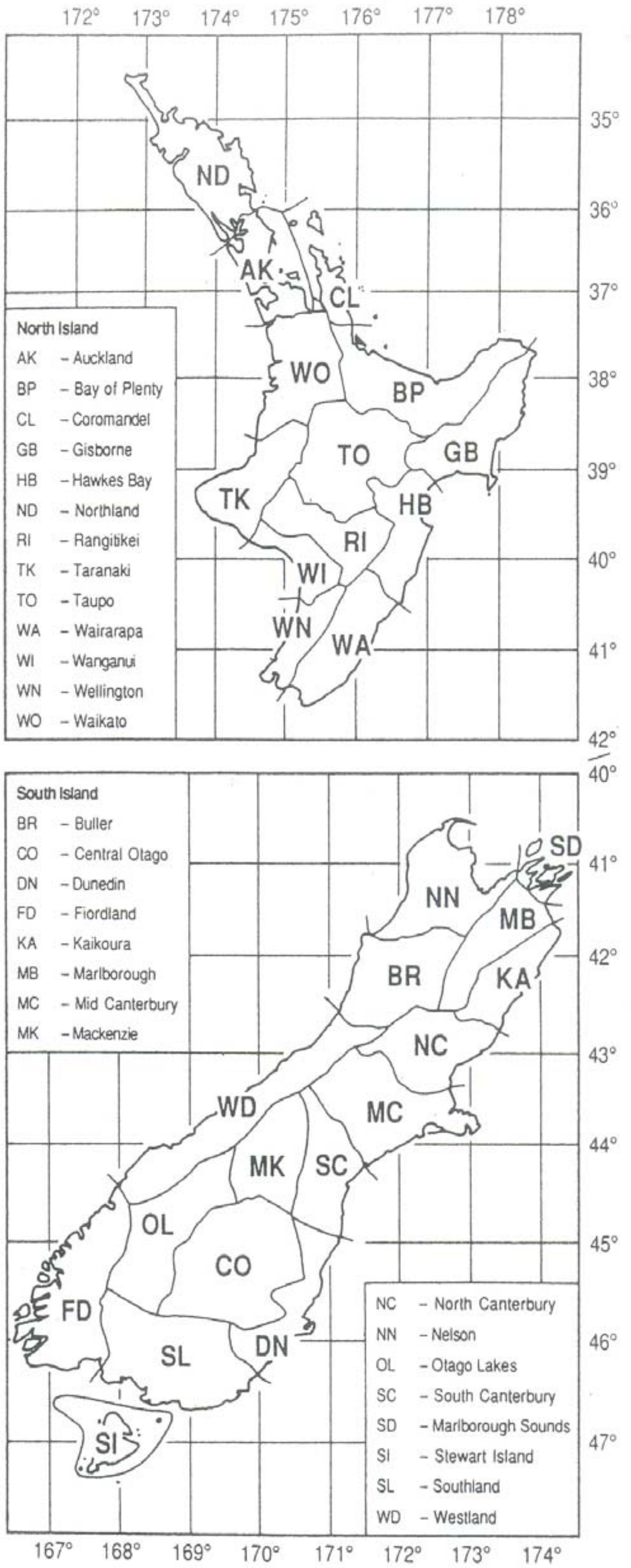
Auckland has the highest rate of naturalised plants of any city in the country. The prime reasons for the high numbers of plant species are considered to be a moderate climate favouring species from many climatic zones and availability of habitats (Esler 1988). Auckland also has the largest population in the country, with the greatest influx of incoming goods and people and contains the largest sea and air ports.

2.8. Locality naming conventions

The system for recording specimen localities of insects (Crosby *et al.* 1976, 1998) has been used in this document to indicate places where exposure and establishment of hazardous organisms could occur. The places referred to on the map (Figure 5) and their two-letter abbreviations are listed. North Island: AK, Auckland; BP, Bay of Plenty; CL, Coromandel; GB, Gisborne; HB, Hawkes Bay; ND, Northland; RI, Rangitikei; TK, Taranaki; TO, Taupo; WA, Wairarapa; WI, Wanganui; WN, Wellington; WO, Waikato. South Island: MC, Mid Canterbury; NN, Nelson; SD, Marlborough Sounds.

There are obvious limitations in the arbitrary nature of the Crosby *et al.* (1976) system when it comes to uncovering biogeographic patterns. However it continues as a well established approach used by most New Zealand entomological collections, museums, and publication series. It has the advantages of allowing distributional information to be uniformly recorded and easily compared (Larivière & Larochelle 2004). Figure 5 below outlines the geographic areas of the code.

Figure 5: Crosby Codes of New Zealand: A map reproduced from the Fauna of New Zealand series showing all Crosby codes for New Zealand.



2.9. History of coconut cultivation in Tuvalu

Coconuts are important for household food security and the many uses of coconuts make them an essential part of life in Tuvalu.
The islands are low lying atolls with a highest point of 4.6m above sea level. In five of the atolls, the reef encloses sizeable lagoons, but in the remainder the islands comprise pinnacles of land rising sheer from the ocean bed (MCNR 1984). Because of the atoll terrain there are no rivers. Vaitupu, Niutao, Naumea and Niulakita are reef islands. Vaitupu has a closed off lagoon, and there is a brackish lake on Niutoa.
Coconut trees are the main vegetation cover on most of the islands. The soils in Tuvalu are of poor quality and the ecosystems fragile. The below ground cover (legumes) such as *Vigna marina* and *Scaveola* constitute the major pasture species found under the coconut trees for ruminant livestock (goats) which were held on smallholder systems of production (Hussain 1987).

Variable amounts of secondary vegetation are seen under coconut plantations. This undergrowth adversely affects the output from the plantations, as it cannot be used for direct human consumption nor can the traditional types of livestock (pigs and poultry) currently reared in the atolls, make use of it for their maintenance (Aregheore 2002).
Breadfruit trees are also abundant in Tuvalu and are likely to be grown alongside coconuts in many areas.

2.10. Production and pre-export handling of commodity

Coconuts unlike other commodities can be harvested all year round. Growers must ensure that coconuts are free from pests, have good size and are of good quality. Germinating nuts are harvested from the ground with roots and shoots intact. These are removed and then the nut is husked with the use of a sturdy, pointed metal stake or ironweed (*Pemphis acidula*) set about waist high in concrete. The germinating nut is struck onto the point nearer the pointed end and twisted. The process is repeated until the husk is loose and removed by hand. Left over husks are cleared.
Coconuts are first graded by the farmer and then a second grade will be done by the copra representative and the extension officer, packed in sacks and sent to the main island (Funafuti). Each registered packhouse is to maintain records of which islands have supplied produce for packing. Packhouse staff will inspect all coconuts for the presence of pests. Nuts are packed in plastic bags (30/bag) and placed in containers a day before shipment.
Inspection record sheets contain:

- Island site number identification
- Amount/exact quantity of coconuts received on an island basis
- Date of receiving the coconuts
- Date of grading
- Quantity of coconuts rejected and reasons for rejection
- Quantity of coconuts transferred to the TPPQS staff for inspection.

TPPQS inspectors are to undertake a 100% inspection of all nuts supplied on an island basis after the packhouse staff has completed their inspection and grading.

TCTC and TPPQS officers will maintain records of all inspections including

- Inspection date
- Name of Island
- Name of exporter
- Quantity of coconut inspected
- Inspection result and action taken
- Treatment if any

TPPQS will formally audit the coconut export pathway of all exporters every three months or as required to ensure compliance with all the requirements. Audit records will contain details on audit date, components checked, any non-conformances and corrective actions taken and date of next audit.

2.11. Major pests of coconut in Tuvalu

There is little information on any pest control programmes implemented in coconut plantations in Tuvalu. As most coconuts are de-husked before export there is a reduced likelihood of organisms associated with coconuts in the production system being associated with the commodity once it is processed and packaged. Especially if good site hygiene and post harvest handling practices are maintained. Hitchhiker organisms will be important elements on the pathway. There are currently no field hygiene practices around the coconut storage areas. These will be reviewed in the management section (Chapter 5) and illustrated in the storage facility hitchhiker survey in Appendix 3.

Table 2: Key pests identified on coconut in Tuvalu (Tuvalu Quarantine Service 2007)

Scientific name	Common name	Presence in Tuvalu
Aspidiotus destructor	Coconut scale	Yes (only 2 islands Nanumaga & Vaitupu)
Chrysomphalus aonidum	Circular scale	yes
Chrysomphalus dictyospermi	Dictyospermum scale	yes
Dysmicoccus brevipes	Pineapple mealybug	yes
Ferrisia virgata	Striped mealybug	yes
Graeffea crouanii	Coconut stick insect	Yes (only 2 islands Nukufetau & Niutao)
Icerya aegyptiaca	Breadfruit mealybug	yes
Icerya seychellarum	Seychelles scale	yes
Neotermes rainbowi	Coconut termite	Yes (except Niutao, Nukufetau & Niulakita)
Pinnaspis strachani	Lesser snow scale	yes
Senna obtusifolia	Sicklepod (weed)	?

2.12. Transportation of commodity

Several shipping lines were researched using information from The New Zealand Shipping Gazette (October 20: No 41/07) to identify the possible time the commodity would be in transit from Tuvalu to New Zealand.

- The Neptune Shipping Line has ships departing from Suva which reach Auckland, New Zealand in 5 days.

- PFL Cargo has ships departing from Suva which go through Samoa, Tonga and the Cook Islands to reach Auckland in 13 days.

The ships pass through the tropics and are therefore subject to higher temperatures than air freighted produce. Humidity is also likely to be high. Containers are refrigerated in transit, to a temperature of between 3-13°C. Sometimes cold treatment of fruit requiring cooler temperatures (between 0-1°C) is carried out during ship transportation.

3. Hazard identification

The Hazard list for this analysis was compiled using host association information supplied by the Tuvalu Quarantine Service, interception records for coconut (QuanCargo Database 2007), various databases with presence in Tuvalu records and the hitchhiker storage facility survey carried out in Tuvalu in 2007. A report (Dabek 1998) covering a survey of the islands for pests and diseases, and Ward's (2007) PhD thesis looking at the distribution of ants in the pacific islands were also used.

3.1. Existing quarantine issues with imported coconuts

Grandison (2001, 2002) looked at fresh fruit coming from the Pacific Islands to New Zealand and noted that green coconut imports often have to be treated due to scale and insect larvae being found under the sepal remains on the unhusked green nut. Problems have also been observed with insects in the fibre remains covering the "eyes" that are left in the husked nuts for religious reasons. These husked nuts are used in Hindu religious ceremonies (Grandison 2002). Pathogenic diseases can be expressed if the calyx end is not cut off, rot can start there and affect the coconut within the husk. See Figure 6 below (Grandison 2001).

Figure 6: Trimming of calyx end of coconuts.

Calyx end trimmed | Calyx end not trimmed

3.2. Interceptions on coconuts from existing pathways

There are no other fresh produce commodities similar to coconut. Its exterior form and the methods used to dehusk it are unique. A large proportion of interceptions of live organisms found on coconut entering the country are hitchhikers. Other fresh produce commodities tend to have more host associated pests and diseases. Between 2003 and June 2007 a total of 3,335,634kg of coconuts were imported into New Zealand from the following countries: Fiji, Niue, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga and Vanuatu as commercial consignments (QuanCargo Database 2007). Coconuts are only imported into

New Zealand from the pacific region. The only other country for imported coconut which has an Import Health Standard is from the Philippines, also in the Pacific region. The size of consignment ranged from 25 to 20,920kg. From this volume there were a total of 417 inspection interceptions. Of the 417 interceptions 346 organisms were recorded as being alive and for the remaining 71 it was unsure what their life status was.

These interceptions were part of the visual inspection regime for imported fresh produce where 600 units (a unit is one coconut in this instance) are randomly chosen and inspected on arrival in New Zealand for pests or pathogens. The number of interceptions divided by total percentage of imported coconuts over the period 2003 to 2007 suggest there was a 0.012% percent rate of pest organisms arriving and being detected within the 600 unit sample on the pathway during the 5 years. It is important to consider that recorded interceptions are likely to be an underestimate of the total number of organisms present. Dead organisms are not recorded, and as the 600 units are a sample, there are likely to be other organisms present in other areas of a consignment not sampled. Some species may not be detected, and others will be detected on some occasions and not others. In 5 years only 12 consignments of green coconuts are recorded. Distinctions between mature, dehusked and green coconuts are not usually made in interception records, so assuming which pests are associated with different coconut forms is difficult. Taxonomists at the Identification and Diagnostic Centre (Ministry of Agriculture and Forestry) say it is common for scales and mealybugs to be seen on green coconuts and mites on dehusked ones (D. Gunawardana pers. comm. 2008).

Of those species listed as pests of coconut in Tuvalu the following have been intercepted on coconut from other countries (QuanCargo Database 2007). The numerical value is the number of times each pest category was found:

Chrysomphalus aonidium (Diaspididae)	1
Dysmicoccus brevipes (Margarodidae)	1
Pinnaspis strachani (Diaspididae)	2

It is considered likely that *C. aonidum*, *D. brevipes* and *P. strachani* could be represented in interceptions on coconut from Tuvalu when that pathway opens. These species may have a higher likelihood of entry than other species on the pest list.

Many invasive ant species though not directly associated with plant parts for food, can be hitchhikers on the commodity, becoming associated with the coconut during storage.
The following ants have been intercepted on coconut from other countries and are known to occur in Tuvalu:

Anoplolepis gracillipes (yellow crazy ant)	2
Paratrechina longicornis (crazy ant)	1
Paratrechina vaga (forest parrot ant)	2
Tetramorium bicarinatum (guinea ant)	1
Tetramorium simillimum (similar groove headed ant)	1
Wasmannia auropunctata (little fire ant)	1
Monomorium destructor (destructive trailing ant)	1
Monomorium pharaonis (pharaoh's ant)	1

Several of these ants (*A. gracillipes*, *P. longicornis* and *W. auropunctata*) are highly invasive and cause damage to crops, ecosystems and create human health issues (Harris *et al.* 2005).

Although not initially on the pest list because they are not directly associated with coconuts in cultivation, interception data enables us to pinpoint these species as more likely to be associated with the commodity as hitchhikers. A small sample of ants found around storage areas on Funafuti confirm the presence of 8 species including *M. destructor*, *M. pharaonis*, *T. simillimum, T. bicarinatum*, *A. gracilipes* and *P. longicornis*.

The 5 pest groups represented by the highest number of interceptions were mites, beetles, flies, ants and scales. Some organisms can be identified only to family level when they arrive. Some life stages such as eggs, pupae and larvae are more difficult to identify to species or genus level than adult stages. The following table shows the number of organisms identified to species level and the number of family level identifications in order of greatest number of representatives of a group to least. Other groups represented by smaller numbers included mealybugs, moths, thrips, spiders, cockroaches, snails, slaters, book lice, nematodes, earwigs and bugs. Full data sets are available in Appendix 2.

	Species	**Family**
Mites	25	12
Flies	7	12
Beetles	17	9
Scales	9	2
Ants	17	1

Although it will depend on exactly which species are in Tuvalu, it is likely that similar groups of organisms would be associated with coconut from Tuvalu. Future interception records of Tuvaluan coconuts arriving in New Zealand will provide information on these other species.

3.3. Interception data on other pathways from the pacific

Because coconuts share few characteristics with other fresh produce including other types of nuts or fruit and vegetables, the interception data from several other pathways is tabled here to highlight the similarities and differences between coconuts and other pathways in the Pacific. The following show the differences between managed and relatively unmanaged pathways and their organism components (Table 3).

Table 3: Comparison between different commodity pathways from the Pacific Islands

	Scrap Metal	Coconut	Taro	Papaya
Timeline	3 months: 2006	2003-2007	2003-2007	2003-2007
Quantity	2,971,400 Kg	3,056,454 Kg	26,996,332 Kg	1,618,582 Kg
Individuals	Ants 40+	Mites 106	Nematodes 1397	Lepidoptera 5
	Spiders 35	Beetles 40	Mites 1027	Spiders 2
	Cockroaches 23	Flies 39	Flies 195	Snails 1
	Reptiles 8	Ants 33	Snails 156	Scales 1
	Snails 8	Scales 21	Beetles 144	Mites 1
	Centipedes 4	Moths 9	Mealybugs 102	Hymenoptera 1
Total Interceptions	129+	417	3505	12

Source: QuanCargo Database 2007 & Scrap Metal Survey Report 2005

Almost all species associated with the scrap metal pathway are hitchhikers. They seek shelter within the structural complexity of the scrap metal which provides a multi-faceted environment enabling organism survival. Where there are exposed surfaces, there is the potential for water to pool, and if machinery has been in contact with soil, soil residue would also be present. These factors of water and soil, combined with contaminants such as leaves or other fresh organic material would be utilised by opportunist species seeking shelter.

Taro which is a similar size to coconut but a different shape grows underground, and many of the species intercepted complete part or all of their lifecycle in soil. There are many root nematodes and mites, ground dwelling snails and beetle larvae which pupate in soil found on this pathway. There are few hitchhikers, with the majority of organisms closely associated with the commodity in its natural environment. For example ants are not listed in the top 6 intercepted groups for this root crop.

Papaya, which is heat treated or cold disinfested before export has the fewest interceptions recorded. The benefits of pre export treatment are seen in these low numbers. Papaya essentially is the most similar of the products exported from the Pacific to coconut. It grows in a tree, hanging from branches, and is a fruit. The types of organisms associated with papaya are very different to those associated with coconut however. The most common interceptions on the pathway are of moths. It is likely that all moths are utilising the fruit directly for food. It appears that hitchhikers are less of a problem on this pathway.

Coconut is intermediate to all these commodities. Its surface structure is more like an inanimate object, either smooth in the case of coconut with its husk intact, or fibrous when unhusked. Unlike papaya and taro which are mainly associated with organisms directly utilising the product for particular life cycle requirements, recorded interceptions on coconuts include both direct host associations and many hitchhiker associations. Scrap metal, which is structurally complex, has no host associations and all hitchhiker species. On green coconut mealybugs and scale insects and some mites are likely to have direct host associations, while many mites, beetles, ants and flies are opportunistic hitchhikers on dehusked coconut post harvest. Because of this complex hitchhiker and non hitchhiker array of species, effective management options may include a systems approach and involve consideration of many factors around storage, contamination points along the pathway as well as appropriate treatments for the commodity.

3.4. Hitchhiker species and their characteristics

Hitchhiker species can be associated with any number of pathways for fresh produce because their association with the commodity is not biological but opportunistic. They do not require it to fulfil any part of the life cycle, but can use of its structural elements if it is present. These are either accidental tourists, which were in the area that the commodity was, at the right time and place to be transported with the commodity, or are human associated or commodity contaminant associated (Melanie Newfield pers. comm. 2008). Contaminant associations include things like soil, with micro-organisms, plant material such as bits of foliage or seeds. Human associated or synanthropic organisms utilise some aspect of anthropogenically modified environments to sustain their life cycle. Greenhouses are a simple example of this. The higher temperatures and elevated humidity inside these growing houses are more likely to provide the elements suitable for survival to an organism migrating from the tropics to a temperate or boreal zone.

The risk associated with each hitchhiker organism is dependant on the likelihoods of entry exposure and establishment as well as the number of times it is associated with the commodity, and the numbers of organisms on the volume of commodity (Memmott *et al.* 1998). For commodities which are arriving in the country in high volumes but very infrequently, there appears to be less likelihood of potential hazards establishing, than many smaller frequent volumes over the same period. The likelihood of exposure is increased when volumes are smaller and frequent. Logically high volumes at frequent intervals would be of the most concern.

For some organisms such as gypsy moths it has been demonstrated that a relatively large founder population size is required for the species to establish (Liebhold & Bascompte 2003). Though what this size is remains uncertain. There is unlikely to be a precise threshold above which establishment is certain and below which it is impossible (Simberloff 1989). The same has been observed for ants. Generally a colony with reproductives, workers and other life stages is needed for the species to become established. It is unknown however what the least number of individuals required would be to establish a colony.

In contrast, Berggren (2001) found that for Roesel's bush cricket (*Metrioptera roeseli*) at last nymph stage, a founder population of 32 individuals gave close to 100% probability of the population persisting for 3 years (the completion of the experiment). Successful establishment of arthropods (from studies on the release of biological control agents) has been recorded from introduction of fewer than 20 individuals (Berggren 2001, Hee *et al.,* 2000, Simberloff 1989). In an experiment with chrysomelid beetles Grevstad (1999) observed that out of 20 introductions of a single gravid female, one persisted to at least 3 generations (the completion of the experiment).

3.5. Significant uncertainties in the risk analysis

3.5.1. Unlisted pests

Although many pests dealt with in this risk analysis have adequate information for assessment, we can not predict future or present risks that currently escape detection for a variety of reasons, including pests that are not yet identified. There is difficulty in predicting likely hitchhiker species, which are associated with the commodity opportunistically and not for any life cycle requirements. With a trend towards decreasing use of chemical products in agriculture and further reliance on Integrated Pest Management strategies it is assumed that new pests will enter the system at some time in the future. Prolonged use of large doses of pesticides can lead to previously non pest species becoming economically important through resistance to pest treatments. Any of these types of organism could initially appear in very small numbers associated with the commodity, and may not be identified as hazards before their impacts become noticeable.

3.5.2. Symptomless micro-organisms

Pests such as microbes (bacteria, viruses, viroids and mycoplasmas etc.) and fungi infect fruit before transit and may not produce symptoms for some time becoming apparent only when they reach a suitable climate to sporulate or reproduce. Fungi can infect fruit after arrival making it difficult to distinguish the origin of saprobes and pathogens without adequate identification. Consumers tend to throw away moulded fruit rather than take it to a diagnostic laboratory so there is little data on post entry appearance of "invisible organisms".

Plants form associations with micro-organisms that are considered to be endophytes or saprobes (saprophytes). Some organisms are capable of acting as a pest or causing diseases on one plant or group of plants, but can form an association with another plant or group of plants on which they act beneficially. In the case of endophytes these organisms live symbiotically within the plant tissue and, in return for a safer environment and perhaps some nutrition, it is believed can in some circumstances provide limited protection to the plant from other disease-causing organisms. Endophytes can be relatively host specific.

Saprophytes live on or around the plant and survive on dead organic material. While usually not causing the initial disease expression, they invade damaged areas of the plant surface, and so become important after physical damage produced by environmental stressors like wind or insect attack. In contrast to endophytes, saprophytes are not usually host specific. It is likely that the majority of disease-causing micro-organisms were at one stage saprophytes or endophytes as the mechanisms for plant invasion by these organisms are modified from those used by endophytes and saprophytes. When a micro-organism kills its host directly it becomes pathogenic. Some pathogens such as *Phytophthora* species cause widespread devastation to crops. Many of these pathogens are well researched and implicated in dieback of trees or shrubs (Beever *et al.* 2007), while others are not. Serious diseases caused by viruses, viroids and mycoplasmas are prevalent in many coconut growing countries of the world. However in Tuvalu no diseases caused by these organisms are reported in the literature. Foliar decay disease caused by a viroid is reported in Vanuatu and a disease of unknown etiology is recorded in Papua New Guinea (Frison *et al.* 1993).

From a biosecurity risk analysis perspective therefore, latent or asymptomatic organisms pose a significant problem as their level of pathogenicity in a plant in all likelihood is unknown.

3.5.3. Assumptions and uncertainties about hazard biology

- The biology of insects that have been reared in the laboratory for several generations is often different to wild counterparts established in greenhouses or in field conditions (Mangan & Hallman 1998). Aspects such as life cycle, preovipositional period, fecundity and flight ability (Chambers 1977), as well as cold or heat tolerance can be influenced by the highly controlled laboratory environment. Laboratory reared insects may differ in their responses to environmental stress and exhibit tolerances that are exaggerated or reduced when compared with wild relatives. For example longevity and fecundity of adult *Aphis gossypii* in a greenhouse was longer and higher than those in a growth chamber with similar conditions (Kim & Kim 2004).

- If a pest species occurs in New Zealand often its full host range is unknown its behaviour may or not change and information about it in the colonised environment remains patchy. It is difficult to predict how a species will behave in a new environment, particularly if it has not become established as a pest elsewhere outside its natural range. Therefore there will be considerable uncertainty around the likelihood of an organism colonising new hosts or the consequences of its establishment and spread on the natural environment. Where indigenous plants are discussed as potential hosts this is extrapolated from the host range (at genus and family level) overseas and is not intended as a definitive list.

- For fungal pathogens it is sometimes unclear from the literature or current databases whether an organism is a synonym of another closely related species in the genus or its own entity. This becomes more complicated when a closely related species and possible synonym occurs in New Zealand while the organism in question does not.

- Ants are a key hitchhiker species on many pathways including used vehicles, scrap metal, and fresh produce such as coconut. There are often tritrophic interactions involving a plant host a honeydew producing hemipteran and an ant species seen in the field or cropping system. These associations cannot be said to definitively occur when a product is in storage ready for export. It is unknown for example what elements of harvested coconuts are attracting foraging ants. It may be structural aspects of piled coconuts, it may be honeydew produced by live scales and mealybugs on the outside of the nut, or dead insects still associated with the husk that would become a protein source. There may be some unknown food element or functional use for the coconut fibre utilised by ants that has not yet been identified. All possibilities are theoretical, and likelihoods of each being correct are unknown.

- Because there are difficulties around distinguishing *Paratrechina bourbonica* and *Paratrechina vaga* and there is no consensus on which of the two species are present in New Zealand, both are considered potential hazards on the pathway, until further resolution of taxonomy has been reached.

- Mites make up the majority of organisms recorded on coconuts from other Pacific Islands. Because of their tiny size and colouring, they would be hard to pick up in pre export inspections. There is very little data on the mite fauna of the Tuvalu Island group. One mite is recorded in the literature occurring in Tuvalu and on coconut: *Tetranychus neocaledonicus*. There are no records of any *Tetranychus* species associated with coconut in interception records, and because of its unlikely association with the mature nuts this species is not considered. The taro mites from the genus *Rhizoglyphus* are commonly intercepted. If further information becomes available around the mite fauna of Tuvalu it is recommended that a reassessment of this organism group be undertaken.

3.5.4. Assumptions and uncertainties about produce inspection

Some uncertainty exists around the efficacy of risk management measures. Interception data is one way of estimating efficacy, as records of live and dead organisms indicate the success of a treatment and the thresholds for growth and development of each individual organism. A sample audit is required to monitor efficacy. Currently this is 600 units of fruit/vegetable product per consignment. The assumption is that this monitoring will adequately record type and number of organisms associated with each commodity.

The 600 sample inspection requirement to achieve a 95 percent level of confidence that the maximum pest level will not be exceeded makes assumptions around consignment homogeneity, that samples will be random, and that the inspector has a 100 percent likelihood of detecting pests if they are present in the sample. It is accepted that the sampling system is based on a level (percentage) of contamination rather than a level of surviving individuals, and that because for lines of less than 600 units, 100 percent inspection is required, it is therefore acceptable that the effective level of confidence gained by the sampling method significantly increases as the consignment size moves below 10,000. This is because a sample of around 590 provides 95 percent confidence that a contamination level of 1 in 200 (0.5 percent) will be detected in consignments larger than about 25,000 individuals.

3.6. References for chapters 1-3

Aregheore, E A (2002) Country Pasture/Forage Resource Profiles: Tuvlau http://www.fao.org/ag/AGP/AGPC/doc/counprof/southpacific/tuvalu.htm

Beever, R E; Waipara, N M; Ramsfield, T D; Dick, M A; Horner, I J (2007) Kauri (*Agathis australis*) under threat from *Phytophthora*? Proceedings 4th IUFRO working party on Phytophthoras in Forests and Native Ecosystems, 26-31 August 2007, Monterey, California, USA (submitted)

Berggren, A (2001) Colonisation success in Roesel's bush cricket *Metrioptera roeseli*: the effects of propagule pressure. *Ecology* 82(1): 274-280

Chambers, D L (1977) Quality control in mass rearing. *Annual Review of Entomology* 22: 289-308

Crosby, T K; Dugdale, J S; Watt, J C (1976) Recording specimen localities in New Zealand: an arbitrary system of areas and codes defined. *New Zealand Journal of Zoology* 3: 69

Crosby, T K; Dugdale, J S; Watt, J C (1998) Area codes for recording specimen localities in the New Zealand subregion. *New Zealand Journal of Zoology* 25: 175–183

Cseligman.com (2007) Website of Courtney Seligman, Professor of Astronomy http://www.cseligman.com/

Dabek, A J (1998) *Final Report; Entomology & Plant Protection Project, Tuvalu (August 1996-August 1998).* Commonwealth Fund for Technical Cooperation (CFTC)

Esler, A E (1988) The naturalisation of plants in urban Auckland, New Zealand 5. Success of the alien species. *New Zealand Journal of Botany*. 26: 565-584

Frison, E A, Putter, C A J; Diekmann, M (1993) *FAO/IBPGR Technical Guidelines for the safe movement of coconut germplasm.* Food and Agriculture Organisation of the United Nations, Rome – International Board for Plant genetic Resources, pp. 48

Grandison, G (2001*) Progress Report for post harvest quality survey of fresh produce from Pacific Island countries.* For Ministry of Agriculture and Forestry, New Zealand www.spc.int/pps/Other/PH%20NZ%20November%20report.doc

Grandison, G (2002) Final Report for post harvest quality survey of fresh produce from Pacific Island countries. For Ministry of Agriculture and Forestry, New Zealand http://www.spc.int/pps/Other/PH%20NZ%20Final%20Report.doc

Grevstad, F S (1999) Experimental invasions using biological control introductions: the influence of release size on the chance of population establishment. *Biological Invasions* 1: 313-323

Harris, R; Abbott, K; Barton, K; Berry, J; Don, W; Gunawardana, D; Lester, P; Rees, J; Stanley, M; Sutherland, A; Toft, R (2005) *Invasive ant pest risk assessment project for Biosecurity New Zealand.* Series of Internet published Landcare Research contract reports http://www.landcareresearch.co.nz/research/biocons/invertebrates/Ants/invasive_ants/documents/angora.pdf

Hee, J J; Holway, D A; Suarez, A V; Case, T J (2000) Role of propagule size in the success of incipient colonies of the invasive Argentine ant. *Conservation Biology* 14(2): 559-563

Hussian, M Z (1987) Goat development on atolls of the Pacific: Kiribati and Tuvalu experience. *Alafua Agricultural Bulletin*, 12(3):99-105

Kim, Y H; Kim, J H (2004) *Biological control of Aphis gossypii using barley banker plants in greenhouse grown oriental melon*. Conference on Biological Control Berkeley, California. 13-15 July 124-126pp

Larivière M-C; Larochelle, A (2004) Heteroptera (Insecta: Hemiptera): catalogue. *Fauna of New Zealand* 50

Liebhold, A; Bascompte, J (2003) The allee effect, stochastic dynamics and the eradication of alien species. *Ecology letters* 6: 133-140

Maddison, P (1989) *UNDP/FAO-SPEC Survey*. Vol. 1

MAF BNZ Risk Analysis Procedures (2006)

MAF (2010) MAF Biosecurity New Zealand standard 152.02 Importation and clearance of fresh fruit and vegetables into New Zealand

Mangan, R L; Hallman, G J (1998) Temperature Treatments for Quarantine Security: New Approaches for Fresh Commodities. Chapter 8 In Hallman, G J; Denlinger, D L (eds) *Temperature Sensitivities in Insects and Applications in Integrated Pest Management*. Westview Press, Boulder, Colorado. Pp 201-236

MCNR (1984) Ministry of Commerce and Natural Resources, *Tuvalu Annual Report*

Memmott, J; Fowler, S V; Hill, R L (1998) The effect of release size on the probability of establishment of biological control agents: gorse thrips (*Sericothrips staphylinus*) released against gorse (*Ulex europaeus*) in New Zealand. *Biocontrol Science and Technology* 8: 103-115

NIWA (2006) *Overview of New Zealand Climate*. NIWA Science. National Institute of Water and Atmospheric Research. New Zealand. http://www.niwascience.co.nz/edu/resources/climate/overview/

QuanCargo Database (2007) Interception Record Database. Ministry of Agriculture and Forestry

Simberloff, D (1989) Which insect introductions succeed and which fail? In Drake, J A; Di Castri, F; Groves, R H; Kruger, F J; Rejmanek, M; Williamson, M (ed) *Biological invasions: a global perspective*. John Wiley & Sons Ltd; New York, pp61-74

Slippers, B; Summerell, B A; Crous, P W; Coutinho, T A; Wingfield, B D; Wingfield, M J (2005) Preliminary studies on *Botryosphaeria* species from Southern Hemisphere conifers in Australasia and South Africa. *Australasian Plant Pathology* 34(2): 213-220

Trewren, K (1986) *Technical Report on Tree Crops Research*, Ministry of Commerce and Natural Resources, Department of Agriculture, Vaiaku, Funafuti, Tuvalu

Ward, D F (2007) The Distribution and Ecology of Invasive ant species in the Pacific Region. Doctoral Thesis, The University of Auckland

4. Review of management options

4.1. Introduction

This chapter reviews some management options for organisms considered to be an unacceptable risk on coconuts imported from Tuvalu. Visual inspection, site hygiene, ant baiting, washing and cold storage are the treatments and systems approaches to risk mitigation considered. It is expected that the majority of coconuts for export to New Zealand will be dehusked, significantly reducing the pest loading on the commodity.

4.2. In field control, pre-export measures and area freedom

There is no comprehensive pest management and pest control system for specific pests of coconut in Tuvalu. *Aspidiotus destructor* is considered the most important pest, with field measures to reduce outbreak intensity undertaken.

4.3. Site hygiene measures

Examples of site hygiene practices that require remediation are featured in Appendix 3. The following site hygiene measures relate directly to the review of post harvest handling and storage of coconuts in Tuvalu. Issues are recorded in the November 2007 field report (MAF Unpublished Report 2008).

4.3.1. Post harvest

- Fallen coconuts should not be left on the ground in contact with soil to mature. This increases the likely association of pests with the commodity.
- After dehusking, coconuts should immediately be removed and stored separately from husks. All husks and old coconut shells should be removed from in and around storage facilities.
- When coconuts are being prepared for coconut apple production, contact with the ground is generally the common germination technique. Polythene or plastic sheeting as a single layer in a shady place, with regular watering can also be utilised (P. Fernando pers comm. September 2008). All coconut apples should be exported dehusked and with sufficient care taken to remove organisms from the remaining shoot part and use wax to seal fresh organic material to prevent infestation.

4.3.2. Warehouse

- Any rotting fruit such as bananas or plant material inside or in close proximity to warehouse storage facilities should be regularly cleaned up and disposed of.
- Bags of dehusked coconut ready for export should be stored upright and in rows.
- Where other products in containers such as toddy are being stored in the same space in warehouses, care should be taken to clean the outside of containers to prevent sweet dried liquid becoming an attractant for hitchhiker species such as ants.
- It is suggested that crab cages outside the warehouse facility, be removed from their close proximity to the building.
- Building materials including timber, metal and scrap piled up along the front and side walls of the warehouse building provide shelter and nest sites for ants. All building material should be removed from this area and stored elsewhere.

4.3.3. In transit

- Loose coconuts next to packaged dehusked coconuts could increase recontamination in transit. Packaged dehusked coconut must be segregated from loose coconuts.
- Fresh plant material such as pandanus leaves should not travel in contact with coconuts for export as recontamination could occur. All non packaged organic material should be segregated from coconuts for export.
- Cold storage will maintain quality and freshness of the product while deterring recontamination by pest organisms.

4.4. Washing, brushing and waxing

There is no literature around washing regimes to clean coconuts for quarantine purposes. One experiment is reported for estimating the population size of coconut mite *Aceria guerreronis* on coconut. The authors removed mites by washing bracts and the surface of an infested coconut (with the intact husk) with 30ml of detergent solution. Shaking the wash for 5 seconds allowed the mites to distribute uniformly (Siriwardena *et al.* 2005). Literature around washing, brushing and waxing in the citrus industry is reviewed here, as good data exist. Often producers in the Pacific do not harvest their coconuts. Mature nuts are left on the ground (Figure 7) and are gathered by the farmer or the family members of the farming family at regular intervals. Harvested nuts are usually gathered together in a single layer on the ground. If the soil is moist there is always the tendency for the nuts to germinate. Hence nuts are not allowed on the damp ground for a long time but are moved to drier places. If the end product required is coconut apples, coconuts are often arranged on the ground so they can easily germinate in rows which makes harvesting the embryo (apple) easier (Figure 8).

Figure 7: Maturing coconut

Figure 8: Cultivated coconut apples

Often nuts are kept for about a month in this way. This practice promotes desirable changes in the greener or somewhat less mature nuts. Producers claim that seasoning or storage of 10-11 month old green nuts for one month or so improved the coconut kernel, and makes dehusking easier (FAO information sheet). This increases the likelihood of pest organisms becoming associated with the fallen coconuts before export. Unless the coconut is dehusked, or prepared with calyx trimmed off green nuts and the outer surface washed and scrubbed clean it is highly likely that small insects such as mites, scales and mealybugs will remain.

The USDA-PPQ Treatment Manual for fruit nuts and vegetables (2007) states that water used for washing, treatments and cooling must be fortified with sodium hypochlorite (household bleach) and be constantly maintained at a chlorine level not to exceed 200ppm. The FAO (2004) advocates harvested fruit should be trimmed of any leaves or stem and well washed to remove any superficial dirt, plant debris, pests and pathogens. The water should be clean and contain the appropriate concentration of sanitizers to minimise the transmission of pathogens from water to fruit, from infected fruit to healthy fruit within a single batch and from one batch of fruit to another batch over time (FAO 2004). Both organisations provide treatment schedules for methyl bromide only regarding coconut or copra products.

Adding surfactants to water increases the washing efficacy. Surfactants break the surface tension allowing water to reach otherwise protected areas such as under the calyx. The waxy coating on grape mealybugs and woolly aphids were reduced when in contact with a particular organosilicone surfactant (Hansen *et al.* 2006).

Coatings such as an approved food grade wax applied to fruit can be used in addition with other measures to reduce the likelihood of entry of hazard organisms. This would be especially important for the stem end of coconut apple. Any exposed fresh plant material should be waxed to reduce insect infestation. Citrus Lustr 402 has been shown to kill *Anastrepha ludens* immatures in grapefruit, possibly by inhibiting gaseous exchange, but is not considered sufficient as a quarantine measure on its own (Hallman 1997). Hallman (1997) suggests coatings could be incorporated as a component of an integrated systems approach to quarantine security where a series of pest infestation reducing steps decrease the risk to insignificant levels.

Gould and McGuire (2000) tested 4 different coatings (2 petroleum based, 1 vegetable oil and a soap) on limes. The coatings were applied at a 3% (vol:vol) rate in 10L of water. The limes, in groups of 60 were immersed for 10 minutes, removed and rinsed with tap water for 10 minutes then held for 2-3 days. Mortality of nymphs and adult mealybugs was then assessed. Results varied between 30-65% mortality. However one petroleum oil, AMPOL (Caltex Australia, Sydney, New South Wales) provided 94% mortality, although the number of invertebrates tested is not stated. The very low number of dead and living invertebrates recovered from the treatments versus controls implied the oil repelled the invertebrates causing them to leave the fruit. As a quarantine measure the AMPOL coating does not provide 99.9968% mortality (probit 9), however, applied as a postharvest dip before shipment it is thought it would reduce the number of actionable pests (Gould and McGuire 2000).

An additional benefit of coating fruit is the decrease of moisture loss from the fruit during cool storage or during cold disinfestation treatment (Irtwange 2006). Wild (1993) observed a reduction in the susceptibility of grapefruit and oranges to chilling injury after a thorough application of wax. It is important to wax coat not only the cut ends of fruit shoots for coconut apples, but also the cut surface of green coconut after removal of the calyx to avoid contamination especially from micro-organisms. If possible waxing the eye area of the de-husked coconut will reduce likelihood of contamination of the kernel (P. Fernando *pers comm.* September 2008).

Although efficacy data is not available it is noted that limes imported into the USA from Chile undergo a soapy water wash and wax treatment against *Brevipalpus chilensis* (Chilean false spider mite). The treatment schedule (T102-b-1) specifies a 20 seconds immersion in a soapy water bath of one part soap solution (such as Deterfruit) to 3,000 parts water. This is followed by a pressure shower rinse to remove excess soap. The fruit is then immersed for 20 seconds into an undiluted wax coating (such as Johnson's wax Primafresh 31 Kosher fruit coating). This coating must cover the entire fruit (USDA-PPQ 2007).

To conclude, water used for washing should be fortified with sodium hypochlorite to ensure that pathogen transfer is minimised. The use of surfactants increases the efficacy of the washing process, so will contribute to reducing risk. Washing is best done after removal of the calyx for green coconuts. De-husked coconuts have the tendency for water to enter the soft eye and cause rotting (P. Fernando *pers. comm.* September 2008).Alternative to submerging fruits in water, wiping the fruit surface with a bleach+detergent may be more practical as the drying process is quicker (P. Fernando *pers. comm.* September 2008). Wax coatings minimise risk further and provide some protection for the fruit from chilling or moisture loss.
To increase the effectiveness of washing, fruit should be submersed in the water, and brushed to remove any superficial invertebrates or dirt, or wiped clean with a detergent+bleach mix and left to dry. This same process can be applied to coconuts thus reducing contamination by hazard organisms.
Washing and coatings are a component of a systems approach towards risk mitigation of hazard organisms.

4.5. Visual inspection

Visual inspection by a trained inspector can be used in three main ways for managing biosecurity risks on goods being imported into New Zealand, as:

- a biosecurity measure, where the attributes of the goods and hazard organism provide sufficient confidence that an inspection will be able to achieve the required level of detection efficacy;
- an audit, where the attributes of the goods, hazard organisms and function being audited provide sufficient confidence that an inspection will confirm that risk management has achieved the required level of efficacy;
- a biosecurity measure in a systems approach, where the other biosecurity measures are not able to provide sufficient efficacy alone or have significant levels of associated uncertainty.

In the case of inspection for audits, this is considered a function of assurance and is considered as part of the implementation of the identified measures. Inspection as a biosecurity measure uses the direct comparison of required efficacy to manage risk versus actual efficacy of an inspection (maximum pest limit versus expected measure efficacy).

Inspection as a biosecurity measure in a systems approach can be used either directly, as a top-up to the efficacy achieved by other measures in the system or indirectly as a check to ensure an earlier measure was completed appropriately. In the latter case an appropriate inspection for the target organism may not be practical (the sample size may be too large) and an indirect sign of less-than-adequate efficacy may be used. Examples of indirect indications of failed treatments include:

- surviving non-target organisms that are more easily detected;
- symptoms of infestation such as frass or foliage damage in the case of cut flowers or nursery stock;
- symptoms of treatment such as damage to goods;
- the use of indicators during treatment such as live organisms or colour indicators.

4.6. Baiting for ant control

Direct treatment with baiting and residue applications will manage infestations. For most ant species killing the queens using baits is the key to effective management (Stanley 2004).

4.6.1. *Anoplolepis gracilipes*

Poisoning with toxic baits is the most effective method for control of *A. gracilipes* (Harris *et al.* 2005). Successful control programmes have been carried out for high densities of *A. gracilipes* in the Seychelles (Haines & Haines 1979a) and on Christmas Island (Green *et al.* 2004), both using toxic bait distributed throughout infested areas.

Toxicants and commercial baits: Bait and toxicant development for the control of *A. gracilipes* in the Seychelles resulted in the use of the organochlorine insecticide Aldrin incorporated into a bait based on a carrier of sieved coir waste (fibre from around the seed of coconut palm) (Haines & Haines 1979b). On Christmas Island, after unsuccessful laboratory and field trials with several commercially available ant poisons, fish meal bait was chosen, with an active constituent of fipronil at 0.1g/kg. Its commercial name is Presto®01 Ant Bait. Fipronil is one of a new class of neurotoxic insecticides, and disrupts normal nerve function (Harris *et al.* 2005). There is considerable debate over the use of this chemical due to its high toxic in water (P. Lester *pers comm*. September 2008). For small localised incursions, direct nest treatment methods currently used for other invasive ants are likely to be sufficient (V. Van Dyke pers comm. in Harris *et al.* 2005).

4.6.2. *Monomorium destructor*

Bait matrix and carrier: Field trials in Malaysia using food attractants found peanut butter (80%) was strongly preferred over honey (20%) by *M. destructor* (Lee 2002). Lee and Kooi (2004) recommend using protein or sugar based attractants in targeting *M. destructor*. In Western Australia Davis and Van Schagen (1993) found that in food preference tests, plain white bread proved to be the most attractive of a range of food types and was used to monitor ant activity before and after baiting (Davis & Van Schagen 1993).
Toxicants and commercial baits: Davis and others (1993) trialled several commercial ant baits developed for *S. invicta* based on soybean oil on corn-grit-bait matrix: Finitron® (sulfamurid), Ascend® (abamectin), Award® (fenoxycarb), Amdro® (hydramethylnon) and Bushwacker® (boric acid in ground shrimp offal bait matrix). Field trials found that at least 6 months control of *M. destructor* was achieved from one application of Finitron®. The ant did not pick up any of the Bushwacker® or Award® granules, and there was some recovery in the Ascend® plot after 2 weeks (Davis & Van Schagen 1993).
In replicated laboratory tests with *M. destructor* colonies, after 21 days Finitron®, Ascend® and Amdro® proved equally effective at killing workers. However, Amdro® caused significantly more queen mortality (75%) than the other two products (Davis & Van Schagen 1993).

Finitron has been taken off the market in the US since these western Australian trials, making Amdro® the most effective commercial bait available for the control of *M. destructor*. At least 3 formulations containing 7.3g/kg hydramethylnon (Drax Ant Kil Granular with hydramethylnon, Garrards granular ant bait, Faslane granular ant bait) and 1 containing 10g/kg hydramethylnon (Maxforce Granular Insect Bait) are registered for use against *M. destructor* in Australia in addition to Amdro® (Harris *et al*. 2005).

4.6.3. *Paratrechina bourbonica*

Little is known about control for this species. *P. bourbonica* workers often forage long distances, so nests may be difficult to find for control (Harris *et al*. 2005).
Bait matrix and carrier: Peanut butter baits have been used in Hawaii to collect *P. bourbonica* (Gruner 2000).

Toxicants and commercial baits:
Bait attractiveness trials on Palmyra Atoll showed *P. bourbonica* preferred sugar water, with Xtinguish™ the next preferred bait (Krushelnycky & Lester 2003). *P. bourbonica* ignored Maxforce® granules (silkworm pupae matrix) and was not observed carrying away Amdro® granules (soybean oil on corn grit) (Krushelnycky & Lester 2003). Exterm-An-Ant® would likely be recommended for control of *P. bourbonica* by specialist pest control (S. O'Connor pers. comm. 2008). The active ingredient is Boron, a naturally occurring element toxic to insects but not humans or other animals (Pest Rid New Zealand 2006).

4.6.4. *Paratrechina longicornis*

Crazy ants are difficult to control, with commercially available baits showing limited effectiveness (Hedges 1996a; Hedges 1996b; Mampe 1997; Lee 2002) as the ant often nests some distance from its foraging area, and nests can be difficult to locate and control (Harris *et al.* 2005).
Bait matrix: Experiments using food attractants found 80% of *P. longicornis* preferred honey over peanut butter (Lee 2002). Paste and granular formulations are reported seldom effective against *P. longicornis* in Singapore and Malaysia (Lee & Kooi 2004). Sugar based liquid or gel formulations are recommended as more effective (Lee 2002). Tuna (in oil) baits used in Biosphere 2 (in which *P. longicornis* was the dominant ant) were consistently more attractive to *P. longicornis* than pecan cookie baits (carbohydrate) put out at the same time (Wetterer *et al.* 1999). Although this was not observed with oil baits in Hawaii (Cornelius *et al.* 1996) or New Zealand (Harris *et al.* 2005).

Toxicants or commercial baits: Hedges (1996b) reported *P. longicornis* would not feed for sufficient time on commercial baits to ensure effective control. Lee *et al.* (2003) found some evidence that Protect-B® (0.5% methoprene) baits and CombatAnt Killer® bait stations (1% hydramethylnon) are not effective against *P. longicornis*. Observations during incursions in New Zealand show that *P. longicornis* recruits well to Xtinguish™, however no formal testing of this bait against *P. longicornis* has been undertaken. Exterm-An-Ant® (8% Boric acid + 5.6% sodium borate) has also been used, and is attractive to foragers, but its ability to kill queens within the nest is unknown (Harris *et al.* 2005).

4.6.5. *Paratrechina vaga*

Bait matrix and carrier:
Foragers have been collected on peanut butter and also tuna baits (Morrison 1996; Gruner 2000).

Toxicants and commercial baits:
Paratrechina species in New Zealand readily feed on Xstinguish™ Argentine ant bait but no efficacy trials have been conducted. *P. vaga* is susceptible to hydrogen cyanide treatment, particularly at the highest tested concentration – 4600 ppm (Hansen *et al.* 1991). It is likely that Exterm-An-Ant® would be recommended by specialist pest control (S. O'Connor pers. comm. 2008).

4.6.6. *Tetramorium simillimum*

There is very little data around control methods for *T. simillimum* in the literature. In experiments testing bait for controlling larvae of the weevil *Diaprepes abbreviatus* RPA107382 (0.38 kg EC) an analog of fipronil, (a phenyl pyrazole) was utilised. McCoy *et al.* (2001) found that of the total percentage of different ant species trapped on the soil surface around citrus trees via baited traps, 4.7% were *Tetramorium simillimum*. The bait carrier was hamburger (meat- protein based).

4.6.7. *Wasmannia auropunctata*

Bait matrix and carrier:
The food preferences of *W. auropunctata* have been well studied by Williams and Whelan (1992) in laboratory and field tests in the Galápagos Islands. In laboratory tests, peanut butter, followed by honey, were more attractive to foragers than all other types of food. Testing conducted on oil type preferences confirmed soybean oil was most attractive followed by tuna, sunflower, peanut, safflower and codliver oils (Williams & Whelan 1992). The attractiveness of food attractants, such as peanut butter was also tested in field conditions. Tuna oil and peanut butter were used on Santa Fe Island in 1987 and proved highly attractive to foragers, but also to birds, lizards and rats (Abedrabbo 1994). Peanut butter was highly attractive to *W. auropunctata* foragers, and placement technique meant there was no removal by lizards and doves (Causton *et al.* 2005).

Toxicants and commercial baits:
In laboratory tests Amdro® was slightly less attractive than peanut butter, while Logic® was significantly less attractive than peanut butter. The following baits are in order of attractiveness in the field: Amdro®, peanut butter, lard, Raid Max®, Maxforce®, honeywater, peanut butter oil, honey, Logic®, water (Williams & Whelan 1992). Laboratory tests on small colonies showed Amdro® caused 100% mortality in all colonies within 20 days (Williams & Whelan 1992). Amdro® was applied to the 3ha of Santa Fe Island infested with *W. auropunctata* in 1987 and eradication was successful (Abedrabbo 1994). Hydramethylnon degrades rapidly in sunlight and therefore the timing of bait applications may influence its efficacy (Vander Meer *et al.* 1982).

4.6.8. Alternative to Fipronil

Comparisons have been made between contact and oral toxicities of spinosad a bio-insecticide and fipronil against worker ants of *Solenopsis invicta* in China (Zeng *et al.* 2006). Spinosad with good oral toxicity and low contact toxicity, was found to more effective than fipronil in both cases, and with its high transferring insecticidal activity (from feeding workers, to other workers and larvae) is suitable for bait preparation (Zeng *et al.* 2006).

4.6.9. Indirect effects of baiting

While there is minimal risk to non-target insects from hydramethylnon as it is not absorbed through insect cuticle, there is some risk to scavenging arthropods and arthropod predators feeding on the bait. It is of low toxicity to most vertebrates but is highly toxic to fish, so extreme care would be needed treating ants near waterways. It does not appear to accumulate in the environment (Vander Meer *et al.* 1982). Amdro is a group 20A insecticide, and resistance to these insecticides is possible through normal genetic variation in any insect population, however there are no documented cases of ant resistance to pesticides (Harris *et al.* 2005). Fipronil is a phenylpyrazole insecticide and is released into the environment as a racemic mixture of two enantiomers (optical isomers) which are highly toxic to marine and freshwater animal and phytoplankton species. Increased mortality and minimal recovery was observed in all species tested for recovery from fipronil exposure (Overmyer *et al.* 2007). Toxicity may be more common in crustaceans than in other aquatic organisms (Overmyer *et al.* 2007).

4.6.10. Consultant

A consultant who has expertise in ant baiting and eradication should visit Tuvalu, and set up a programme for controlling these ant species outlined above. The regime can be tailored specifically to meet the structural and compositional environment of the storage warehouses on Funafuti. Training for quarantine staff and co-operation between the consultant and Tuvalu Agriculture Department staff will ensure a successful ant reduction for quarantine purposes.

4.7. Container hygiene system

After coconuts have been washed and prepared for export they will be taken to ships for transit between Tuvalu and New Zealand, with a possible stop in Fiji which is en route. Containers are a large source of contamination for fresh produce, particularly of hitchhiker species such as ants. In 2006 MAF Biosecurity New Zealand (MAFBNZ) implemented a cooperative sea container hygiene system (EQ2) to manage all contaminants and included pests, such as ants and giant African snails, in or on containers. The system was designed to be "equivalent to quarantine" (EQ) standards as required in the MAFBNZ sea container standard. It involved cleaning and treating containers in the country of origin to remove contaminants and exclude pests and has measures to ensure that re-contamination likelihood is very low. Trials conducted in Honiara, Solomon Islands and in Lae and Port Moresby in Papua New Guinea led to threshold levels for general contaminants and ants set at 5% and 0.16% being met and levels dropping below these limits. Since EQ2 began, ant infestation has dropped 98.5%. Previously levels of ant contamination found during inspections of containers were as high as 17%.

The system has led to:

- reduced biosecurity contaminant and pest levels in New Zealand
- Significant cost reductions for importers and faster container clearance in New Zealand
- An increase in Pacific Island export trade and greater regional employment

These positive outcomes illustrate its applicability for implementation in Tuvalu.

4.8. Cold storage in transit

During transport cold storage on ships has been used to maintain product freshness and quality while deterring recontamination by pests during transit.
It is assumed that cooler temperatures in storage facilities will either kill pests associated directly with packaged coconuts, and deter hitchhiker organisms.

4.9. Assessment of residual risk

Residual risk can be described as the risk remaining after measures have been implemented. Assuming:

a) the measures have been implemented in a manner that ensures they reduce the level of risk posed by the hazard(s) to a degree anticipated by the risk analysis; and
b) the level of risk posed by the hazard(s) was determined accurately in the risk analysis.

The remaining risk may or may not be acceptable and can result in changes to risk management. Residual risk information in this case would be interception data from the coconut consignments coming into New Zealand from Tuvalu. To effectively manage the risks of the majority of hazard organisms, phytosanitary measures would need to ensure that with 95% confidence not more than 0.5% of the units in any given consignment of fresh coconuts were infested with live organisms when given a biosecurity clearance into New Zealand. There can be no assessment of residual risk until this data eventuates.

While there are already many established pathways for coconuts coming into New Zealand, from the Pacific interception data cannot be extrapolated to predict any possible level of slippage from Tuvalu or efficacy of treatments. Each new pathway must be regarded as unique, given differing pre and post harvest practices and treatment measures. Different pest species are associated with each pathway and measures therefore must be tailored to the individual organisms. There is a certain amount of extrapolation around treatment efficacy from one species within or outside a genus or family group to another.

4.10. References for chapter 4

Abedrabbo, S (1994) Control of the little fire ant, *Wasmannia auropunctata*, on Santa Fe Island in the Galápagos Islands. In Williams, D F (ed) *Exotic ants: biology, impact, and control of introduced species.* Westview Press, Boulder. Pp 219-227

Causton, C E; Sevilla, C R; Porter, S D (2005) Eradication of the little fire ant, *Wasmannia auropunctata* (Hymenoptera: Formicidae) from Marchena Island, Galapagos: on the edge of success? *Florida Entomologist* 88(2): 159-168

Cornelius, M L; Grace, J K; Yates, J R III (1996) Acceptability of different sugars and oils to three tropical ant species (Hymenoptera: Formicidae). *Anzeigerfur Schadlingskunde, Pflanzenschutz, Umweltschutz* 69(2): 41-43

Davis, P; Van Schagen, J (1993) Effective control of pest ants. *Journal of Agriculture, Western Australia* 34: 92-95

Davis, P R; van Schagen, J J; Widmer, M A; Craven, T J (1993) *A review of Argentine ant research in Western Australia particularly for the period 1989 to 1993.* Agriculture Protection Board of Western Australia, Perth, Australia

FAO (2004) The role of post-harvest management in assuring the quality and safety of horticultural crops. *Agricultural Bulletin* 152. Agriculture and Consumer Protection Department. Food and Agricultural Organisation of the United Nations http://www.fao.org/ag/ags/subjects/en/harvest/publications.html

Gould, W P; McGuire, R G (2000) Hot water treatment and insecticidal coatings for disinfesting limes of mealybugs (Homoptera: Pseudococcidae). *Journal of Economic Entomology* 93(3): 1017-1020

Grandison, G (2001) *Progress Report for post harvest quality survey of fresh produce from Pacific Island countries.* For Ministry of Agriculture and Forestry, New Zealand www.spc.int/pps/Other/PH%20NZ%20November%20report.doc

Grandison, G (2002) *Final Report for post harvest quality survey of fresh produce from Pacific Island countries.* For Ministry of Agriculture and Forestry, New Zealand http://www.spc.int/pps/Other/PH%20NZ%20Final%20Report.doc

Green, P T; Comport, S; Slip, D (2004) *The management and control of the invasive alien crazy ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean: the aerial baiting campaign September 2002*. Parks Australia and Monash University, Melbourne, Australia 79p

Gruner, D S (2000) *Distribution of the little fire ant* Wasmannia auropunctata *(Roger) in Hawaii: A partnership of K-12 schools, the University of Hawaii, and the Hawaii Department of Agriculture.* Unpublished report (http://www.hawaii.edu/gk-12/evolution/Ant_Report00.pdf)

Haines, I H; Haines, J B (1979a) Toxic bait for the control of *Anoplolepis longipes* (Jerdon) (Hymenoptera: Formicidae) in the Seychelles. 1: The basic attractant carrier, its production and weathering properties. *Bulletin of Entomological Research* 69: 65-75

Haines, I H; Haines, J B (1979b) Toxic bait for the control of *Anoplolepis gracilipes* (Jerdon) (Hymenoptera: Formicidae), in the Seychelles. 111. Selection of toxicants. *Bulletin of Entomological Research* 69: 203-211

Hallman, G J (1997) Mortality of Mexican fruit fly (Diptera: Tephritidae) immatures in coated Grapefruits. *Florida Entomologist* 80(3): 324-328

Hansen, J D; Hara, A H; Chan, H T Jr; Tenbrink, V L (1991) Efficacy of hydrogen cyanide fumigation as a treatment for pests of Hawaiian cut flowers and foliage after harvest. *Journal of Economic Entomology* 84: 532–536

Hansen, J D; Heidt, M L; Neven, L G; Mielke, E A; Bai, J; Chen, P M; Spotts, R A (2006) Effect of high-pressure hot-water washing treatment on fruit quality, insects, and disease in apples and pears PartIII. Use of silicone-based materials and mechanical methods to eliminate surface pests. *Postharvest Biology and Technology* 40: 221-229

Harris, R; Abbott, K; Barton, K; Berry, J; Don, W; Gunawardana, D; Lester, P; Rees, J; Stanley, M; Sutherland, A; Toft, R (2005) *Invasive ant pest risk assessment project for Biosecurity New Zealand.* Series of Internet published Landcare Research contract reports http://www.landcareresearch.co.nz/research/biocons/invertebrates/Ants/invasive_ants/documents/angora.pdf

Hedges, S A (1996a) The great bait debate. *Pest Control Technology* 24: 32–101

Hedges, S A (1996b) Identical cousins. *Pest Control Technology* 24: 40–101

Irtwange, S V (2006) Hot water Treatment: a non-chemical alternative in keeping quality during postharvest handling of *Citrus* fruits. *Agricultural Engineering International: the COGR Ejournal.* Invited Overview No. 5 Vol. 8

Krushelnycky, P D; Lester, P (2003) *Report on observations pertaining to ants and parasitic Hymenoptera, Palmyra Atoll, November 18-24, 2003.* Unpublished Report to US Fish & Wildlife Service 10pp

Lee, C Y (2002) Tropical household ants: pest status, species diversity, foraging behaviour, and baiting studies. In Jones, S C; Zhai, J; Robinson, W H (eds) *Proceedings of the 4th international conference on urban pests.* Pocahontas Press; Virginia, pp 3–18

Lee, C Y; Kooi, T E (2004) *Guide to urban pest ants of Singapore.* Singapore, SPMA for Pest Management Professionals. pp 40

Lee, C Y; Lee, L C; Na, P S J; Loke, P Y; Lim, K T; Teo, H H (2003) Evaluation of methoprene granular baits against foraging Pharaoh ants, *Monomorium pharaonis* (Hymenoptera: Formicidae). *Sociobiology* 41(3): 717-724

Loke, P Y; Lee, C Y (2004) Foraging behaviour of field populations of the big headed ant *Pheidole megacephala* (Hymenoptera: Formicidae). *Sociobiology* 43(2): 211-220

MAF (2008) MAF Unpublished Report *Field Trip report to Tuvalu November 2007*

Mampe, C D (1997) Crazy ant baiting may drive you nuts. *Pest Cont*rol 65(5): 8

McCoy, C W; Stuart, R J; Jackson, I; Fojtik, J; Hoyte, A (2001) Soil surface applications of chemicals for the control of neonate *Diaprepes abbreviatus* (Coleoptera: Curculionidae) and their effect on ant predators. *Florida Entomologist* 84(3); 327-335

Morrison, L W (1996) The ants (Hymenoptera: Formicidae) of Polynesia revisited: species numbers and the importance of sampling intensity. *Ecography* 19: 73–84

Overmyer, J P; Rouse, D R; Avants, J K; Garrison, A W; Delorenzo, M E; Chung, K W; Key, P B; Wilson, W A; Black, M C (2007) Toxicity of fipronil and its enantiomers to marine and freshwater non-targets. *Journal of Environmental Science and Health B.* 42(5): 471-480

Pest Rid New Zealand (2006) *Exterm-An-Ant pest control chemical* https://site273.mysite4now.com/nightswan/pestrid/ViewItem.php?ItemID=37

Siriwardena, P H A P; Fernando, L C P; Peiris, T S G (2005) A new method to estimate the population size of coconut mite *Aceria guerreronis* on a coconut. *Experimental and Applied Acaralogy* 37(1/2): 123-129

Stanley, M C (2004) *Review of the efficacy of baits used for ant control and eradication.* Landcare Research Contract Report: LC0405/044 Prepared for Ministry of Agriculture and Forestry

USDA-PPQ Treatment manual (2007) Treatment schedules.pdf http://www.aphis.usda.gov/import_export/plants/manuals/ports/treatment.shtml

Vander Meer, R K; Williams, D F; Lofgren, C S (1982) Degredation of the toxicant AC 217,300 in Amdro imported fire ant bait under field conditions. *Journal of Agricultural and Food Chemistry* 30: 145-148

Wetterer, J K; Miller, S E; Wheeler, D E; Olson, C A; Polhemus, D A; Pitts, M; Ashton I W; Himler, A G; Yospin, M M; Helms, K R; Harken, E L; Gallaher, J; Dunning, C E; Nelson, M; Litsinger, J; Southern, A; Burgess, T (1999) Ecological dominance by *Paratrechina* *longicornis* (Hymenoptera: Formicidae), an invasive tramp ant, in biosphere 2. *Florida Entomologist* 82: 381–388

Wetterer, J K (2002) The ants of Tonga. *Pacific Science* 56: 125–135

Wild, B L (1993) Reduction in chilling injury in grapefruit and oranges stored at 1˚C by prestorage hot dip treatments, curing and wax application. *Australian Journal of Experimental Agriculture* 33(4): 495-498

Williams, D F; Whelan, P M (1992) Bait attraction of the introduced pest ant, *Wasmannia auropunctata* (Hymenoptera: Formicidae) in the Galápagos Islands. Journal of Entomological Science 27(1): 29-34

Zeng, X N; Xiong, Z H; Guo, J; Huang, T F; Wu, S X (2006) Toxicity and transferring activity of spinosad against *Solenopsis invicta* Buren. *Journal of South China Agricultural University* 27(3): 26-29

Pest risk analyses

5. Coconut scale

5.1. Hazard identification

*Scientific name***:** *Aspidiotus destructor* Signoret (Hemiptera: Diaspididae)

Synonyms for A. destructor: Temnaspidiotus destructor

*New Zealand Status***:** Not known to be present in New Zealand.
Sources that do not record presence**:** (PPIN 2008; Charles & Henderson 2002).
A. destructor was erroneously recorded as occurring in New Zealand in Fernald's 1903 catalogue of scale insects and later Borschenius (1966) repeated the error in his major catalogue of the Diaspididae (Charles & Henderson 2002). *A. destructor* has never been recorded in the literature as either a border interception or as occurring in New Zealand.

5.1.1. Biology

Aspidiotus destructor occurs on palms in most parts of the world and is considered one of the major pests on coconut where the palm and scale exist together (Mariau 2001). It attacks mainly the under surface of leaves, but frond stalks, flower clusters and young fruit can also be affected (Watson 2005). Older trees (over 4 years) or trees on well drained soil are seldom seriously infested (Watson 2005). *A. destructor* reproduces sexually, with the female attracting males by pheromones (Watson 2005). The females are sessile while males have one pair of wings and are motile (Williams & Watson, 1988). Each female can lay from 50-148 eggs under her scale cover over a few days (Rafiq-Ahmad & Ghani 1972; Taylor 1935; Hutson 1933).

There are 2 nymphal instars, with male and female development differentiating at this point. Males are full grown at the end of the second larval stage and become pupae after their second moult. The pupal period lasts 4-6 days (Taylor 1935). Females continue to grow after their second moult for 8-9 days and do not change body shape. When egg production begins, after growth has stopped females are considered adults (Taylor 1935). The pre-oviposition period can be up to 25 days (Zhou *et al.* 1993). Eggs develop over 5-8 days, and larvae up to 17 days. Longevity is between 24-32, and 23-38 days for adult females and males respectively (Zhou *et al.* 1993; Aisagbonhi & Agwu 1985; Tabibullah & Gabriel 1973). Total development from egg to death is between 30-38 days (Aisigbonhi & Agwu 1985; Taylor 1935; Simmonds 1921).

There may be as few as one generation per year as recorded by Murakami (1970) in Japan, between 3 and 6 generations recorded in China and India (Zhou *et al.* 1993; Tang & Qin 1991; Gupta & Singh 1988) and more or less continuous generations observed in the tropics (Kessing & Mau 1992). It appears fecundity is governed by climatic factors (Jalaluddin *et al.* 1992). Mortality of crawlers is high during heavy rain as they fall off the leaves easily (Watson 2005). In studies on kiwifruit (*Actinidia chinensis*) in China temperature thresholds for development of *A. destructor* were observed as 10.49ºC for females, with males having a thermal threshold almost 2 degrees lower at 8.68 ºC (Zhou *et al.* 1993). Tang and Qin (1991) found that eggs survived temperatures down to 12.33 ºC +- 1.47 ºC in research conducted in Shanghai, China.

This scale is thought to disperse primarily with the aide of other creatures, such as birds insects and as is the case in Fiji, by bats (Taylor 1935). Although little evidence exists, it is believed that wind blown crawlers are another important mode of dispersal (May & Kessing 1992). Males and young first instar larvae, being the only mobile life stages are therefore responsible for this dispersal (Mariau 2001).

In March 1994 an outbreak of coconut scale occurred in Nanumaga Island, Tuvalu. Leaflets of coconut fronds of all ages were infested, and became extensively yellowed, necrotic and gradually withered (Dabek 1998). The yellowing is caused by the removal of sap by the mouthparts and the toxic effects of the saliva that kills the surrounding tissues at the feeding site (Waterhouse and Norris 1987). It was speculated that the massive epidemic infestation initially observed may have been due to the relatively dry climate experienced in Nanumaga (mean annual rainfall 2610mm) compared to the other Tuvaluan islands/atolls eg. Funafuti (mean annual rainfall 3465mm) and the lack of natural enemies (Dabek 1998).

Simmonds (1921) observed that in Fiji closely planted trees and those with a considerable amount of undergrowth appear to suffer less from *Aspidiotus destructor*, possibly because the undergrowth shelters its natural enemies. As a member of the armoured scale group it does not produce honey dew.

5.1.2. Hosts

Aspidiotus destructor is potentially the most destructive pest species on coconut wherever it occurs in the world (Chua & Wood 1990). It is associated with the leaves, flowers and young fruit of its host plants which are primarily coconut, banana, mango, citrus, avocado, brassicas, *Cucumis* spp, capsicum, grape, tomatoes and others (CPC 2007). It has been recorded on 75 genera of 44 different plant families but the host range is considered wider than this (Davidson & Miller, 1990).

The following among others are recorded as host plants in ScaleNet: *Anacardium occidentale* (cashew), *Annona* spp. (custard apple, cherimoya), *Anomianthus heterocarpus*, *Allemanda hendersoni*, *Aluerites* spp. (candlenut), *Albizia lebbek* (siris), *Asparagus sprengeri* (asparagus fern), *Artocarpus* spp. (breadfruit et.), *Averrhoa carambola* (star fruit), *Areca catechu* (Betel nut palm), *Alpinia nutans* (dwarf cardamom), *Barringtonia asiatica* (box fruit tree), *Bixa orellana* (lipstick tree), *Brassica* spp. (cress, mustard, cauliflower), *Calophyllum inophyllum* (Alexandrian laurel), *Camellia* spp. *Canna indica* (Indian shot plant), *Capsicum* spp., *Carica papaya* (papaya) *Cassia tora* (sickle pod), *Catesbaea parviflora* (small flower lilythorn), *Ceiba pentandra* (silk cotton tree), *Celtis occidentalis* (hackberry), *Chaetacme aristata*, *Chrysalidocarpus lutescens* (Butterfly palm), *Cinnamomum camphora* (camphor laurel), *C. zeylanicum* Ceylon cinnamon), *Citrus* spp *Cocos nucifera* (coconut), *Colocasia esculenta* (wild taro), *Combretum erythrophyllum* (river bushwillow), *Crotalaria* spp.(rattlepods), *Cucumis sativus* (cucumber), *Cycas revoluta* (sago palm), *Dalbergia championi*, *Decaspermum fruiticosum*, *Dictyosperma alba*, *Dillenia biflora*, *Dioscorea nummularia* Tivolo yam).

Elaeis guineensis (African oil palm), *Eugenia* spp., *Euonymus radicans* (wintercreeper), *Euphorbia pulcherima* (Euphorbia), *Eurya japonica*, *Eucalyptus deglupta* (Mindanao gum), *Ficus* spp. (fig), *Gnetum pirifolium*, *Grevillea robusta* (silky oak), *Heliconia bahai*, *Hevea brasiliensis* (rubber tree), *Ilex colchicum*, *Inocarpus fagifer* (Tahitian chestnut), *Jasminum* spp. (jasmin), *Lagerostroemia indica*, *Lantana camara* (lantana), *Lapotrea photiniphylla*, *Laurus nobilis* (bay laurel), *Ligustrum japonicum* (Japanese privet), *Litsea vitiensis, Lonicera japonica* (Japanese honeysuckle), *Lycopersicon esculentum* (tomato), *Maesa indica* (wild berry), *Mangifera indica* (mango), *Macaranga seemannii, Manihot glazioui, Michaelia alba* (white michelia), *Musa spp.* (banana), *Nipa fruticans* (nipa palm), *Ophiopogon japonicus* (mondo grass, lily turf), *Osmanthus asiaticus, Pandanus spp.* (pandanus), *Passiflora quadrangularis* (giant granadilla), *Persea americana* (avocado), *P. gratissima* (avocado), *Phoenix fruticans, Physalis lanceolata* (sandhill ground cherry), *P. peruviana* (goldenberry), *Piper spp.* (pepper), *Platanocephalus morindae, Prunus persica* (peach), *Psidium guajava* (guava).

Psychotrea elliptica, Raphanus sativus (radish), *Raphia ruffia* (Kosi palm, Raphia palm), *Ravenala madagascariensis* (travelers palm), *Saccharum officinarum* (sugar cane), *Sapium sebiferum* (Chinese tallow tree), *Scolopia oldhami, Solanum melongena* (eggplant), *Sonneratia caseolaris* (mangrove apple), *Stauntonia obovatitolia, Strelitzia reginae* (bird of paradise), *Swietnia mahogoni* (mahogany), *Trachycarpus excelsum, Theobromae cacao* (cocoa), *Uncaria gambir* (gum catechu), *Vigna unguiculata* (cowpea), *Vitis vinifera* (grapevine), *Xanthosoma sagittifolium* (elephant ear), *Zingiber officianalis* (ginger), *Ziziphus jujuba* (common jujuba) (ScaleNet 2008).

5.1.3. Distribution

A. destructor is widespread throughout Asia, Central America, parts of southern USA and northern South America and also parts of Europe and has been recorded in the Krasnodar coastal region of south eastern Russia (Chumakova 1965). It is found in Australia, American Samoa, Belau, Caroline Is., Fiji, French Polynesia, Guam, Marshall Is., New Caledonia, Northern Mariana Is., Papua New Guinea, Samoa, Soloman Is., Tuvalu, Vanuatu, and Wallis and Futuna (CPC 2007; Williams & Watson 1988)

5.1.4. Hazard identification conclusion

Aspidiotus destructor is a serious pest of coconut palms in many parts of the world. It devastated coconut crops in Tuvalu in 1994, as well as attacking a number of other crop plants including taro and breadfruit. It has a very broad host range and low thermal thresholds where it occurs in more temperate areas. For these reasons it is considered a potential hazard in this risk analysis.

5.2. Risk assessment

5.2.1. Entry assessment

Females are sessile, while adult males have one pair of wings and are motile. It’s unlikely therefore that adult males will be found on picked coconuts. They would likely escape the drupe during harvesting. Larvae crawl over the leaf surface after hatching until they find a suitable feeding site where they attach themselves. Once a feeding site has been selected the scale will not move (Taylor 1935). This mobile crawler stage in diaspid scales usually lasts between 2hrs-3 days (Beardsley & Gonzalez 1975). It is unlikely given this brief time frame that crawlers walking on to coconuts before they were harvested would still be crawlers were they to arrive in New Zealand on the commodity. It is more likely they would have become settled on the coconut during transport. Larval development takes up to 17 days, with a pupal period of 4-6 days. Total adult female longevity is between 24 and 32 days. These time frames combined more than encompass the transit time for coconuts to arrive in New Zealand from Tuvalu by boat. There is a chance though unlikely that adult females could produce crawlers while in transit, and this life stage could emerge at the border.

The likelihood of larval, pupal and adult female lifestages entering the country on coconut is moderate for crawler larvae and high for later larval instars, pupal and adult female life stages.

5.2.2. Exposure assessment

There would be no shortage of host plants available for *A. destructor* should it enter the country on the pathway. Many widely cultivated horticultural crops could become hosts including citrus, avocado, brassicas, capsicum, grape and tomato.

5.2.3. Establishment assessment

In China temperature thresholds for development of *A. destructor* were observed as 10.49ºC for females, with males having a thermal threshold almost 2 degrees lower at 8.68 ºC (Zhou *et al.* 1993). This is well below annual minimum temperatures of 15ºC for northern North Island. These thresholds would be within minimum temperatures recorded in most parts of coastal and lowland North Island over all.

The likelihood of exposure and establishment of Aspidiotus destructor in New Zealand is high.

5.2.4. Consequence assessment

5.2.4.1. Economic

It attacks the under surface of leaves, frond stalks, flower clusters and less commonly young fruit. In extreme cases the leaves dry up, entire fronds drop off, and eventually crown dieback with loss of the whole crop occurs (Chua & Wood 1990). After a heavy attack by *A. destructor* on coconuts in the Ivory Coast, yield was reduced by at least 25% over the next 2-3 years (Mariau & Julia 1977). In Tuvalu in 1994 there was a massive outbreak of *A. destructor* which killed coconut trees of all ages. It also attacked cassava, breadfruit and other crop plants during the infestation (Dabek 1998).

A. destructor is a cosmetic pest on a wide variety of fruits, affecting fruit setting in mango plants and ruining young shoots in nursery plants (Chua & Wood 1990). It occasionally causes severe damage to guava in India (Hayes 1970).

Many crops and ornamental fruit trees in New Zealand could be affected by coconut scale were it to become established, including: *Citrus* spp., avocado, *Brassica* spp., *Cucumis* spp., grapes, tomato, capsicum, *Prunus* spp. and guava.

5.2.4.2. Environmental

Most native plants are endemic and it is uncertain if *A. destructor* were to host switch, which native plants would be affected. Some likely examples are outlined. Two species recorded as hosts overseas have representatives in genera found in New Zealand, *Passiflora* and *Litsea.* There are two main species that would be affected were the scale to invade native forest areas, which is considered unlikely as its current distribution suggests a pest largely restricted to cultivated areas with monoculture crops. These species are *Litsea calicaris* and *Passiflora tetranda*. Both are found only in native forest, and would not be commonly grown in gardens. Both species are traditionally used by Maori for medicinal purposes (Brooker *et al.* 1961).

The consequences of establishment of A. destructor are likely to be high

5.2.5. Risk estimation

The likelihood of *A. destructor* entering the country is moderate to high. Exposure and establishment are considered moderately to highly likely and the consequences of establishment are also moderate to high.

As a result the risk estimate for A. destructor is non-negligible and it is classified as a hazard on the commodity. Therefore risk management measures are justified.

5.3. Risk management

5.3.1. Options

Aspidiotus destructor is a surface pest of coconut. As no chemical, heat or cold treatments are being utilised for coconuts, it is important that infield measures, post harvest handling and packaging and washing the commodity are undertaken. Various washing regimes are proposed in the review of management options in Chapter 5.

Pest management systems in coconut stands, screening measures and pre export visual inspection are considered to be included with each disinfestation treatment option given below.

Green coconut

Option 1. Scrubbing and washing of fruit surface after removal of calyx and waxing the cut surface immediately, following good hygiene practice to prevent recontamination, and then cold storage of coconuts in transit.

Option 2. Remove calyx, peeling skin of the fruit and waxing cut surface, followed with good hygiene practice to prevent recontamination, and cold storage of coconuts in transit.

Brown coconut

Option 1. De-husking, following good hygiene practice to prevent recontamination, and cold storage of coconuts in transit.

Option 2. De-husking, waxing of ‘eye’ region, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

Coconut apple

Option 1. De-husking, cutting off shoot and root material, waxing of cut surfaces, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

Option 2. De-husking, cutting off shoot and root material, waxing of whole coconut, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

5.4. Assessment of uncertainty

It is uncertain which native species *A. destructor* may host switch to if it were to become established in New Zealand.

5.5. References for chapter 5

Ahmad, R; Ghani, M A (1972) Studies on *Aspidiotus destructor* Signoret (Hemiptera: Diaspididae) and its parasites, *Aphytis melinus* DeBach (Hymenoptera: Aphelenidae) and *Pakencyrtus pakistanensis* Ahmad (Hymenoptera: Encyrtidae) in Pakistan. *Technical Bulletin of the Commonwealth Institute of Biological Control* 15: 51-57

Aisagbonhi, C I; Agwu, S I (1985) The life cycle of *Aspidiotus destructor* Signoret (Homoptera: Diaspididae) on coconut seedlings. *Journal of the Nigerian Institute for Oil Palm Research* 7(1): 120-129

Beardsley, J W; Gonzalez, R H (1975) The biology and ecology of armored scales. *Annual Review of Entomology* 20: 47-73

Borschenius, N S (1966) *A Catalogue of the Armoured Scale Insects (Diaspididae) of the World*. 'Nauka' Moscow, Leningrad 449pp

Brooker, S G; Cambie, R C; Cooper, R C (1961) *New Zealand Medicinal Plants*. Raupo Publishing (NZ) Ltd; New Zealand

Charles, J G; Henderson, R C (2002) Catalogue of the exotic armoured scale insects (Hemiptera: Coccoidea: Diaspididae) in New Zealand. *Journal of the Royal Society of New Zealand* 32(4): 587-615

Chua, T H; Wood, B J (1990) Other tropical fruit trees and shrubs. In Rosen, D. (ed) *Armored scale insects, their biology, natural enemies and control.* Volume B. Elsevier pp 547

Chumakova, B M (1965) The importance of the parasite *Aspidiotiphagus citrinas* (Crwf) (Hymenoptera: Aphelenidae) in reducing the numbers of injurious armoured scales in the subtropics of the RSFSR. *Entomol. Obozr.* 44(pt. 3): 520-526

CPC (2007) Crop Protection Compendium. *Aspidiotus destructor*; distribution http://www.cabicompendium.org/cpc/report.asp?CCODE=ASPDDE&criteria=T/DI1

Dabek, A J (1998) *Final report; Entomology & Plant Protection Project, Tuvalu (August 1996-August 1998).* Commonwealth Fund for Technical Cooperation (CFTC) Pp

Davidson, J A; Miller, D R (1990) Ornamental plants. In Rosen, D (ed) *Armoured scale insects, their biology, natural enemies and control.* Vol 4B. Elsevier, Amsterdam, the Netherlands: 603-632

Fernald, M E (1903) *A catalogue of the Coccidae of the world*. Amherst, Massachusetts, Carpenter & Moorehouse. 360p

Gupta, B P; Singh, Y P (1988) Mango scale insects – occurrence in western Uttar Pradesh and their control. *Progressive Horticulture* 20(3-4): 357-361

Hayes, W B (1970) *Fruit growing in India.* Third Edition. Kitabistan, Allahabad 512pp

Hutson, J C (1933) The coconut scale (*Aspidiotus destructor*) Tropical Agriculturalist (Ceylon) 80: 254-256

Jalaluddin, S M; Mohanasundaram, M; Sundarababu, P C (1992) Influence of weather on fecundity potential of coconut scale *Aspidiotus destructor* Signoret. *Indian Coconut Journal* 22(12): 5-7

Kessing, J L M; Mau, R F L (1992) *Aspidiotus destructor* (Signoret). Crop Knowledge Master, University of Hawaii
http://www.extento.hawaii.edu/kbase/crop/Type/a_destru.htm

Mariau, D (2001) *The fauna of oil palm and coconut. Insect and mite pests and their natural enemies.* Translated from the French by Peter Biggins. Centre de coopération internationale en recherche agronomique pour le développement (CIRAD). Pp 89-90

Mariau, D; Julia, J F (1977) Nouvelle recherches sur la cochenille du cocotier *Aspidiotus destructor* Signoret. *Oléagineux* 32(5): 217-224

Murakami, Y (1970) A review of biology and ecology of Diaspine scales in Japan (Homoptera: Coccoidea) (some 180 species). *Mushi* 43(Pt. 7): 65-114

PPIN (2007) *Plant Pest Information Network.* Database for the Ministry of Agriculture and Forestry

Rafiq Ahmad; Ghani M A (1972) Studies on *Aspidiotus destructor* Signoret (Hemiptera: Diaspididae) and its parasites, *Aphytis melinus* DeBach (Hymenoptera: Aphelinidae) and *Pakencyrtus pakistanensis* Ahmad. (Hymenoptera: Encyrtidae) in Pakistan. *Technical Bulletin of the Commonwealth Institute of Biological Control* 15: 51-57

ScaleNet (2008) *Aspidiotus destructor*, Hosts of a scale query
http://www.sel.barc.usda.gov/scalecgi/hostsof.exe?Family=Diaspididae&genus=Aspidiotus&species=destructor&subspecies=

Simmonds, H W (1921) The transparent coconut scale, *Aspidiotus destructor* and its enemies in Southern Pacific. *Fiji Department of Agriculture Bulletin* 14, 4pp

Tabibullah, M; Gabriel, B F (1973) Biological study of *Aspidiotus destructor* Signoret in different coconut varieties and other host plants. *Philippine Entomologist* 2(6): 409-426

Tang, S J; Qin, H Z (1991) Study on *Temnaspidiotus destructor* (Signoret). *Journal of Shanghai Agricultural College* 9(3): 190-196

Taylor, T H C (1935) The campaign against *Aspidiotus destructor*, Signoret, in Fiji. *Bulletin of Entomological Research* 26: 1-102

Waterhouse, D F; Norris, K R (1987) Chapter 8: *Aspidiotus destructor*. Pp 62-71 In *Biological Control Pacific Prospects*. Inkata Press, Melbourne. 454pp

Watson, G W (2005) *Aspidiotus destructor*: *Diaspididae of the world. Arthropods of economic importance. World Biodiversity database* http://nlbif.eti.uva.nl/bis/diaspididae.php?menuentry=soorten&id=86

Williams, D J; Watson, G W (1988) *The scale insects of the tropical South Pacific region. Part 1. The armoured scales (Diaspididae).* CAB International, Wallingford, UK 290pp

Zhou, C A; Zou, J J; Peng, J C (1993) Bionomics of coconut scale – a main pest on *Actinidia* and its control. *Entomological Knowledge* 30(1): 18-20

6. *Chrysomphalus* scales

6.1. Hazard identification

Aetiologic agent: *Chrysomphalus aonidum* Linnaeus (Hemiptera: Diaspididae)
Synonym: *Chrysomphalus ficus*

Aetiologic agent: *Chrysomphalus dictyospermi* Morgan (Hemiptera: Diaspididae)
Synonym: *Aspidiotus dictyospermi***,** *Chrysomphalus mangiferae*

Aetiologic agent: *Chrysomphalus propsimus* Banks (Hemiptera: Diaspididae)
Synonym: *Chrysomphalus calami*

New Zealand Status: Not known to be present in New Zealand (not recorded as present in Charles & Henderson 2002). *C. aonidum* was found in Auckland Domain nurseries in March 2004, but a containment programme appears to have successfully eradicated it. There have been no more collections of the scale since its eradication.

6.1.1. Biology of *C. aonidum*

Chrysomphalus aonidum is a polyphagous species with a preference for citrus, but has been recorded from hosts in 77 plant families, covering a range of crops, ornamentals, palms and forestry trees (Borschenius 1966). It has been associated with green coconuts in historical quarantine records in the U.S. since 1915 (Maskew 1915).
Reproduction is sexual (Mathis 1947) with females laying between 50-438 eggs (Klein 1937; Mathis 1947) over 1-13 weeks (De Toledo 1940; Mathis 1947; McClure 1990). Females infesting fruits were found to be more fecund than those on leaves (Mathis 1947; Rosen & DeBach 1978). There are two nymphal stages in female development before maturity. Males also undergo pupation after two nymphal stages (4 moults in total) to become winged adults (Mathis 1947). Egg to adult takes 7-16 weeks depending on temperature (De Toledo 1940).

Depending on environmental conditions between 2 and 9 generations have been recorded occurring annually from Taiwan, China, California, Brazil and New South Wales (De Toledo 1940; Mathis 1947; Cheng & Tao 1963; Gan *et al.* 1993; Smith *et al.* 1997; Gill 1997). Tropical conditions and heated glasshouses allow continuous breeding and asynchronous generations (CPC 2007). The optimal temperature for nymphal development was around 25˚C at a relative humidity of 70% (Andrade & Busoli, 2004).

Females tend to settle more on the lower surface of leaves, while males appear to prefer the top surface. Mathis (1947) looked at *C. aonidum* in Florida and found that of coccids on leaves 59% were females and 96% of the males and 13% of females were found on the upper surface. Some authors have suggested gravity and light may be factors affecting settling orientation for larvae. In investigations in Florida settled larvae were found as far as 48.3 cm from the mother scale on a citrus tree (Mathis 1947).

In a small scale study looking at the length of time adult females of *C. aonidum* could survive on picked citrus fruit or the peel of citrus, Schweig & Grunberg (1936) found that the death of full grown females on picked fruits occurred 3-4 weeks after picking. Oviposition started 30-35 days after picking. Larvae settled on fruits and died after the first month because the fruits decayed. On peels the adult females survived from 6-17 days. Further experimentation was undertaken to test whether fruits heaped underneath non-infested trees or peels scattered in a clean grove would provide a source of infection. Infestations only took place where tree branches came into contact with the soil and leaves and stems had direct contact with the fruit (Schweig & Grunberg 1936).

In early research into the biology of *Chysomphalus aonidum* in Jordan, Klein (1937) established 10.6ºC as a threshold temperature for development, although there is evidence that females can survive temperatures down to freezing point before death occurs (Mathis 1947). Numerous authors have reported the fact that freezing temperatures markedly reduce red scale populations (Thompson & Griffiths 1949).

6.1.2. Hosts of *C. aonidum*

C. aonidum prefers *Citrus* species, infesting mainly leaves but also fruits, stems and trunks, especially those on lower and central parts of mature trees. It has hosts recorded in 77 plant families, including crop, ornamental, palm and forestry species.
Major hosts include:
Citrus, *Citrus aurantiifolia* (lime), *Citrus limon* (lemon), *Citrus maxima* (pummelo), *Citrus sinensis* (navel orange), *Citrus x paradisi* (grapefruit).
Amongst the minor hosts are:
Asparagus officinalis (asparagus), *Camellia sinensis* (tea), *Carica papaya* (papaw), *Cinnamomum verum* (cinnamon), *Cocos nucifera* (coconut), *Dracaena*, *Gossypium* (cotton), *Lauraceae*, *Malus domestica* (apple), *Mangifera indica* (mango), *Musa* (banana), *Musa x paradisiaca* (plantain), *Phoenix dactylifera* (date-palm), *Pinus* (pines) (CPC 2007).

6.1.3. Distribution of *C. aonidum*

C. aonidum is found throughout Asia, the Middle East, Africa, Europe, parts of North America, throughout Central and South America. In the South Pacific it is found in Australia including Tasmania, American Samoa, Cook Islands, Caroline Is., Fiji, French Polynesia, Kiribati, New Caledonia, Niue, Papua New Guinea, Samoa, Solomon Is., and Tuvalu (Williams & Watson 1988; CPC 2007).

6.1.4. Biology of *C. dictyospermi*

C. dictyospermi is bisexual, ovoviviparous and is found on the upper side of leaves, on branches, twigs and fruits (Chkhaidze & Yasnosh 2001). It has been recorded in quarantine interception records on coconut in California from 1931 (Fleury 1931). Females have two nymphal stages and males like its congener *C. aonidum* develop into winged adults after a pupal stage (Williams & Watson 1988). Reproduction is sexual, although parthenogenetic populations have been noted in the USA (Brown 1965). The female, who lives for several months, lays 1-200 eggs beneath her scale (Chkhaidze & Yasnosh 2001). Crawlers develop for 10-15 days before the first moult, with the entire lifecycle completed in 91 days at 18ºC and 71 days at 25 ºC (Cabido-Garcia 1949).

Along the Black Sea Coast of Georgia *C. dictyospermi* has 2-3 generations annually without winter diapause (Chkhaidze & Yasnosh 2001). In Tunisia 3 generations were observed and the young adult females or first instar nymphs overwintered (Benassy & Soria 1964; Tuncyurek & Oncuer 1974). Three to four overlapping generations per year have been observed in California (Gill 1997), 2 in Egypt (Salama, 1970) and 3 in Turkey (Sureya 1933). Grown on *Ficus nitida* under local environmental conditions Salama (1970) found optimal temperatures for *C. dictyospermi* in Egypt were 22-25˚C with a mean relative humidity of 50-58%. Experiments conducted in Portugal (Cabido-Garcia 1949) determined the threshold temperature for development of the species was at 5.8 ºC. It is thought that females are more resistant to low temperatures (Chkhaidze 1984).

Larvae have a tendency to climb, especially if they happen to be on the trunk or lower branches, and if the lower portion of the foliage is infested, this is largely due to larvae falling from infested parts above. However larvae which fall to the ground perish (Del-Guebcio & Malenotti 1915). Early research in Sicily accounted the majority of dispersal events to be wind related. Branches isolated by rings of cotton from the infested portion of a plant were found to be infested after a certain time if the wind was blowing (Del-Guebcio & Malenotti 1915).

6.1.5. Hosts of *C. dictyospermi*

C. dictyospermi is found on many citrus species, feeding primarily on leaves, also fruit and occasionally branches (CPC 2007). A pest on *Citrus* and other species throughout the Pacific (Williams & Watson 1988), it is recorded on plants from 73 families.
Major hosts include:
Albizia julibrissin (silk tree), *Areca*, *Citrus* spp., *Cocos nucifera* (coconut), *Dracaena*, *Howea*, *Mangifera indica* (mango), *Musa* (banana), *Olea* (olive), *Persea americana* (avocado), *Plumeria* (frangipani), *Rosa* (roses), *Solanum melongena* (aubergine), *Syzygium malaccense* (malay-apple), *Taxus baccata* (English yew), *Zingiber* (ginger)

Minor hosts
Acacia (wattles), *Acer palmatum* (Japanese maple), *Agave*, *Aloe* (grey alder), *Annona*, *Araucaria angustifolia* (Paraná pine), *Artocarpus* (breadfruit trees), *Asparagus*, *Bambusa vulgaris* (common bamboo), *Buxus* (box), *Cactaceae* (cacti), *Camellia*, *Carica papaya* (papaw), *Cinnamomum*, *Colocasia*, *Crataegus* (hawthorns), *Cupressus macrocarpa* (Monterey cypress), *Cycas*, *Cymbidium*, *Cypripedium*, *Dendrobium*, *Dictyosperma*, *Diospyros* (malabar ebony), *Elaeis guineensis* (African oil palm), *Erythrina variegata* (Indian coral tree), *Eucalyptus* (Eucalyptus tree), *Eugenia*, *Euphorbia regis-jubae*, *Ficus*, *Fraxinus* (ashes), *Grevillea*, *Hedera* (Ivy), *Hibiscus syriacus* (shrubby althaea), *Howea forsteriana* (paradise palm), *Latania, Laurus* (laurel), *Ligustrum* (privet), *Macadamia tetraphylla* (rough-shell macadamia nut), *Malus* (ornamental species apple), *Manihot*, *Monstera deliciosa* (ceriman), *Morus* (mulberrytree), *Myristica* (nutmeg), *Nerium oleander* (oleander), *Opuntia cochinellifera*, *Pandanus graminifolia*, *Passiflora coerulea* (blue-crown passionflower), *Pelargonium* (pelargoniums), *Phoenix* (date palm), *Phormium*, *Pinus* (pines), *Pistacia, Pittosporum*, *Platanus* (plane tree), *Populus* spp. (poplars), *Prunus* spp.(stone fruit), *Psidium guajava* (guava), *Punica*, *Pyrus* (pears), *Quercus* (oaks), *Rhamnus* (Buckthorn), *Roystonea*, *Ruscus*, *Ruta* (rue), *Salix* (willows), *Sida*, *Sophora*, *Spondias* (purple mombin), *Strelitzia*, *Tamarindus*, *Thuja occidentalis* (Eastern white cedar), *Vanilla planifolia* (vanilla), *Vitis vinifera* (grapevine), *Xanthosoma* (cocoyam), *Yucca* (CPC 2008).

6.1.6. Distribution of *C. dictyospermi*

This scale probably originates from Southeast Asia (Danzig 1993) and is present throughout Asia, Africa, parts of the Middle East and Europe including southern Russia; USA, Central and South America. It is widespread in the South Pacific: Australia, Belau, Cook Is., Caroline Is., Fiji, French Polynesia, Guam, Kiribati, Marshall Is., New Caledonia, Niue, Northern Mariana Is., Papua New Guinea, Samoa, Solomon Is., Tonga, Tuvalu and Johnston Is (CPC 2007; Williams & Watson 1988).

6.1.7. Biology of *C. propsimus*

There is little information on the biology of *Chrysomphalus propsimus*. It is assumed to have life history and biological characteristics similar to its congeners *C. aonidum* and *C. dictyospermi*. It has been recorded on coconut coming from the Pacific Islands to New Zealand in interception records (QuanCargo Database 2008). In the literature it was first associated with coconut palm in the Philippines (Banks 1906; Wester 1918), but is usually found on leaves (McKenzie 1939).

6.1.8. Hosts of *C. propsimus*

There are only four known hosts for this scale insect all of which are palms, *Calamus spectabilis*, *Cocos nucifera*, *Corypha elata* and *Pandanus odoratissimum* (ScaleNet 2008).

6.1.9. Distribution of *C. propsimus*

It is found on various island groups in the Pacific including Hawaii, Kiribati, Tuvalu, Indonesia, Malaysia, Philippines and Jamaica (Williams & Watson 1988).

6.1.10. Hazard identification conclusion

Two of these scales have been recorded on coconut entering the country from other Pacific Islands in interception records, *C. aonidum* and *C. propsimus*. *Chrysomphalus dictyospermi* and *C. aonidum* are well known pests of coconut and many other plant species. They have low temperature thresholds for development are highly polyphagous and attack many plants of economic importance in New Zealand. These two species are considered hazards in this risk analysis.

C. propsimus has been recorded on four species of palm trees none of which occur in New Zealand. This restricted host range implies the scale would be unable to find suitable host material even if it did enter the country and is therefore unlikely to establish. The likelihood of it establishing on the native palm *Rhapalostylus sapida* (nikau) is considered negligible. Therefore *C. propsimus* is not considered further in this risk analysis.

6.2. Risk assessment

6.2.1. Entry assessment

In a small scale study looking at the length of time adult females of *C. aonidum* could survive on picked citrus fruit or the peel of citrus, Schweig & Grunberg (1936) found that the death of full grown females on picked fruits occurred 3-4 weeks after picking. On peels the adult females survived from 6-17 days (Schweig & Grunberg 1936).
Crawlers of *C. dictyospermi* develop for 10-15 days before the first moult, with the entire lifecycle completed in 91 days at 18ºC and 71 days at 25 ºC (Cabido-Garcia 1949). Both species have relatively high longevity, with the time of development and adult stages more than encompassing transit time of the commodity by ship to New Zealand. *C. aonidum* has been recorded in interception records on coconut coming from the Pacific in the past.

The likelihood of nymphal and adult stages of C. dictyospermi and D. aonidum entering the country on coconut are moderate to high respectively

6.2.2. Exposure assessment

Chrysomphalus dictyospermi has a very diverse host range within its established distribution. Plants attacked overseas which occur in New Zealand include: citrus, olives, avocado, roses, aubergine, *Acacia*, *Eucalyptus*, *Euphorbia*, *Ficus*, macadamia, passiflora, *Phormium*, pines, *Pittosporum*, *Prunus* sp., guava, pears, oaks, willows, *Sophora*, *Strelitzia* and grapes. It also attacks *Araucaria angustifolia* which is a member of the Araucariaceae of which there is a representative in New Zealand, the native kauri (*Agathis australis*). There would be no shortage of host material available year round were *C. dictyospermi* to enter the country. Although *Chrysomphalus aonidum* has less recorded hosts than its congener, the 4 species it attacks that occur in New Zealand, citrus, asparagus, apples and pine trees are widespread, and would provide adequate host material if *C. aonidum* was to enter New Zealand on the pathway.

6.2.3. Establishment assessment

While optimal temperature for nymphal development is around 25ºC for *C. aonidum* 10.6 ºC is the established threshold for development (Klein 1937). There is evidence that females can survive down to freezing before death occurs (Mathis 1947).
In Portugal experiments conducted to determine thermal thresholds for development of *C. dictyospermi* found 5.8 ºC as a lower limit (Cabido-Garcia 1949).
New Zealand regions most at risk from the establishment of permanent populations would be those where mean temperatures do not fall below 12°C. Using the Crosby *et al.* (1976) locality definitions and climate data of Gerlach (1974) and Anon (1983), these criteria are satisfied in parts of ND, AK, CL, WO, BP, GB, TK, NN, and small parts of HB, RI, WI and MC (Crosby *et al.* 1998 See Figure 2 Chapter 3).

The likelihood of exposure and establishment for both C. aonidum and C. dictyospermi is moderate to high.

6.2.4. Consequence assessment

6.2.4.1. Economic

In Poland *Chrysomphalus aonidum* which is regularly imported on decorative pot plants spreads quickly in commercial greenhouses and causes damage to a variety of ornamentals (Abanowski 1999). The adoption of *C. aonidum* to its food plants in Palestine was found to vary greatly among plant species and was influenced by climatic and geographic conditions (Schweig & Grunberg 1936). It is the most injurious coccid attacking citrus in Egypt (Priesner 1931) and this is the most likely group of species it would affect were it to establish in New Zealand.

Chrysomphalus dictyospermi has a much broader host range than *C. aonidum*, and could attack species of significant commercial value in New Zealand such as Pines, *Prunus* spp., *Pyrus* spp, grapes, avocado and citrus. *C. dictyospermi* is widely distributed and occasionally causes serious damage to avocado in Florida. Young trees seem to be more severely attacked than old ones, and some varieties more than others (Wolfenbarger 1951). Like *C. aonidum* it also causes damage to citrus species (Del-Guebcio & Malenotti 1915).

6.2.4.2. Environmental

There are several genera which are infested by *C. dictyospermi* within its native and introduced host range which have representatives in the New Zealand flora. *Pittosporum*, *Sophora*, *Phormium*, *Passiflora*, *Euphorbia* and *Solanum*. Also an *Araucaria*, *A. angustifolia* which is related to the species of kauri *Agathis australis* that grows in northern North Island. Members of *Phormium*, *Sophora* and *Pittosporum* are common garden plants found widely in

both Islands. Amenity plantings of *Phormium*, *Sophora* and *Pittosporum* are found in many cities.
Solanum aviculare and *S. laciniatum* are 2 of 3 native solanums traditionally used as food and for medicinal purposes by Maori. The ripe berries which grow up to 2cm long are eaten, and the unripe berries are a source of steroids utilised in the pharmaceutical industry (Brooker *et al.* 1991). *S. aviculare* is also used as a rootstock for grafting eggplant (*Solanum melongena*).

It would be easy for both species to come into contact with and establish harmful populations on any of the abovementioned genera. *Passiflora tetranda* the native passionvine, is restricted to native forests, and is not grown in cultivation. *Euphorbia glauca*, the native shore spurge inhabits coastal environments preferring coarse sand or fine shingle. Because of their restriction to forest and coastal habitats it is unlikely *P. tetranda* or *E. glauca* would be affected by the establishment of either *Chrysomphalus*.

The consequences of establishment of C. aonidum and C. dictyospermi are likely to be moderate to high

6.2.5. Risk estimation

The likelihood of *C. aonidum* and *C. dictyospermi* entering the country is high, exposure and establishment are moderate to high and consequences of establishment are also moderate to high.

As a result the risk estimate for C. aonidum and C. dictyospermum is non-negligible and they are classified as hazards on the commodity. Therefore risk management measures can be justified.

6.3. Risk management

6.3.1. Options

Pest management systems in coconut stands, screening measures and pre export visual inspection are considered to be included with each disinfestation treatment option given below.

Green coconut

Option 1. Scrubbing and washing of fruit surface after removal of calyx and waxing the cut surface immediately, following good hygiene practice to prevent recontamination, and then cold storage of coconuts in transit

Option 2. Remove calyx, peeling skin of the fruit and waxing cut surface, followed with good hygiene practice to prevent recontamination, and cold storage of coconuts in transit.

Brown coconut

Option 1. De-husking, following good hygiene practice to prevent recontamination, and cold storage of coconuts in transit

Option 2. De-husking, waxing of ‘eye’ region, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit

Coconut apple

Option 1. De-husking, cutting off shoot and root material, waxing of cut surfaces, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

Option 2. De-husking, cutting off shoot and root material, waxing of whole coconut, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

6.4. Assessment of uncertainty

There is some uncertainty around the potential for either species to host switch and attack members of genera overseas which have native representatives in the New Zealand flora.

6.5. References for chapter 6

Abanowski, G (1999) Scale insects – dangerous pests of Dracaena. *Ochrona Roslin* 43(6): 14-15. In Polish

Andrade, L de L; Busoli, A C (2004) Influence of temperature on the duration of nymph period of the *Chrysomphalus aonidum* (Hemiptera: Diaspididae) reared on "cabotia squash". *Arquivos do Instituto Biologico Sao Paulo* 71(Suplemento RAIB): 195-197

Anon (1983) Summaries of Climatological Observations to 1980. *New Zealand Meteorological Service Miscellaneous publication* 177. pp 172

Banks, C S (1906) New Philippine Insects. *Philippine Journal of Science* 1: 229-236

Bernassy, C; Soria, F (1964) Ecological observations on the Diaspine Coccids injurious to citrus in Tunisia. *Annals of the Institute of National Research, Agronomie Tunisie* 37(pt. 3): 193-221

Borschenius, N S (1966) *A Catalogue of the Armoured Scale Insects (Diaspididae) of the World.* 'Nauka' Moscow, Leningrad 449pp

Brooker, S G; Cambie, R C; Cooper, R C (1991) *Economic native plants of New Zealand*. Oxford University Press

Brown, S W (1965) Chromosomal survey of the armoured and palm scale insects (Coccoidea: Diaspididae and Phoenicococcidae). *Hilgardia* 36(5): 189-294

Cabido-Garcia, R (1949) A contribution to the study of the systematics, morphology, biology and ecology of the yellow scale (*Chrysomphalus dictyospermi*). *Bolletin Jta. Nac. Frutas* 9(3): 374-465

Charles, J; Henderson, R C (2002) Catalogue of the exotic armoured scale insects (Hemiptera: Coccoidea: Diaspididae) in New Zealand. *Journal of the Royal Society of New Zealand* 32(4): 587-615

Cheng, C H; Tao, C C C (1963) Florida red scale, *Chrysomphalus ficus* Ashmead. *Plant Protection Bulletin: Taiwan* 5(3): 313-322

Chkhaidze, L (1984) *Criterium establishment of the expedience of conducting the exterminated measures against* Chrysomphalus dictyospermi *on Citrus plants (*in Russian) Report thesis of the XI Session of the Caucasus Council on the Work Coordination of Plant Protection Everan: 161-162

Chkhaidze, L; Yasnosh, V (2001) The Dictyospermum scale *Chrysomphalus dictyospermi* (Morgan) (Coccinea: Diaspididae), pest of fruit and ornamental plants in the Black Sea coast of Georgia: a review. *Bolletino di Zoologia Agraria e de Bachicoltura* 33(3): 495-499

CPC (2007) Crop Protection Compendium, *Chrysomphalus dictyospermi* http://www.cabicompendium.org/cpc/report.asp?CCODE=CHYSDI&criteria=T/HO1

Crosby, T K; Dugdale, J S; Watt, J C (1976) Recording specimen localities in New Zealand: an arbitrary system of areas and codes defined. *New Zealand Journal of Zoology* 3: 69

Crosby, T K; Dugdale, J S; Watt, J C (1998) Area codes for recording specimen localities in the New Zealand subregion. *New Zealand Journal of Zoology* 25: 175-183

Danzig, E (1993) Fauna of Russia and neighbouring countries. *Rhynchota, X Scale insects (Coccinea)* (in Russian) Nauka, St Petersburg 1-452

Del-Guebcio, G; Malenotti, E (1915) Researches and new experiments against *Chrysomphalus dictyospermi*, Morg. In Sicily in 1914. *Redia* 11: 1-126

De Toledo, A A (1940) Notes on the biology of *C.ficus* Ashm, in Sao Paulo. *Arq Inst Biol* 11: 559-578

Fleury, A C (1931) Plant Quarantine Service. *Monthly Bulletin of the Department of Agriculture California* 19(12): 811-831

Gan, Z Y; Liu, X Q; Zhang, S J (1993) Occurrence and forecasting of the orange brown scale, *Chrysomphalus aonidum* (L.) *Entomological Knowledge* 30(6): 347-348

Gerlach, J C (1974) Climatographs of New Zealand. *Ruakura Agricultural Research Centre. Hamilton, Research Bulletin* 74:1

Gill, R J (1997) *The scale insects of California. Part 3. The armored scales (Homoptera: Coccoidea: Coccidae).* Technical series in Agriculture Biosystematics and Plant Pathology. No 3. California Department of Food and Agriculture, Sacramento, California, USA 307pp

Klein, H Z (1937) On the biology of the black scale *Chrysomphalus aonidum* L. in the Jordan Valley. *Bulleting of Agricultural Research Station Rehovoth january* 23(18): 6

Maskew, F (1915) *Quarantine Division; Report for the Month of March 1915.* Monthly Bulletin of the State Commission for Horticulture 4(5): 287-289

Mathis, W (1947) Biology of the Florida Red Scale in Florida. *Florida Entomologist* 29(2-3); 13, 15-35

McClure, M S (1990) 1.4.6. Influence of environmental factors pp319-330 in Rosen, D (ed) *Armoured scale insects, their biology, natural enemies and control.* Vol 4A World crop pests, Elsevier, Amsterdam, The Netherlands

McKenzie, H L (1939) A revision of the genus *Chrysomphalus* and supplementary notes on the genus *Aonidiella* (Homoptera: Coccoidea: Diaspididae). *Microentomology* 4: 51-77

Priesner, H (1931) On the biology of *Chrysomphalus ficus* Ril (Hemiptera: Coccidae) with suggestions on the control of this species in Egypt. *Egypt Ministry of Agriculture Bulletin* 117: 1-19

QuanCargo Database (2008) *Interception Record Database*. Ministry of Agriculture and Forestry

Rosen, D; DeBach, P (1978) Diaspididae. In Clausen CP (ed) *Introduced parasites and predators of arthropod pests and weeds: a world review.* United States Department of Agriculture. Agricultural Handbook No. 480: 78-128

Salama, H S (1970) Ecological studies of the scale insect *Chrysomphalus dictyospermi* (Morgan) in Egypt. *Zeitschift für Angewandte Entomologie* 65: 427-430

ScaleNet (2008) *Chrysomphalus* spp. Arthropods of Economic Importance http://nlbif.eti.uva.nl/bis/diaspididae.php?selected=beschrijving&menuentry=soorten&id=102

Sureya, M (1933) Turkey: Plant Enemies observed in Anatolia during 1933. *International Bulletin of Plant Protection* 7(11): 247-248

Schweig C & Grunberg A (1936) The problem of the black scale (*Chrysomphalus ficus* Ashm.) in Palestine. *Bulletin of Entomological Research* 26: 677-717

Smith, D; Beattie, G A C; Broadley, R (eds) (1997) *Citrus Pests and their Natural Enemies: integrated pest management in Australia.* Queensland Department of Primary Industries QL97001, ISSN 0727-6273

Thompson, W L; Griffiths, Jr. (1949) Purple Scale and Florida Red Scale as Insect Pests of Citrus in Florida. *Bulletin of the Florida Experimental Agricultural Station* 462: 5-40

Tuncyurek, M; Oncuer, C (1974) Studies on Aphelenid parasites and their hosts, *Citrus* Diaspine scale insects in citrus orchards in the Aegean region. *Bulletin SROP (Section Regionale Ouest Palearctique)* 3: 95-108

Wester, P J (1918) The coconut, its culture, and uses. *Philippine Agricultural Review* 11(1): 5-57

Williams, D J; Watson, G W (1988) In *The scale insects of the tropical south Paciific region. Part 1. The armoured scales (Diaspididae)* CAB international Institute of Entomology London

Wolfenbarger, D O (1951) *Dictyospermum* scale control on avocados. *Florida Entomologist* 34(2): 54-58

7. Pineapple/ *Dysmicoccus* mealybugs

7.1. Hazard identification

Scientific name: *Dysmicoccus boninsis* (Kuwana) (Hemiptera: Pseudococcidae)
Synonyms: *Dactylopius boninsis, Pseudococcus boninensis, Pseudococcus heterospinus, Pseudococcus aegyptiacus, Trionymus boninsis, Trionymus taiwanus, Erium boninense, Erium taiwanum, pseudococcus zeae, Trionymus kayashimai, Vryburgia graminae, Dysmicoccus boniansis*

Scientific name: *Dysmicoccus brevipes* (Cockerell) (Hemiptera: Pseudococcidae)
Synonyms: *Dactylopius* (*Pseudococcus*) *ananassae*, *Dactylopius brevipes, Dysmicoccus brevipes, Pseudococcus brevipes*; *Pseudococcus cannae*, *Pseudococcus defluiteri, Pseudococcus longirostralis, Pseudococcus missionum, Pseudococcus palauensis*, *Pseudococcus pseudobrevipes* (Ben-Dov *et al.* 2008).

New Zealand Status: Not present in New Zealand (not recorded in Cox 1987; PPIN 2008). An adult *Dysmicoccus brevipes* was found in a plum orchard in Auckland in November 1997, but a subsequent survey in 1998 did not detect the Pseudococcid. This suggests that it either failed to establish or that populations are currently below detectable levels on host crops (Richmond & Crowley 1998) No further records have been collected of the mealybug in New Zealand since 1997.
D. boninsis is erroneously recorded as being present in New Zealand in Ben-Dov *et al.* (2008) quoting Kirkaldy (1909). Kirkaldy's publication reviews the hemipteran fauna of Hawaii, not New Zealand, and Cox (1987) in his review of the Pseudococcids of New Zealand does not include this species as present here.

7.1.1. Biology of *D. boninsis*

Dysmicoccus boninsis is common wherever sugarcane is grown, but is also found on a wide range of other grass species. The records on *Cocos nucifera* and *Pandanus* are unusual but not unlikely (Williams & Watson 1988). The authors do not state what part of the plant the mealybug occurs on. It is recorded on roots of *Panicum maximum* and *Sorghum halapense*, in soil under *Saccharum officinarum* (Williams & Watson 1988) and deep under leaf sheaths of sugarcane (*S. officinarum*) (Trjapitzin 2005). It is assumed to attack leaves, roots and stems. There is no record of it infesting fruit of any plant host. There is little information on the biology of this species. It is assumed to have a similar life cycle to its congener *D. brevipes*.

7.1.2. Hosts of *D. boninsis*

D. boninsis is most commonly found on sugarcane, and a variety of other grasses. Hosts include:
Canna sp., *Ipomea* sp., *Juniperus* sp., *Brachairia mutica*, *Coix lacryma*, *Cortadaria argentata*, *Cymbopogon citratus*, *Cynodon dactylon*, *Echinochloa colonum*, *Eragrostis variabilis, Gynerium saggitatum*, *Lasiacis divaricata*, *Miscanthus* sp., *Oryza sativa*, *Panicum barbinode*, *Panicum maximum*, *Paspalum distinchum*, *Saccharum arundinaceum*, *Sorghum halapense*, *Sorghum verticilliflorum*, *Stenotaphrum secundatum*, *Syntherisma sanguinalis*, *Thysanolaena agrostis*, *Tripsacum* sp., *Zea mays*, *Iris* sp., *Sisyrinchium* sp., *Cocos nucifiera*, *Pandanus* sp., *Citrus* sp., *Ciccus rombifolia* (Ben-Dov *et al.* 2008).

7.1.3. Distribution of *D. boninsis*

It occurs throughout the Americas, in Sicily, Iran, Egypt, China, Afghanistan, Taiwan, Singapore, Malaysia, Indonesia, South Africa and is widespread in the Pacific including Western Samoa, Tuvalu, Tonga, Palau, Niue, New Caledonia, Guam, Federated States of Micronesia, Fiji and Australia (Ben-Dov *et al.* 2008).

7.1.4. Biology of *D. brevipes*

Dysmicoccus brevipes is a widespread pest in the Pacific region and has been recorded inside the perianth of immature coconuts (Bindhu-Radhakrishnan *et al.* 2003) as well as in interception records from mature coconut entering New Zealand (QuanCargo Database 2008). There are references to both parthenogenetic ovoviviparous (eggs hatch within the body, then live young are born) (Ghose 1983) and bisexual sexually reproducing races in the literature (Lim 1973). Colonies of the mealybug can develop arboreally on host plants or in large subterranean colonies as observed in pineapple fields in Hawaii (Carter 1960).

Females have 3 nymphal instars, reaching maturity in about 19-25 days (Lim 1973; Ghose 1983). Males have 2 nymphal, a prepupal and a pupal stage, maturing at around 22 days (Lim 1973). Up to 240 eggs are laid over a 9-40 day period, with females dying 3-5 days after oviposition (Real 1959; Lim 1973; Ghose 1983). The entire life cycle of adults is between 1-49 days (Real 1959; Lim 1973). In studies looking at the effects of temperature on development of *D. brevipes* in Brazil, Colen and others (2000) found that development was not completed at 35 ºC. Thermal thresholds for first and second instar and pupal life stages were 12.1 ºC, 13.5 ºC and 12.8 ºC respectively (Colen *et al.* 2000). Its occurrence was closely related to heavy rainfall in China, which could reduce its harmfulness (Yang & Yi 1998).

D. brevipes is a known vector of at least 4 wilt associated viruses on pineapple crops (Gambley *et al.* 2008). Ant species attending the mealybug (which produces copious amounts of honeydew; Pandey & Johnson 2006) play a major role in the build up of the mealybug colonies and thereby of the pathogen. Ant species from the following genera have been observed transporting or tending mealybugs; *Camponotus*, *Pheidole*, *Crematogaster*, *Solenopsis* (Real 1959; Mau & Martin-Kessing 1992). Investigations into reduction of the wilt diseases emphasise minimising ant numbers and removal of weeds between crop rows (Sulaiman 2000).

7.1.5. Hosts of *D. brevipes*

D. brevipes can occur on the foliage, stems, fruit and roots (Hargreaves 1929; Berry & Abrego 1953; Bindhu-Radhakrishnan *et al.* 2003). This species is highly polyphagous and is recorded from more than 100 genera in 53 families including :
Anacardium occidentale (cashew nut), *Ananas comosus* (pineapple), *Annona muricata* (soursop), *Annona squamosa* (sugarapple), *Apium graveolens* (celery), *Arachis hypogaea* (groundnut), *Brassica rapa subsp. chinensis* (Chinese cabbage), *Canna indica* (Queensland arrowroot), *Capsicum* (peppers), *Casuarina equisetifolia* (casuarina), *Citrus*, *Cocos nucifera* (coconut), *Coffea arabica* (arabica coffee), *Colocasia esculenta* (taro), *Cucumis sativus* (cucumber), *Cucurbita* (pumpkin), *Daucus carota* (carrot), *Elaeis guineensis* (African oil palm), *Ficus*, *Gossypium* (cotton), *Hibiscus* (rosemallows), *Ipomoea batatas* (sweet potato), *Malus domestica* (apple), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Medicago sativa* (lucerne), *Musa* (banana), Orchids, *Persea americana* (avocado), *Phoenix dactylifera* (date-palm), *Piper betle* (betel pepper), *Poaceae* (grasses), *Psidium guajava* (guava), *Saccharum officinarum* (sugarcane), *Solanum tuberosum* (potato), *Sorghum halepense*

(Johnson grass), *Theobroma cacao* (cocoa), *Trifolium pratense* (purple clover), *Trifolium repens* (white clover), *Zea mays* (maize), *Zingiber officinale* (ginger) (CPC 2008).

7.1.6. Distribution of *D. brevipes*

D. brevipes is found worldwide in tropical and subtropical zones. In Oceania it is found in American Samoa, Australia, Belau, Caroline Is., Cook Is., Fiji, French Polynesia, Guam, Irian Jaya, Kiribati, Marshall Is., New Caledonia, Niue, Northern Mariana Is., Papua New Guinea, Samoa, Solomon Is., Tokelau, Tonga, Tuvalu, and Vanuatu (Williams and Watson 1988; Ben-Dov 1994).

7.1.7. Hazard identification conclusion

Dysmicoccus boninsis is commonly found on sugarcane and other grasses, on roots, in soil and in foliage. There is no evidence the mealybug attacks fruit. It has not been recorded anywhere in the literature attacking the coconut itself, and is not represented in interception records. It is thought unlikely that it would crawl off host grasses onto coconuts left on the ground before harvest. Therefore there is a negligible likelihood *D. boninsis* will be associated with the commodity and is not considered a hazard in this analysis.

Dysmicoccus brevipes, shows a clear association with the commodity, is highly polyphagous and a major vector of wilt associated viruses on pineapple crops. It also has a relatively long life cycle and low thermal thresholds for development. For these reasons *D. brevipes* is considered a potential hazard on the pathway.

7.2. Risk assessment

7.2.1.1. Entry assessment

The lifecycle of the mealybug means the nymphs and adults could be associated with the coconut when it is harvested. It has been found in the perianth of immature coconuts (Bindhu-Radhakrishnan *et al.* 2003) as well as in interception records from mature coconut entering New Zealand (QuanCargo Database 2008). Female nymphs of *D. brevipes* take between 19-25 days to reach maturity, with the total adult lifecycle lasting between 1-49 days. Females die 3-5 days after oviposition (Real 1959; Lim 1973; Ghose 1983). This developmental time would more than encompass transport time of coconuts to New Zealand by ship from Tuvalu.

The likelihood of D. brevipes *entering the country on the commodity is moderate to high.*

7.2.1.2. Exposure assessment

There would be no shortage of host material available all year round if *D. brevipes* was to enter the country. Many horticultural plants including celery, capsicum, citrus, taro, pumpkin, cucumber, carrot, avocado, guava, potato, clover and maize are widely grown in North Island, and to a lesser extent parts of South Island New Zealand.

7.2.1.3. Establishment assessment

Experiments looking at temperature tolerances of *D. brevipes* were carried out in Brazil (Colen *et al.* 2000). Development was not completed at 35ºC. Lower thermal thresholds for first and second instar and pupal life stages were 12.1 ºC, 13.5 ºC and 12.8 ºC respectively. New Zealand regions most at risk from the establishment of permanent populations would be those where mean temperatures do not fall below 12°C. Using the Crosby *et al.* (1976) locality definitions and climate data of Gerlach (1974) and Anon (1983), these criteria are satisfied in parts of ND, AK, CL, WO, BP, GB, TK, NN, and small parts of HB, RI, WI and MC (Crosby *et al.* 1998 See Figure 2 Chapter 3).

The likelihood of exposure and establishment for D. brevipes are moderate to high.

7.2.2. Consequence assessment

7.2.2.1. Economic

This is one of the most economically important mealybug pests in Hawaii because it vectors diseases of pineapple. Pineapple wilt, or mealybug wilt, causes the most serious type of damage and is the principal cause of crop failure in Hawaii. Pineapple wilt has also been called "edge wilt" because the margins of the field are affected first and the infection moves inward as the mealybug infestation disperses inwards. This disease has been controlled for the last 3 decades by routine ant control. However, it may once again become prevalent if mealybugs are not continually suppressed by limiting ant populations (Mau & Martin-Kessing 1992).

If it were to establish in New Zealand, many horticultural and ornamental plant species would be impacted.

7.2.2.2. Environmental

There appear to be no species attacked overseas which have native representatives in the New Zealand flora. It is unknown the potential *D. brevipes* may have for host switching.

The likelihood of economic consequences due to the establishment of D. brevipes is therefore moderate.

7.2.3. Risk estimation

The likelihood of entry for *D. brevipes* is moderate to high, exposure high and establishment moderate. Consequences of establishment are likely to be moderate also.

As a result the risk estimate for D. brevipes is non-negligible and it is classified as a hazard on the commodity. Therefore risk management measures can be justified.

7.3. Risk management

7.3.1. Options

Pest management systems in coconut stands, screening measures and pre export visual inspection are considered to be included with each disinfestation treatment option given below.

Green coconut

Option 1. Scrubbing and washing of fruit surface after removal of calyx and waxing the cut surface immediately, following good hygiene practice to prevent recontamination, and then cold storage of coconuts in transit

Option 2. Remove calyx, peeling skin of the fruit and waxing cut surface, followed with good hygiene practice to prevent recontamination, and cold storage of coconuts in transit.

Brown coconut

Option 1. De-husking, following good hygiene practice to prevent recontamination, and cold storage of coconuts in transit

Option 2. De-husking, waxing of 'eye' region, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit

Coconut apple

Option 1. De-husking, cutting off shoot and root material, waxing of cut surfaces, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

Option 2. De-husking, cutting off shoot and root material, waxing of whole coconut, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

7.4. Assessment of uncertainty

The potential for *D. brevipes* to host switch and attack native plants is unknown.

7.5. References for chapter 7

Anon (1983) Summaries of Climatological Observations to 1980. *New Zealand Meteorological Service Miscellaneous publication* 177. pp 172

Ben-Dov, Y (1994) *A systematic catalogue of the mealybugs of the world (Insecta catalogues: Homoptera: Coccoidea: Pseudococcidae and Putoidea) with data on geographical distribution, host plants, biology and economic importance.* Intercept Limited, Andover, UK 686pp

Ben-Dov, Y; Miller, D R; Gibson, G A P (2008) *Dysmicoccus brevipes*. Distribution Query. *ScaleNet.* http://www.sel.barc.usda.gov/scalenet/scalenet.htm

Berry, P A; Abrego, L (2003) Insects and Diseases affecting some crops in El Salvador. *FAO Plant Protection Bulletin* 1(10): 151-153

Bindhu-Radhakrishnan, Mathew, T B; Premila, K S; Priya-Mohan (2003) New report of mealybugs occurring inside the perianth of immature nuts in coconut. *Insect Environment* 9(2): 53-54

Carter, W (1960) A study of mealybug populations (*Dysmicoccus brevipes* (Cockerell)) in an ant free field. *Journal of Economic Entomology* 53(2): 296-299

Colen, K G F; Santa-Cecilia, L C V; Moraes, J C; Reis, P R (2000) Effects of temperature upon the biology of the mealybug *Dysmicoccus brevipes* (Cockerell) (Hemiptera: Pseudococcidae). *Revista Brasileira de Fruticultura* 22(2): 248-252

Cox, J M (1987) Pseudococcidae (Insecta: Hemiptera). *Fauna of New Zealand* 11

CPC (2008) Crop Protection Compendium, *Dysmicoccus brevipes* hosts
http://www.cabicompendium.org/cpc/report.asp?CCODE=DYSMBR&criteria=T/HO1

Crosby, T K; Dugdale, J S; Watt, J C (1976) Recording specimen localities in New Zealand: an arbitrary system of areas and codes defined. *New Zealand Journal of Zoology* 3: 69

Crosby, T K; Dugdale, J S; Watt, J C (1998) Area codes for recording specimen localities in the New Zealand subregion. *New Zealand Journal of Zoology* 25: 175-183

Gambley, C F; Steele, V; Geering, A D W; Thomas, J E (2008) The genetic diversity of ampleoviruses in Australian pineapples and their association with mealybug wilt disease. *Australasian Plant Pathology* 37(2): 95-105

Gerlach, J C (1974) Climatographs of New Zealand. *Ruakura Agricultural Research Centre. Hamilton, Research Bulletin* 74:1

Ghose, S K (1983) Biology of parthenogenetic race of *Dysmicoccus brevipes* (Cockerell) (Pseudococcidae: Hemiptera). *Indian Journal of Agricultural Sciences* 53(11): 939-942

Hargreaves, E (1929) *Report on the Entomological Section. Section 1*. Report for Lands and Forestry Department Sierre Leone 20-22

Kirkaldy, G W (1909) Catalogue of the Hemiptera (Heteroptera) with biological and anatomical references, lists of foodplants and parasites, etc. Prefaced by a discussion on nomenclature, and an analytical table of families. *Cimicidae Berlin* : Felix L. Dames Vol. 1 xl 392 pp

Lim, W H (1973) Studies on the bisexual race of *Dysmicoccus brevipes* (Cockerell): its bionomics and economic importance. *Malaysian Agricultural Journal* 49(2): 254-267

Mau, R F L; Martin-Kessing, M J L (1992) *Dysmicoccus brevipes* (Cockerell), Pineapple mealybug. *Crop Knowledge Master*.
http://www.extento.hawaii.edu/kbase/crop/Type/d_brevip.htm

Pandey, R R; Johnson, M W (2006) Enhanced production of pink pineapple mealybug *Dysmicoccus brevipes* (Hemiptera: Pseudococcidae). *Biocontrol Science and Technology* 16(3/4): 389-401

PPIN (2008) *Plant Pest Information Network*. Database for the Ministry of Agriculture and Forestry, New Zealand

QuanCargo Database (2007) *Interception Record Database*. Ministry of Agriculture and Forestry

Real, P (1959) Le oyole annuel de la cochenille *Dysmicoccus brevipes* Cockerell vectrice d'un "wilt" de l'ananas en basse Cote d'Ivoire; son determinisme. *Review Path Veg*. 38: 3-111

Richmond, J E; Crowley, J M (1998) Pineapple mealybug in New Zealand? *Orchardist* 71(7): 71

Sulaiman, S F M (2000) Implications of the use of excess of coir dust mulch in pineapple cultivation on the mealybug wilt disease of pineapple. *Acta Horticulturae* (529): 221-235

Trjapitzin, V A (2005) A review of species of the genus *Anagyrus* Howard (Hymenoptera : Chalcidoidea : Encyrtidae) of the world with long ovipositor sheaths. *Entomologicheskoe Obozrenie* 84(1) : 209-214

Williams, D J; Watson, G W (1988) *The scale insects of the tropical South Pacific region. Part 2. The Mealybugs (Pseduococcidae).* CAB International Institute of Entomology, Wallingford, UK. Pp 51

Yang, F R ; Yi, L E (1998) The occurrence regularity and contorl of pineapple powdery scale. *South China Fruits* 27(5): 28-29

8. Guava/Striped mealybug

8.1. Hazard identification

Scientific name: *Ferrisia virgata* (Cockerell) (Hemiptera: Pseudococcidae)

Synonyms: *Dactylopius segregatus*, *Dactylopius virgatus, Dactylopius virgatus farinosus, Dactylopius virgatus humilis*, *Dactylopius ceriferus, Dactylopius talini,Dactylopius dasylirii, Dactylopius setosus, Pseudococcus virgatus, Dactylopius magnolicida*, *Pseudococcus magnolicida, Pseudococcus virgatus farinosus, Pseudococcus dasylirii, Pseudococcus segregatus, Pseudococcus virgatus humilis*, *Dactylopius virgatus madagascariensis, Pseudococcus marchali, Pseudococcus virgatus madagascariensis, Pseudococcus bicaudatus, Ferrisia virgata, Ferrisiana virgata, Heliococcus malvastrus, Ferrisiana setosus, Ferrisia neovirgata, Dactylopius cerciferus* (Ben-Dov *et al.* 2005).

New Zealand Status: Not known to be present in New Zealand (not recorded in Cox 1987; NZBugs 2006; PPIN 2008).

8.1.1. Biology

Ferrisia virgata is now recognized as a species complex (Gullen 2003) and has been easily confused with related species particularly with *Ferrisia malvastra* in India where both species occur (CPC 2006). Slide-mounted preparations are needed for examination. Descriptions and illustrations prior to 1980 appear to contain a combination of the diagnostic characters of both *F. virgata* and *F. malvastra*. Willink (1991) and Williams (1996) both separate or synonymise species from the complex and clarify the taxonomy. It is recorded as a pest of coconut in neotropical regions (Williams & Granara de Willink 1992) although is not specifically associated with the nut in the literature.

F. virgata is biparental, and in India, can produce several overlapping generations a year (Nayer *et al.* 1976), while three generations have been observed in Saudi Arabia (Ammar *et al.* 1979). It feeds on leaves, twigs, inflorescences and fruit peduncles of cashew in India (Ikisan 2000). In laboratory experiments in Iraq Awadallah and others (1979) observed eggs were laid singly, and total duration of the nymphal stage in females averaged 43.2 days at 28.9°C and 92.6 days at 16.6°C while in males it averaged 25.4 days at 25-26.5°C. Females lived longer in general than male *F. virgata* with total life span from egg stage to end of adult stage averaging 76.2-154.6 days in females as opposed to 19-47 days in males (Awadallah *et al.* 1979).

The adult female overwinters in cracks and junctions of trunks and large branches and on fallen leaves. In the laboratory females migrated to the soil in winter (Ammar *et al.* 1979). In a study in Saudi Arabia a significant positive correlation was found between population density and daily maximum and minimum temperatures, but not between population density and relative humidity (Ammar *et al.* 1979).

8.1.1.1. *Ferrisia virgata* as a vector

Two distinct virus strains transmissible by *F. virgata* infect cacao in tropical Central America and Africa; cocoa swollen shoot virus (CSSV), in West Africa and cocoa Trinidad virus (CTV, Diego Martin valley isolate) in Trinidad (Ollenu 2001). There is also a badnavirus associated with black pepper transmitted by *F. virgata* in India (Bhat *et al*. 2003) which shows a positive serological relationship with Banana streak virus (BSV) and Sugarcane bacilliform virus (ScBV). Cacao and black pepper are not grown in Tuvalu, and these viruses are not known to be present there (Dabek 1998).

8.1.2. Hosts

Ferrisia virgata is one of the most highly polyphagous mealybugs known, attacking plant species belonging to some 150 genera in 68 families. Many of the host species belong to the Leguminosae and Euphorbiaceae (CPC 2006).

Among the more important host plants are: *Abelmoschus esculentus* (okra), *Acalypha* (Copperleaf), *Anacardium occidentale* (cashew nut), *Ananas comosus* (pineapple), *Annona*, *Cajanus cajan* (pigeon pea), *Carica papaya* (papaw), *Citrus*, *Coccoloba uvifera* (seaside grape), *Cocos nucifera* (coconut), *Codiaeum variegatum* (croton), *Coffea* spp.(coffee), *Colocasia esculenta* (taro), *Corchorus* (jutes), *Cucurbita maxima* (giant pumpkin), *Cucurbita pepo* (ornamental gourd), *Dracaena* spp., *Elaeis guineensis* (African oil palm), *Ficus* spp., *Gossypium* spp. (cotton), *Ipomoea batatas* (sweet potato), *Leucaena leucocephala* (leucaena) (CPC 2006).

Litchi chinensis (litchi), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Manilkara* spp., *Musa* spp. (banana), *Nicotiana tabacum* (tobacco), *Phaseolus* spp. (beans), *Phoenix dactylifera* (date-palm), *Piper betle* (betel pepper), *Piper nigrum* (black pepper), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Solanum melongena* (aubergine), *Solanum nigrum* (black nightshade), *Theobroma cacao* (cocoa), *Vigna unguiculata* (cowpea), *Vitis vinifera* (grapevine), *Zingiber officinale* (ginger). Lesser hosts include: *Arachis hypogaea* (groundnut), *Hibiscus* spp. (rosemallows), *Malpighia glabra* (acerola), *Persea americana* (avocado), *Saccharum officinarum* (sugarcane) and *Zea mays* (maize) (CPC 2006).

8.1.3. Distribution

F. virgata is cosmopolitan in distribution, found throughout Africa, Asia and the Americas, and is widespread in the Pacific including Australia. Europe and New Zealand are two of the few areas unaffected by the pest (CPC 2006).

8.1.4. Hazard identification conclusion

F. virgata is a widespread and serious pest of many crops throughout the tropical and subtropical regions of the world. It has the capacity to produce several generations per year, and is a vector of a badnavirus that affects black pepper, which is from the Piperaceae family that has 3 representatives in New Zealand. As a result of its ecology, its longevity and overwintering capacity *F. virgata* is considered a potential hazard in this risk analysis.

8.2. Risk assessment

8.2.1. Entry assessment

There have been no previous interceptions at the border of *Ferrisia virgata* on coconut coming from other Pacific Islands. It is likely to be associated with coconuts either directly or as a hitchhiker species. The life cycle averages from 24 days to 155, easily encompassing the transit time from Australia to New Zealand. Mealybugs are attached to their hosts very firmly, making the effect of mechanical or chemical control hard to evaluate, due to the remaining presence of dead individuals. It is unlikely that *F. virgata* would transmit any viruses here given that none of the three viruses mentioned occur in Tuvalu or in association with coconut trees. Transport via ship would also exclude the possibility of transmitting a virus into the New Zealand environment given the long time frame of the journey, which could be more than two weeks from packhouse in Tuvalu to New Zealand. Many viruses are semi-persistent, and would not be retained by the mealybug through such a long transit time.

The likelihood of F. virgata or its vectored viruses entering the country on the pathway is low, therefore non-negligible.

8.2.2. Exposure assessment

Many of the host plants of this mealybug including citrus, sweet potato, taro, tomato, guava, grapes, avocado, beans, maize, eggplant, cucurbits and *Lucerne* are grown in New Zealand with some occurring more commonly in northern north island (e.g. guava and citrus). There would be no shortage of host plants available throughout the year were *F. virgata* to enter the country.

8.2.3. Establishment assessment

Climate may be a limiting factor for *F. virgata* establishing in many parts of New Zealand as it is largely found in tropical and subtropical climates, surviving at an optimal temperature for growth and development of 25°C. There are no data for lower thresholds for development, but its lifespan is extended at cooler temperatures (e.g. 16.6°C). It is likely that a summer population could survive but establishment through the winter months is unlikely except in northern North Island. Greenhouse conditions could enable the establishment of a permanent population of *F. virgata.*

The likelihood of F. virgata being exposed to the local environment in New Zealand and establishing is moderate.

8.2.4. Consequence assessment

8.2.4.1. Economic

Hosts of economic importance in New Zealand include citrus, avocado, grapes, asparagus, olive, tomato, eggplant, potato, *Phaseolus* (beans), sweet potatoes, cucurbits and *Lucerne* (MAF, 2001).

Infestations of *F. virgata* remain clustered around the terminal shoots, leaves and fruit, sucking the sap which results in yellowing, withering and drying of plants and shedding of leaves and fruit. The foliage and fruit also become covered with large quantities of sticky honeydew which serves as a medium for the growth of black sooty moulds. The sooty moulds and waxy deposits result in a reduction of photosynthetic area. Ornamental plants and produce lose their market value (CPC 2006).

8.2.4.2. Environmental

Two plant species attacked by the guava mealybug overseas are *Piper betel* and *Piper nigrum*. The family Piperaceae is represented by a very common native species *Macropiper excelsus* which is widespread in coastal areas of New Zealand. There is the potential for *F. virgata* to attack this plant as an alternative host.

The likelihood of F. virgata and causing unwanted economic and environmental consequences is moderate to low, therefore non-negligible.

8.2.5. Risk estimation

The likelihood of *F. virgata* entering the country, being exposed to suitable hosts and establishing is low to moderate. The risk estimation for *F. virgata* therefore is non-negligible. The likelihood of any viruses associated with the mealybug entering the country and establishing negligible.

8.3. Risk management

8.3.1. Options

Pest management systems in coconut stands, screening measures and pre export visual inspection are considered to be included with each disinfestation treatment option given below.

Green coconut

Option 1. Scrubbing and washing of fruit surface after removal of calyx and waxing the cut surface immediately, following good hygiene practice to prevent recontamination, and then cold storage of coconuts in transit

Option 2. Remove calyx, peeling skin of the fruit and waxing cut surface, followed with good hygiene practice to prevent recontamination, and cold storage of coconuts in transit.

Brown coconut

Option 1. De-husking, following good hygiene practice to prevent recontamination, and cold storage of coconuts in transit

Option 2. De-husking, waxing of 'eye' region, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit

Coconut apple

Option 1. De-husking, cutting off shoot and root material, waxing of cut surfaces, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

Option 2. De-husking, cutting off shoot and root material, waxing of whole coconut, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

8.4. Assessment of uncertainty

Because *F. virgata* is a vector of viruses in other parts of its distribution, it is unknown what the likelihood is of it vectoring other viruses that may be found in Tuvalu currently.

8.5. References for chapter 8

Ammar E D; Awadallah K T; Rashad, A (1979) Ecological studies on *Ferrisia virgata* Cockerell on *Acalypha* shrubs in Dokki, Giza (Homoptera, Pseudococcidae). *Deutsche Entomologische Zeitschrift* 26(4/5):207-213

Awadallah, K T; Ammar, E D; Tawfik, M F S; Rashad, A (1979) Life history of the white mealy bug *Ferrisia virgata* (Cockerell) (Homoptera: Pseudococcidae). *Deutsche Entomologische Zeitschrift* 26(1/3): 101-110

Ben-Dov, Y; Miller, D R; Gibson, G A P (2005) *Ferrisia virgata,* Query. *ScaleNet* http://www.sel.barc.usda.gov/scalenet/scalenet.htm

Bhat, A I; Devasahayam, S; Sarma, Y R; Plant, R P (2003) Association of a badnavirus in black pepper (*Piper nigrum* L.) transmitted by mealybug (*Ferrisia virgata*) in India. *Current Science* 84(12): 1547-1550

Cox, J M (1987) Pseudococcidae (Insecta: Hemiptera). *Fauna of New Zealand* 11

CPC (2006) *Ferrisia virgata* Crop Protection Compendium, Wallingford, UK, CAB International
http://www.cabicompendium.org/cpc/datasheet.asp?CCODE=CERPPS&COUNTRY=0

Dabek, A J (1998) *Final report; Entomology & Plant Protection Project, Tuvalu (August 1996-August 1998).* Commonwealth Fund for Technical Cooperation (CFTC)

Gullen, P J (2003) Relationships of *Ferrisia* (Pseudococcidae) and the identity crisis of the striped mealybug *Ferrisia virgata*. Presentation part of: *Ten Minute papers, Section A. Systematics, Morphology and Evolution.*
http://esa.confex.com/esa/2003/techprogram/paper_11676.htm

Ikisan (2000) Pests of Cashew. *Ferrisia virgata. Ikisan Agri-Portal for Indian farmers*
www.ikisan.com/links/tn_cashewInsectsManagement.shtml

MAF (2001) *Ferrisia virgata*: *Pest Risk Analysis.* Ministry of Agriculture and Forestry

Nayar, K K; Ananthakrishnan, T N; David, B V (1976) *General and Applied Entomology.* India: Government Press

NZBugs (2006) *New Zealand Terrestrial Invertebrates Database*. Landcare Research
http://nzbugs.landcareresearch.co.nz/default.aspx?NavControl=search&selected=NameSearch

Ollennu, L A A (2001) Synthesis: case history of cocoa viruses. *Paper at Plant Virology in Sub-Saharan Africa (PVSSA) Conference.* Published on the web by International Institute of Tropical Agriculture (IITA)
http://agrifor.ac.uk/hb/10833204d63df874ba3476b61e355244.html

PPIN (2008) *Plant Pest Information Network*. Database for the Ministry of Agriculture and Forestry, New Zealand

Williams, D J (1996) A synoptic account of the mealybug genus *Ferrisia* Fullaway (Homoptera: Pseudococcidae). *Entomologists Monthly Magazine* 132(3): 1-10

Williams, D J; Granara de Willink, M C (1992) *Mealybugs of Central and South America,* CAB International, Wallingford Uk pp 635

Willink, Granara de M C (1991) A new species of *Ferrisia* Fullaway in the Republic of Argentina (Homoptera: Pseudococcidae). *Insects Mundial* 5(3/4): 181-184

9. Seychelles/Egyptian scales

9.1. Hazard identification

Scientific name: *Icerya aegyptiaca* Douglas (Homoptera: Margarodidae)
Synonyms: *Icerya aegyptiacum, Crossotosoma aegyptiacum, Icerya tangalla*
Scientific name: *Icerya seychellarum* (Westwood) Maskell (Hemiptera: Margarodidae)
Synonyms: *Dorthesia seychellarum*

New Zealand Status: Not known to be present in New Zealand (not recorded in PPIN 2007; Morales 1991). Fernald's world catalogue of Coccidae (1903) listed *Icerya seychellarum* as occurring in New Zealand on the basis of a paper by Maskell (1897) in which he identified some coccids sent to him by Koebele from China and Formosa (Morales 1991). There is no evidence for the scale occurring here.

9.1.1. Biology of *I. aegyptiaca*

Icerya aegyptiaca is common throughout the Pacific and causes damage of economic importance to fruit trees, shade trees and ornamental plants within its distribution range, covering shoots, leaves, stems and branches (Azab *et al.* 1968; Ullah 1994). It has been recorded on young coconut palms in Micronesia (Beardsley 1955).

In Egypt *I. aegyptiaca* probably has two generations a year and a partial third. One generation occurs in spring and one in autumn (Azab *et al.* 1968). There are 3 larval instars which develop for between 11 and 35 days per instar (Azab *et al.* 1968; Ullah 1994). The female produces 31-319 eggs, which hatch after 1-17 days. The oviposition period lasts up to 49 days. The total lifecycle from egg to death is between 87-105 days (Azab *et al.* 1968; Ullah 1994).

There are no thermal thresholds for this species in the literature but there is a positive correlation of low relative humidity and temperature and slower development rates over the winter season in Bangladesh (Ullah 1994).

The mealybug is regularly attended by various ant species (Siddappaji *et al.* 1984). The honeydew produced by *I. aegyptiaca* causes growth of a sooty mould which may be partially responsible for the debilitation of infested trees (Beardsley 1955).

9.1.2. Hosts of *I. aegyptiaca*

Major hosts include:
Annona muricata (soursop), *Artocarpus* (breadfruit trees), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Citrus*, *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Morus alba* (mora), *Psidium guajava* (guava)

Minor hosts include:
Acacia decurrens (green wattle), *Acalypha* (Copperleaf), *Cajanus cajan* (pigeon pea), *Capsicum* (peppers), *Casuarina equisetifolia* (casuarina), *Cocos nucifera* (coconut), *Codiaeum variegatum* (croton), *Coffea* (coffee), *Colocasia esculenta* (taro), *Dodonaea viscosa* (switch sorrel), *Ficus*, *Glycosmis pentaphylla*, *Indigofera* (indigo), *Jatropha podagrica* (gout plant), *Lycopersicon esculentum* (tomato), *Malus domestica* (apple), *Musa*

(banana), *Parkinsonia aculeata* (Mexican palo-verde), *Persea americana* (avocado), *Piper nigrum* (black pepper), *Plumbago auriculata* (Cape leadwort), *Pseuderanthemum*, *Punica granatum* (pomegranate), *Rosa* (roses), *Solanum melongena* (aubergine), *Solanum nigrum* (black nightshade), *Syzygium cumini* (black plum), *Tectona grandis* (teak), *Vernicia fordii* (central China wood oil tree), *Zea mays* (maize) (CPC 2007)

9.1.3. Distribution of *I. aegyptiaca*

It occurs in tropical and subtropical regions, including parts of Africa, and the Middle East; Israel, areas in the Pacific; Australia, Belau, Bonin Islands, French Polynesia, Federated States of Micronesia, Caroline Islands, Fiji, Guam, Marshall Islands, Kiribati, Nauru, Samoa, Tuvalu, and in Asia; India, Bangladesh, Pakistan, China, Hong Kong, Philippines, Sri Lanka, Thailand, Japan, Malaysia and Taiwan (Ben-Dov *et al.* 2008; CPC 2007).

9.1.4. Biology of *I. seychellarum*

I. seychellarum is a highly polyphagous and widespread pest throughout the tropics (Ben-Dov 2005) and has been intercepted several times on fresh produce entering New Zealand (Morales 1991). There is no literature associating it directly with fruit but Lepesme (1947) lists it on *Cocos nucifera* in his book on palm pests, particularly in the Seychelles. Females are orange-red covered in a granular yellowish-white waxy covering with silky tubular threads. They produce posterior ovisacs almost as long as their bodies (Williams & Watson 1990). *I. seychellarum* can grow up to 10mm long and feeds largely on the undersides of leaves (Hill 1980).

There are three nymphal instars and typically a larviform ovoviviparous (reproducing by means of eggs that hatch in the body of the parent) adult stage (Veyssiere 1961 in Hill 1980). Alate males are rare and reproduction is asexual (Hill 1980). Five or six days after production of the ovisac the female will begin laying eggs, and does so for about 6-17 days. First instar nymphs hatch within 24 hours, remaining in the egg sac for 2-3 days then emerge to crawl over the leaves of the host. There are three instars to adulthood and the development time from egg to adult is about 3 months. In Japan there is one generation per year with winter passed as mature females (Kuwana 1922).

This species produces copious amounts of honey dew and is often attended by ants (Roberts & Seabrooks 1989).

In a study on Aldabra Atoll in the West Indian Ocean, Hill (1980) determined that aerial dispersal of *I. seychellarum* occurs on the atoll by a small proportion (though large numbers) of the population with a periodic diurnal rhythm (Hill 1980). This dispersal is generated by the earlier rhythm of crawler emergence from adult brood pouches in response to a light-dark cue. Evidence of large numbers of crawlers leaving individual bushes, and their ability to survive reasonable lengths of time under extreme conditions confirms that the atoll was colonised by aerial dispersal of *I. seychellarum* crawlers (Hill 1980).

Although thriving at minimum night temperatures well above 20ºC (Hill 1980) there is no information on the developmental thresholds for this species.

9.1.5. Hosts of *I. seychellarum*

Icerya seychellarum is highly polyphagous. Major hosts include:
Acacia spp.(wattles), *Albizia* spp., *Annona* spp., *Artocarpus* spp.(breadfruit trees), *Casuarina equisetifolia* (casuarina), *Citrus* spp., *Cocos nucifera* (coconut) (Lepesme 1947), *Ficus* spp.,

Grevillea robusta (silky oak), *Magnolia* spp., *Persea americana* (avocado), *Psidium guajava* (guava), *Pyrus* spp.(pears), *Rosa* spp.(roses)

Minor hosts include:
Acalypha spp. (Copperleaf), *Alpinia purpurata* (gingerlily), *Anthurium andreanum*, *Areca catechu* (betelnut palm), *Asplenium nidus* (bird's nest fern), *Averrhoa carambola* (carambola), *Bixa orellana* (annatto), *Broussonetia papyrifera* (paper mulberry), *Caesalpinia pulcherrima* (Paradise flower), *Cajanus cajan* (pigeon pea), *Calophyllum* spp. (beauty-leaf), *Camellia sinensis* (tea), *Capsicum annuum* (peppers), *Carica papaya* (papaw), *Cassia* spp. (sennas), *Ceiba pentandra* (kapok), *Chrysophyllum cainito* (caimito), *Cinnamomum* spp., *Citharexylum quadrangulare* (Fiddlewood), *Clerodendrum* spp.(Fragrant clerodendron), *Coffea* spp.(coffee), *Convolvulus* spp. (morning glory), *Coprosma* spp., *Cordyline* spp., *Crotalaria* spp., *Cycas* spp., *Derris elliptica* (Tuba root), *Dioscorea* spp.(yam), *Dodonaea viscosa* (switch sorrel), *Elaeis guineensis* (African oil palm), *Epipremnum pinnatum* (Hunters-robe), *Eriobotrya japonica* (loquat), *Eugenia* spp., *Euphorbia* spp. (spurges), *Feijoa sellowiana* (Horn of plenty), *Fragaria* spp.(strawberry), *Garcinia mangostana* (mangosteen), *Gerbera* spp.(Barbeton daisy), *Heliconia* spp., *Hibiscus* spp. (rosemallows), *Inocarpus fagifer*, *Ipomoea batatas* (sweet potato), *Jasminum* spp. (jasmine), *Lactuca sativa* (lettuce), *Litchi chinensis* (litchi) (Williams & Watson 1990), *Lycopersicon esculentum* (tomato), *Malus sylvestris* (crab-apple tree), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Mimosa pudica* (sensitive plant),
Monstera deliciosa (ceriman), *Musa* spp. (banana), *Passiflora edulis* (passionfruit), *Phaseolus* spp. (beans), *Phoenix* spp.(date palm), *Piper* spp. (pepper), *Plumeria rubra* var. *acutifolia* (Mexican frangipani), *Poncirus trifoliata* (Trifoliate orange), *Prunus persica* (peach), *Punica granatum* (pomegranate), *Raphanus sativus* (radish), *Rubus* spp. (blackberry, raspberry), *Samanea saman* (rain tree), *Schefflera* spp. (umbrella tree), *Solanum* spp. (nightshade), *Spondias purpurea* (red mombin), *Syzygium* spp., *Tectona grandis* (teak), *Vitis vinifera* (grapevine), *Xanthosoma sagittifolium* (yautia (yellow)), *Zinnia* spp (CPC 2007, Williams & Watson 1990).

9.1.6. Distribution of *I. seychellarum*

I. seychellarum is widespread in Asia and Africa. It is present in Australia, American Samoa, Belau, Cook Is., Federated States of Micronesia, Fiji, French Polynesia, Kiribati, New Caledonia, Niue, Papua New Guinea, Samoa, Soloman Is., Tonga, Tuvalu and Vanuatu and Japan (CPC 2007; Williams & Watson 1990; Kuwana 1922).

9.1.7. Hazard identification conclusion

There is literature recording both *Icerya* species on *Cococ nucifera* (Beardsley 1955; Williams & Watson 1990) but there is no published evidence *I. seychellarum* or *I. aegyptiacum* occurs on the nut itself. However *I. seychellarum* has been intercepted on fresh produce coming in to New Zealand on a number of occasions (Morales 1991). Crawlers are quite mobile, capable of short distance and aerial dispersal giving them the potential to hitch hike on coconut, as well as being associated in the adult stages. For these reasons *I. aegyptiaca* and *I. seychellarum* are considered potential hazards in this risk analysis.

9.2. Risk assessment

9.2.1. Entry assessment

I. aegyptiaca has 3 larval instars, which develop for between 11 and 35 days per instar. The total lifecycle from egg to death is between 87-105 days (Azab *et al.* 1968; Ullah 1994). *I.*

seychellarum is not inconspicuous growing up to 1cm in length and has been intercepted on produce entering New Zealand a number of times in the past (Morales 1991). Crawlers live for up to three months, with one generation per year while adult females have been shown to overwinter in Japan. The longevity of these life stages of the two mealybugs would more than encompass the transit time for coconuts coming from Tuvalu by sea. However the likelihood of either mealybug being associated with dehusked or coconuts with husks at the time of export is considered very low.

There is a low to very low likelihood that I. aegyptiaca and I. longirostris would enter the country on the pathway

9.2.2. Exposure assessment

A recently mated female or parthenogenetic mealybug about to lay or already laying eggs could survive in warm, dry or slightly humid conditions allowing the eggs to hatch. Newly hatched crawlers have the greater likelihood of exposure. Although they appear to actively disperse only over short distances, scale insects may disperse over several kilometres by wind (Greathead, 1990). *I. seychellarum* is capable of this kind of aerial dispersal as was recorded by Hill in the late1970s throughout the Aldabra Atoll.

There would be no shortage of hosts available year round for *I. aegyptiaca* if it entered the country. Plants from a wide range of cultivated species could be affected, including: *Citrus*, guava, *Morus* spp., *Capsicum*, tomato, apple, *Rosa* spp., aubergine and other *Solanum* spp., *Syzygium* and corn. *I. seychellarum* were it to enter the country could be exposed to commercial hosts including capsicum, feijoa, strawberry, lettuce, tomato, passionfruit, bean, peach, blackberry, raspberry and grapevine.
Ornamentals such as *Clerodendron*, *Convolvulus*, *Hibiscus* and jasmine, plus several genera represented by native species in the New Zealand flora including *Coprosma*, *Cordyline*, *Syzygium* and *Schefflera* spp. could provide host material all year round.

9.2.3. Establishment assessment

There are no thermal thresholds for *Icerya aegyptiaca* in the literature but there is a positive correlation of low relative humidity and temperature and slower development rates over the winter season in Bangladesh (Ullah 1994).
Although there are no published data on the developmental thresholds or environmental tolerances for *I. seychellarum*, its distribution is currently restricted entirely to countries within tropical latitudes. There is some doubt that *I. seychellarum* would survive winter temperatures in most of New Zealand as it has not established in other temperate or boreal zones (the exception being Japan which ranges from tropical to temperate climates).

The likelihood of exposure for I. aegyptiacum and I. seychellarum is low, and establishment very low to negligible.

9.2.4. Risk estimation

As there has been no evidence in interception records for an association with mature coconuts and either *I. aegyptiaca* and *I. seychellarum*, and considering climate would be a significant limitation to establishment of the species there is no justification for management measures to be applied. If systems approaches to post harvest hygiene, packaging and treatment are carried out adequately, the likelihood of these organisms being associated with the commodity will be negligible.

9.3. References for chapter 9

Azab, A K; Tawfik, M F S; Ezz, A I (1968) Studies on *Icerya aegyptiaca* (Douglas) (Homoptera: Margarodidae). *Bulletin de la Societe Entomologique d'Egypte* 52: 155-178

Beardsley, J W Jr (1955) Fluted scales and their biological control in United States administered Micronesia. *Proceedings of the Hawaiian Entomological Society* 15(3): 391-399

Ben-Dov, Y (2005) *A systematic catalogue of the scale insect family Margarodidae (Hemiptera: Coccoidea) of the world.* Intercept limited, Wimborne

Ben-Dov, Y; Miller, D R & Gibson, G A P (2008) *Icerya aegyptiaca*. ScaleNet, Scales in a Country Query results, Systematic Entomology Laboratory, Beltsville Agricultural Research Centre, United States Department of Agriculture http://www.sel.barc.usda.gov/scalecgi/distrib.exe?Family=Margarodidae&genus=Icerya&species=aegyptiaca&subspecies=&intro=A

CPC (2007) *Icerya seychellarum Crop Protection Compendium Online Database* http://www.cabicompendium.org/cpc/search_overview_results.asp?as_search=Icerya+seychellarum&as_sections=NAM2/TXT3/BIB2/LIB2/GLOS/GLOSDEF&highlight=0&SearchBoxView=

Fernald, M E (1903) *A catalogue of the Coccidae of the world.* Amherst, Massachusetts, Carpenter & Moorehouse. 360p

Greathead, D J (1991) Crawler behaviour and dispersal. In Rosen, D (ed) *Armored scale insects: their biology, natural enemies and control*, Elsevier Science, Amsterdam Pp305-308

Hill, M G (1980) Wind dispersal of the coccid *Icerya seychellarum* (Margarodidae: Homoptera) on Aldabra Atoll. *The Journal of Animal Ecology* 46(3): 939-957

Hill, M G; Blackmore, P J M (1980) Interactions between ants and the coccid *Icerya seychellarum* on Aldabra Atoll. *Oecologia* 45(3): 360-365

Kuwana, I (1922) *Studies on Japanese Monophelebinae. Contribution II. The genus* Icerya. Department of Agriculture and Commerce, Imperial Plant Quarantine Station, Yokohama, Japan, No. 2: 43 pp

Lepesme, P (1947) *Les insectes des palmiers.* Paul Lechevalier ed. Paris, 903p

Maskell, W M (1879) On some Coccidae in New Zealand. *Transactions and proceedings of the New Zealand Institute* 11: 187-228

Morales, C F (1991) Margarodidae (Insecta: Hemiptera) *Fauna of New Zealand* 21

PPIN (2007) *Plant Pest Information Network.* Database for the Ministry of Agriculture and Forestry

Roberts, P; Seabrook, W A (1989) A relationship between black rats (*Rattus rattus*), Seychelles fruit bats (*Pteropus seychellensis aldabrensis*) and the coccoid (*Icerya seychellarum*) (Insects, Homoptera) on Aldabra Atoll, Seychelles. *Journal of Zoology* 218(2): 332-334

Siddappaji, C; Puttaraju, B; Venkatagiriyappa, S (1984) *Icerya aegyptiaca* (Douglas) a new pest of mulberry (*Morus alba* Linn.) in India and its control. *Current Science* 53(24): 1298-1299

Ullah, G M R (1994) Seasonal effects on the rate of development, fecundity and sex-ratio of three species of Coccoidea (Homoptera: Coccoidea: Margarodidae and Pseudococcidae). *Annals of Entomology* 12(2): 61-71

Unruh, C M; Gullan, P J (2008) Molecular data reveal convergent reproductive strategies in Iceryine scale insects (Hemiptera: Coccoidea: Monophlebidae) allowing the reinterpretation of morphology and revised generic classification. *Systematic Entomology* 33(1): 8-50

Veyssiere, P (1961) Contributions a l’etudes biologiques des systematiques des coccids. *Annales des Epiphyties* 12: 197-382

Williams, D J; Watson, G W (1990) *The scale insects of the tropical South Pacific region. Part 3. The soft scales and other families.* CAB International Wallingford, UK

10. Snow scale

10.1. Hazard identification

Scientific name: *Pinnaspis strachani* Cooley (Homoptera: Diaspididae)
Synonyms: Chionaspis minor, *Hemichionaspis minor strachani, Hemichionaspis townsendi*, *Chionaspis aspidistrae gossypii, Hemichionaspis aspidistrae gossypii, Hemichionaspis proxima, Hemichionaspis marchali, Hemichionaspis minor, Chionaspis proxima, Pinnaspis minor, Pinnaspis minor strachani, Pinnaspis proxima, Pinnaspis aspidistrae gossypii, Pinnaspis temporaria, Hemichionaspis minor, Pinnaspis aspidistrae gossypii, Pinnaspis gossypii, Pinnaspis marchali, Hemichionaspis gossypii, Chionaspis gossypii, Pinnaspis townsendi*.

New Zealand Status: Not present in New Zealand (not recorded in Charles & Henderson 2002). It was erroneously included in distribution records of the species for New Zealand (Nakahara 1982) because of previous confusion surrounding the names *Chionaspis minor* Maskell and *Hemiberlesia minor* var *strachani* Cooley, and which taxa they represented (Charles & Henderson 2002). It does not occur in New Zealand.

10.1.1. Biology

The snow scale *Pinnaspis strachani* is a bisexual species with multiple generations annually (Tenbrick & Hara 1992). It is morphologically closely related to *P. aspidistrae* (Moghaddam 2000). It has been recorded as a minor pest on the developing fruit of coconut in Sri Lanka (Fernando & Kanagaratnam 1987), and is found in interception records on coconut from the Pacific (QuanCargo 2008). The females undergo three developmental stages and the males five. Development time is approximately 23 days for males and 45 days for females (Fernandez *et al.,* 1993), but this is dependant on temperature, humidity and rainfall (Beardsley & Gonzalez 1975). After hatching, short range dispersal happens as crawlers search out places to settle and feed (Beardsley & Gonzalez 1975) on the stems and leaves of the host. Males appear to settle near or adjacent to females (CPC 2006). The second instar larvae lose their legs and become sessile. The species is mobile only during the crawler (first nymphal) stage and in the male adult. Males emerge from their armour at maturity, in the late afternoon, living only a few hours to mate (Tenbrick & Hara 1992). Females and feeding nymphs are attached to the plant by hair-like mouthparts (Tenbrick & Hara 1992).

P. strachani has been recorded occurring in amenity greenhouses in France and Hungary (Reiderne & Kozar 1994; Germaine & Matile-Ferrero 2005).

10.1.2. Hosts

Major hosts include:
Asparagus officinalis (asparagus), *Cajanus cajan* (pigeon pea), *Citrus*, *Citrus aurantiifolia* (lime), *Citrus limon* (lemon), *Citrus maxima* (pummelo), *Citrus sinensis* (navel orange), *Cocos nucifera* (coconut), *Cycas revoluta*, *Elaeis guineensis* (African oil palm), *Ficus*, *Ficus carica* (fig), *Gossypium* (cotton), *Gossypium hirsutum* (Bourbon cotton), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Nerium*, *Prunus* (stone fruit), *Solanum melongena* (aubergine)

Minor hosts of economic importance include:
Anacardium occidentale (cashew nut), *Annona muricata* (soursop), *Annona reticulata* (bullock's heart), *Arecaceae*, *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Capsicum annuum* (bell pepper), *Capsicum frutescens* (chilli), *Citrus x paradisi* (grapefruit), *Colocasia esculenta* (taro), *Cordyline fruticosa* (Good-luck-plant), *Dioscorea alata* (white yam), *Dioscorea bulbifera* (Air-potato), *Diospyros kaki* (persimmon), *Eucalyptus* (Eucalyptus tree), *Litchi chinensis*, *Lycopersicon esculentum* (tomato), *Musa x paradisiaca* (plantain), *Orchidaceae* (orchids), *Persea americana* (avocado), *Phaseolus vulgaris* (common bean), *Ricinus communis* (castor bean), *Schefflera*, *Senna occidentalis* (coffee senna), *Sophora*, *Vitis vinifera* (grapevine), *Zingiber officinale* (ginger) (CPC 2006; Ben-Dov *et al.* 2006).

10.1.3. Distribution

P. strachani is found throughout Asia, Africa, the Middle East and the Americas; it is widespread in Oceania (CPC 2006) and has been recorded from Hungary and France in Europe (Reiderne & Kozar 1994; Germaine & Matile-Ferrero 2005).

10.1.4. Hazard identification conclusion

This scale insect is widespread and polyphagous with a short lifecycle. There is a chance that it could persist in greenhouse conditions as it has been recorded from these in Hungary and France. However it is unlikely to survive climatic conditions in the outdoors in New Zealand, and consideration of greenhouses is not part of this risk analysis. Although there is no temperature tolerance data for the organism it is predominantly found in tropical areas. It is therefore not considered a hazard in this risk analysis.

10.2. References for chapter 10

Beardsley, J W Jr; Gonzalez, R H (1975) The biology and ecology of armoured scales. *Annual Review of Entomology* 20: 47-73

Ben-Dov, Y; Miller, D R; Gibson, G A P (2008) *Pinnaspis strachani*. ScaleNet, Hosts of a Scale Query results, Systematic Entomology Laboratory, Beltsville Agricultural Research Centre, United States Department of Agriculture http://www.sel.barc.usda.gov/scalecgi/hostsof.exe?Family=Diaspididae&genus=Pinnaspis++&species=strachani&subspecies=

Charles, J G; Henderson, R C (2002) Catalogue of the exotic armoured scale insects (Hemiptera: Coccoidea: Diaspididae) in New Zealand. *Journal of The Royal Society of New Zealand* 32(4): 587-615

CPC (2006) *Pinnaspis strachani* Crop Protection Compendium http://www.cabicompendium.org/cpc/report.asp?CCODE=PINNST&criteria=T/HO1

Fernandez, M; Val, I; del Proenza, M A; Garcia, G (1993) Diagnosis of snow scale insect (Homoptera: Diaspididae) in Isla de la Juventud. *Revista de Proteccion Vegetal* 8(1): 17-22

Fernandez, M; Val, I; del Proenza, M A; Mesa, D; Burgos, T (1996) Some causes for mortality of *Pinnaspis strachani* Cooley (Homoptera: Diaspididae) on grapefruit crops in the Isla de la Juventud. Part 1. *Revista de Proteccion Vegetal*. 11(2): 25-28

Fernando, L C P; Kanagaratnam, P (1987) New records of some pests of the coconut inflorescence and developing fruit and their natural enemies in Sri Lanka. *Cocos* (5): 39-42

Ferris, G F; Rao, V P (1947) The genus *Pinnaspis* Cockerell (Homoptera: Coccoidea: Diaspididae). (Contribution No. 54). *Microentomology* 12: 25-58

Germaine, J F; Matile-Ferrero, D (2005) Scale insects from greenhouses in France: an illustrated survey. III – Diaspididae. *Phytoma* (583): 32-35

Moghaddam, M (2000) The first record of *Pinnaspis strachani* (Coccoidea: Diaspididae) in Iran. *Journal of Entomological Society of Iran* 19(1/2): 105-106

Nakahara, S (1982) *Checklist of the armoured scales (Homoptera: Diaspididae) of the conterminous United States.* Beltsville. United States Department of Agriculture, Animal and Plant Health Inspection Services. Pp 110

QuanCargo Database (2008) *Interception Record Database*. Ministry of Agriculture and Forestry

Reiderne, S K; Kozar, F (1994) Recently appeared scale insect species (Homoptera, Coccoidea: Diaspididae) on glasshouse ornamentals in Hungary. *Novenyvedelem.* 30(9): 423-427

Tenbrick, V L; Hara, A H (1992) *Pinnaspis strachani* (Cooley). *Crop Knowledge Master*. www.extento.hawaii.edu/kbase/Crop/Type/p_strach.htm

11. Coconut stick insect

11.1. Hazard identification

Scientific name: *Graeffea crouanii* Le Guillou (Orthoptera: Phasmidae)
Synonyms: *Graeffea cocophaga, Lopaphus coccophaga*

New Zealand Status: Not present in New Zealand (not recorded in Jewell & Brock 2002).

11.1.1. Biology

Graeffea crouanii has not been recorded on the nut in coconut palms in the literature but is considered to be a pest of significance in Tuvalu (See Table 2 Chapter 2). Females lay up to 100 eggs, most of which fall to the ground. Nymphs are highly mobile and if hatching on the ground move around until they encounter a palm and then climb up it to begin feeding (Swaine 1969). Unless disturbed, nymphs and adults stay on the leaves (Rapp 1995). It is possible eggs or nymphs could be associated with coconuts before they fall or are harvested for export. In the literature the most likely part of the life cycle for dispersal is the egg stage (Nakata 1961). Eggs with their exceedingly hard well protected shell, resistance to adverse weather conditions and lengthy development period allows ample time and more chances for possible dispersal through human agency or rafting (Nakata 1961).

It seems to have been easily dispersed in the Pacific Islands where coconut palms occupy the coastal areas (Nakata 1961).

Prolonged desiccation of eggs leads to their death, but they can survive in both salt and fresh water on which they are able to float (Swaine 1969). The eggs are sensitive to high temperatures in plantations with low ground cover, and probably become rapidly desiccated in the sun, while the high undergrowth of plantations under poor weed management provides shadow for the eggs developing on the ground (Rapp 1995). This theory is supported by the literature; Crooker (1979) and Lever (1969) mention high pest densities in plantations with dense ground cover in Tonga (Rapp 1995).

The first instar nymphs are dependant on moisture for survival. There are six female nymphal instars and five in male development (O'Connor *et al.* 1964). *G. crouanii* is nocturnal, feeding on the edges of leaf fronds at night, and rests during the day. It has a very long life cycle like most phasmids. Studies in Fiji (O'Connor *et al.* 1964) showed the period from egg to egg laying by adult females was around 220 days. The egg stage lasts between 20-100 days, depending on season, and the nymphal stage is between 100-111 days for females. Adult longevity is an average of 167 days for males and 115 days for females in the cool season (Swaine 1969). Adults and nymphs are more susceptible to adverse environmental conditions than the egg stage (Nakata 1961). Experiments in Tonga looked at nymphal emergence from eggs kept at temperatures of 20, 30 and 40ºC (Rapp 1995). 20 ºC was the only temperature at which eggs did not become desiccated.

The ant *Solonopsis geminata*, forages at the base of coconut palms and eats phasmid eggs (Mariau 2001) probably reducing the population of this stick insect in its natural environment in Tuvalu.

11.1.2. Hosts

The main food of the stick insect is the coconut palm, but it has also been found on Sago palm (*Cycas revoluta*), *Pandanus tectorius* and is said to feed on the reed *Miscanthus japonicus* (Swaine 1969; O'Connor 1960).

11.1.3. Distribution

It occurs throughout the Pacific in Australia, Solomon Islands, Caroline Islands, New Caledonia, Fiji, Samoa, Tonga, Society Islands, Marquesas and Mangarera (Nakata 1961), and is considered a significant pest of coconut in Tuvalu (Sam Panapa pers comm. 2007).

11.1.4. Hazard identification conclusion

The most likely lifestage to be associated with coconuts are the eggs which are highly resistant to adverse conditions. Although there is evidence *Graeffea crouanii* has dispersed widely among the Pacific Islands where its main host plant coconut palm is ubiquitous, it is highly unlikely it would encounter any host plants in New Zealand were it to arrive on this pathway. There appears to be a narrow band of temperature tolerance for its survival, and it is not recorded anywhere outside the tropical or subtropical regions, indicating climate would be a significant limitations to its survival here.

For these reasons *G. crouanii* is not considered a potential hazard in this risk analysis.

11.2. References for chapter 11

Crooker, P S (1979) *Final report of the research officer entomologist.* Government Experimental Farm Vaini, Tonga

Jewell, T; Brock, P D (2002) A review of the New Zealand stick insects: new genera and synonymy, keys and a catalogue. *Journal of Orthoptera Research* 11(2): 189-197

Lever, R J A W (1969) *Pests of the coconut palm.* F A O Agricultural Studies Rome 77 (xiii + 190pp)

Mariau, D (2001) *The fauna of oil palm and coconut: Insect and mite pests and their natural enemies.* Translated from the French by Peter Biggins. Montpellier, France. CIRAD

Nakata, S (1961) Some notes on the occurrence of Phasmatoidea in Oceania. *Pacific Insects* 2: 107-121

O'Connor, B; Pillai, J S; Singh, S R (1954) Notes on the coconut stick insect, *Graeffea crouani* Le Guillou. *Fiji Agriculture Journal* 25: 89-92

Rapp, G (1995) Eggs of the stick insect *Graeffea crouanii* Le Guillou (Orthoptera, Phasmidae). Mortality after exposure to natural enemies and high temperature. *Journal of Applied Entomology* 119: 89-91

Swaine, G (1969) The coconut stick insect *Graeffea crouani* Le Guillou. *Oléagineux* 24(2): 75-77

12. Coconut termite

12.1. Hazard identification

Scientific name: *Neotermes rainbowi* Hill (Isoptera: Kalotermitidae)
Synonyms: *Calotermes rainbowi*

New Zealand Status: Not present in New Zealand (not recorded in Bain & Jenkin 1983).

12.1.1. Biology

It is assumed to have been introduced to parts of the Pacific, (where it now occurs), in soil being shipped from Australia (Given 1964). Infestation is visible on the outside of the trunks from an early stage, begins at or near ground level and extends downwards for about 1.5m and upwards to the crown, up to 24m or more. Active colonies tend to be confined to living tissue, except for breeding sections, the old galleries being filled up with earth. When palms are infested young they either collapse prematurely or bear few nuts, the yield from later infestations is less seriously affected (Given 1964). Trunk scarring and live termites were observed on coconut palms in Tuvalu (MAF Unpublished report 2008).

12.1.2. Hosts

Coconut palms are the preferred host, although all woody plants except *Cordia subcordata* were found to be susceptible to attack in the Northern Cook Island group in the 1960's (Given 1964).

12.1.3. Distribution

Ellice Islands, Cook Islands (Hopkins 1927, Given 1964).

12.1.4. Hazard identification conclusion

The coconut termite has not been recorded in association with the nut of coconuts in Interception records or in the literature, as the insect is a wood borer, and generally reproduces in dead tissue such as tree trunks. The likelihood of any life stage being associated with the fruiting part of the palm is considered so low as to be negligible.
Therefore *Neotermes rainbowi* is not considered a hazard in this risk analysis.

12.2. References for chapter 12

Bain, J; Jenkin, M J (1983) *Kalotermes banksiae*, *Glyptotermes brevicornis*, and other termites (Isoptera) in New Zealand. *New Zealand Entomologist* 7(4): 365-371

Given, B B (1964) The coconut termite in the Cook Islands. *SPC quarterly Bulletin*. 14(3): 25-26

Hopkins, G H (1927) Pests of economic plants in Samoa and other Island groups. *Bulletin of Entomological Research*.18 (Part 1.): 23-32

MAF Unpublished Report (2008) *Field Trip report to Tuvalu November 2007*

13. Ants

13.1. Hazard identification

Scientific name: *Anoplolepis gracilipes* (Jerdon) (Hymenoptera: Formicidae)
Synonyms: *Formica longipes, Formica trifasciata, Anoplolepis longipes, Plagiolepis longipes, Prenolepis gracilipes, Plagiolepis gracilipes*

Scientific name: *Monomorium destructor* (Jerdon) (Hymenoptera: Formicidae)
Synonyms: *Atta destructor, Myrmica basalis, Myrmica gracillima, Myrmica vexator, Myrmica atomaria, myrmica ominosa, Monomorium ominosa, Monomorium basale*

Scientific name: *Paratrechina bourbonica* (Forel) (Hymenoptera: Formicidae)
Synonyms: *Prenolepis bourbonica, Prenolepis bourbonica* r. *bengalensis*, *Prenolepis bourbonica* r. *hawaiensis*, *Prenolepis* (*Nylanderia*) *bourbonica* subsp. *skottsbergi*, *Prenolepis bengalensis*, *Prenolepis bourbonica* var. *bengalensis*

Scientific name: *Paratrechina longicornis* (Latreille) (Hymenoptera: Formicidae)
Synonyms: *Paratrechina currens, Formica gracilescens, Formice vagans, Prenolepis longicornis*

Scientific name: *Paratrechina vaga* Forel (Hymenoptera: Formicidae)
Synonyms: *Paratrechina* (*Nylanderia*) *vaga* var. *crassipilis* Santschi, *Paratrechina* (*Nylanderia*) *vaga* var. *irritans* Santschi, *Prenolepis obscurava* var. *vaga* Forel

Scientific name: *Tetramorium simillimum* (Smith) (Hymenoptera: Formicidae)
Synonyms: *Wasmannia auropunctata* subsp. *Brevispinosa, Tetramorium simillimum* r. *denticulatum, Tetramorium pusillum* var *exoleta, Tetromorium simillimum* var *insulare, Tetramorium simillimum* var *opacior, Myrmica parallela, Tetramorium pygmaeum, Tetramorium pusillum* var *bantouanum*

Scientific name: *Wasmannia auropunctata* (Roger) (Hymenoptera: Formicidae)
Synonyms: *Xiphomyrmex atomum, Wasmannia glabra, Hercynia panamana, Ochetomyrmex auropunctatus, Wasmannia auropunctata var. atoma*

New Zealand Status: None of these species are present in New Zealand (not recorded in Don 2008). All species except *Wasmannia auropunctata* are represented in historical quarantine records from 1966-1982 (Richardson 1979; Keall 1981; Townsend 1984). *Paratrechina bourbonica* is thought to be absent from New Zealand but some authors and taxonomists believe there is a high likelihood unidentified or misidentified *Paratrechina* sp. in New Zealand could be *P. bourbonica* (Don 2008; J. Berry pers comm. 2008). There is particular confusion surrounding identifications of *P. vaga* and *P. bourbonica*. This genus is currently being revised (S. Shattuck, under review).
NB: Landcare Research scientists have undertaken literature reviews and climate modelling for many species of invasive ants. Their research and assessments are utilised here (For more details see Harris *et al.* 2005 online reports).

13.1.1. Biology of *A. gracilipes*

Anoplolepis gracilipes forages continuously across the ground and in the canopy over a wide temperature gradient (O'Dowd 2004). It is a scavenging predator, preying on a variety of litter and canopy fauna, from small isopods, myriapods, molluscs, arachnids and insects to large land crabs, birds, mammals, and reptiles. It obtains carbohydrates and amino acids from plant nectaries and especially from honeydew excreted by hemipterans, which it tends on stems and leaves of a wide variety of tree and shrub species (O'Dowd 2004). In coconut plantations it nests at the base of trees and in the crowns and feeds on nectar secreted from male flowers and honeydew producing scale insects (O'Dowd 2004). *A. gracilipes* has been recorded on coconuts entering New Zealand from the Pacific in interception records (QuanCargo Database 2008).

The colonies are polygyne (multi-queened) with nest size averaging thousands of individuals (Harris *et al.* 2005). Colonies readily migrate if disturbed (Passera 1994). Worker production is continuous, although fluctuating throughout the year. Sexual stages can be present year round, but in most instances, initiation of brood follows the onset of the wet season (O'Dowd 2004). It takes 76-84 days for worker eggs to reach maturity at 20-22ºC (Fluker & Beardsley 1970). Eggs hatch in 18-20 days, with larvae developing 16-20 days after hatching. Pupae take around 20 days for development, while queens require 30-34 days. Workers live approximately 6 months, and the queens for several years. In experiments in India queens laid between 1960-2249 eggs in 116-145 days under laboratory conditions (Rao & Veeresh 1991).

Nests are made under leaf litter, in cracks and crevices in the soil, in land crab burrows, bamboo sections when placed on the forest floor and in canopy tree hollows (O'Dowd 2004). They also nest under the ground substrate (broken coral or coarse sand, with some organic material) in urban structures and in anthropogenic debris (Lester & Tavite 2004).

Increase in the abundance of *A. gracilipes* is usually associated with an increase in honeydew producing Hemiptera, and it is hypothesised that the utilisation and acquisition of honeydew are keys to their population build up and subsequent impacts (D. O'Dowd pers. comm. to Harris *et al.* 2005). It has been recorded as a direct pest to humans in the Seychelles, being a severe household pest and a nuisance in public buildings, hotels, food and drink processing establishments and the local hospital (Lewis *et al.* 1976).

13.1.2. Prey items of *A. gracilipes*

Its prey items include isopods, myriapods, molluscs, arachnids and insects to large land crabs, birds, mammals, and reptiles (O'Dowd 2004).

13.1.3. Distribution of *A. gracilipes*

The origin of *A. gracilipes* is the subject of debate, though it is likely to be either Asia (Wheeler 1910) or Africa (Wilson & Taylor 1967). Early records show it to be present in both continents before 1900. In contemporary times it has spread throughout the tropical lowlands of Asia, the Indian Ocean, and the Pacific Ocean and occurs between the Tropics of Cancer and Capricorn (Harris *et al.* 2005). In the Pacific it is found in Fiji, New Caledonia, Solomon Islands and Vanuatu, Caroline Islands, Gilbert Islands, Mariana Islands, Marshall Islands, Palau, Rotuma, Cook Islands, Gambier Island, Hawaii, Line Islands, Marquesas Islands, Niue, Samoa, Society Islands, Tokelau, Tonga, Tuamotu Islands, Tuvalu and Wallis and Futuna (Harris *et al.* 2005).

13.1.4. Biology of *M. destructor*

Monomorium destructor is a slow moving ant that forages along narrow trails. It has a generalist broad diet of living and dead insects, insect eggs, carbohydrates from tending sap-sucking insects, nectar, and seeds (Bolton 1987; Jaffe *et al*. 1990; Deyrup *et al*. 2000). It is found tending the aphid *Macrosiphoniella sanborni* in India (Datta *et al.* 1982). In households they will feed on almost any food available (Smith 1965). In Sri Lanka *M. destructor* was recorded primarily foraging in the crown of coconut trees, but was also seen at the base of trees (Way *et al.* 1989). It has been recorded on coconut coming into New Zealand from the Pacific Islands in interception records (QuanCargo Database 2008).

M. destructor forms large polygyne (multi queen) colonies, and in areas where they become very abundant, such as in populations on the Tiwi Islands off the coast of north Australia, many individuals and nests in a small area give the appearance of a super colony (B. Hoffman pers comm. in Harris *et al*. 2005). They nest anywhere, on the ground or in trees, and in pot plants (Jaffe *et al.* 1990). *M. destructor* may have relatively mobile nests as they have been observed to move around in the wet season in Darwin (B. Hoffman pers. comm. in Harris *et al.* 2005). The colonies disperse naturally by budding with a queen and workers and by the winged dispersal of (likely) inseminated queens to uninfested areas where they start a colony of their own (B. Hoffman pers. comm. in Harris *et al.* 2005).

M. destructor has been suggested as a potential public health and nuisance pest in the United Arab Emirates (Collingwood *et al.* 1997). It damages irrigation tubing in sugar cane plantations in Hawaii (Heinz *et al.* 1980) and has been observed gnawing the rubber insulation of electric wires in shops, as well as damaging clothes and other fabrics (Kalshoven 1937).

13.1.5. Prey items of *M. destructor*

Monomorium destructor eats living and dead insects, insect eggs, honeydew, nectar seeds and household foods.

13.1.6. Distribution of *M. destructor*

Probably native to India, *M. destructor* has spread throughout the tropics and increasingly into temperate zones (Bolton 1987). A pest in West Australia since the 1970s but has probably been there since the 1950s (Davis & Van Schagen 1993). The first published record of its presence in Florida is in 1933 (Deyrup *et al.* 2000).

13.1.7. Biology of *P. bourbonica*

The taxonomy of *P. bourbonica* is complex and it is difficult to distinguish from other members of the *Paratrechina* genus. *P. vaga* and *P. bourbonica* have been consistently misidentified and confused in records, as there is only one insufficient key available in the literature to distinguish them (Wilson & Taylor 1967). Therefore distribution of *P. bourbonica* in the Pacific and possibly in New Zealand is contentious (Don 2008). This genus is under revision (S. Shattuck; in progress). Throughout the Pacific, *P. bourbonica* are found under the bark of coconut palms on tree trunks in rainforest and on the seashore (Wilson & Taylor 1967).

P. bourbonica has been reported as aphidocolous (aphid loving) in India (Devi *et al.* 2000) and is potentially associated with *Saccharicoccus sacchari* (Homoptera: Pseudococcidae) a major pest on sugarcane in Australia (Carver *et al.* 1987).

P. bourbonica is thought to be more cold tolerant than other species found in the Pacific region (Wetterer 1998) and was one of 2 species found commonly in areas disturbed by human activity including roadsides in Hawaii. Wetterer (1998) suggests that this species could pose a more general threat to endemic Hawaiian species found at higher elevations than ants such as *Anoplolepis longipes* and *Pheidole megacephala* which occurring in and around geothermal areas in high numbers (Wetterer 1998).

The nests are usually in soil and colonies require high humidity (Trager 1984; Deyrup *et al.* 2000). Nests can produce alates at any time of the year and have multiple winged males and queens (Wilson & Taylor 1967). Nuptial flights have been observed but the primary method of dispersal is not confirmed (Passera 1994). After mating, females are apparently attracted to areas of high reflectivity such as walkways, buildings and bodies of water (Trager 1984). *P. bourbonica* are found in urban areas, and anthropogenically disturbed sites, such as rubbish piles, rotten wood, orchards, tree buttresses, grass areas and inside houses. It ranges up to 1000-1200m in Hawaii and is occasionally found at 1800m (Reimer 1994).

13.1.8. Prey items of *P. bourbonica*

Paratrechina bourbonica is active day and night and is omnivorous (Deyrup *et al.* 2000). The ant eats seeds, collects honeydew from sap sucking insects and workers aggressively attack and eat small insects and injured or dead larger insects (Trager 1984).

13.1.9. Distribution of *P. bourbonica*

Paratrechina bourbonica occurs throughout the Pacific including Tuvalu (AntWeb 2007) the Indian Ocean and the New World tropics. It is found in the Seychelles (Dorow 1996) French Polynesia (Perrault 1993) and Japan (Teranishi 1929). Most records are from the introduced range and tropical regions, but there are several occurrences in temperate areas associated with heated buildings eg. Montreal and Missouri that may be temporary populations (Harris *et al.* 2005).

13.1.10. Biology of *P. longicornis*

The crazy ant is so morphologically distinctive that it is one of the few *Paratrechina* that is not consistently misidentified in collections (Trager 1984). *Paratrechina longicornis* foragers are opportunists (Andersen 1992). Workers are very fast moving, darting about in a jerky haphazard fashion as if lacking a sense of direction (Smith 1965) hence the name crazy ant. They have been observed foraging up to 25m from the nest (Jaffe 1993). Workers live on live and dead insects, honeydew, fruits and many household foods and are especially fond of sweet foods (Smith 1965). *P. longicornis* has also been recorded foraging on decaying rabbit carcasses in India, feeding on moist areas around the eyes, nose, mouth and anal region during early stages of decay, as well as on dead flies, dead larvae, skin of carrion etc. during later decay stages (Bharti & Singh 2003).

It has been recorded on coconuts entering the country from the Pacific in interception records (QuanCargo Database 2008).

The colonies are polygyne (Passera 1994) with nests containing up to 2000 workers and 40 queens (Mallis 1982). Reproductives are produced throughout the year in warmer climates but are restricted (~5 months) in cooler climates, e.g. Gainsville, Florida (Trager 1984). Workers are probably sterile (Passera 1994). There are 3 larval instars, and longevity for the 3 immature developmental stages, eggs, larvae, and pupae was 16.1, 18.3 and 12.3 days +or-0.1days respectively (Solis *et al.* 2007). Colonies occur in temporary nests (Anderson 2000) are highly mobile and will move if disturbed (Trager 1984). Crazy ants tolerate nesting sites with relatively low humidity such as gaps in walls, thatching and dry litter (Trager 1984).

Outdoor nests are primarily on the ground, often in wood, trash and mulch, but occasionally are found aboreally in tree holes and leaf axils (Trager 1984; Way *et al.* 1989). Colony odours obtained through nutrition influence behaviour of workers, who tolerate members of the same colony but react aggressively towards individuals from distant sites (Lim *et al.* 2003). Trager (1984) has suggested that mating occurs in groupings around the nest entrance. Wings of queens are removed while still callow and males were never observed to fly or use their wings in any way (Trager 1984). However, in several cases it has been observed that males frequently appear at lights (Nickerson & Barbara, 2000). Natural dispersal is thought to occur primarily by budding (Harris *et al.* 2005).

Paratrechina longicornis appears to be a disturbance specialist and is rarely represented in undisturbed natural habitat (Harris *et al.* 2005). It may transmit diseases, and was found to be the second most common species in three Brazilian hospitals, where at least 20% of foragers sampled carried pathogenic bacteria (Fowler *et al.* 1993). In monsoonal Australia, *P. longicornis* is associated with human settlements, where it is one of the most common of the tramp ant species (Anderson 2000). It is generally not considered to infest food or wood items however (Klotz *et al.* 1995). In cold climates crazy ants nest in centrally heated apartments and other similar buildings such as glasshouses and airport terminals (Freitag *et al.* 2000; Nauman 1994).

13.1.11. Prey items of *P. longicornis*

Paratrechina longicornis feeds on live and dead insects, honeydew, fruits and many household foods, especially sweet foods. It eats seeds, carrion and occasionally larger prey items like lizards (most likely as carrion).

13.1.12. Distribution of *P. longicornis*

Paratrechina longincornis is one of the most common ants in the tropics and subtropics. It has also established in temperate regions, where it is found in greenhouses and heated buildings (Harris *et al.* 2005). Some of the notable gaps in its distribution (e.g. southern China, Indonesia) may reflect the lack of published ant checklists from these regions rather than the absence of the species (Harris *et al.* 2005). It occurs throughout the Pacific including Tuvalu (Tuvalu Quarantine service).

13.1.13. Biology of *P. vaga*

There is little published information about the biology of this species. It is commonly recorded on fresh produce in interception data at the border (QuanCargo 2008). Difficulties with the identification within the genus *Paratrechina* may mean some of the interception records identified as *P. vaga* could be other species such as *Paratrechina bourbonica*, and some of the many unidentified *Paratrechina* intercepted may be *P. vaga* (Harris *et al.* 2005).

P. vaga is known as a synanthropic species in the Pacific. It occurs in Tahiti where the scattering of ant species at higher altitudes are dependant on human activities, which are generally limited (Perrault 1987). In Hawaii it is found in disturbed habitats up to altitudes of 1200m, but is more common below 1000m, and is not found in undisturbed sites (Reimer 1994).

Workers of *P. vaga* tend and feed on honeydew from *Saccaricoccus sacchari* a coccid pest of sugar cane in Australia (Carver *et al*. 1987). They also feed on small invertebrates including plant pests (Way *et al.* 2002). Foragers may be widespread but are not particularly aggressive or behaviourally dominant (Morrison 1996; Vargo 2000; Way *et al.* 2002).

Nests are in the ground and are probably monogyne (single queen) (Harris *et al.* 2005). This species is one of the early colonisers of disturbed sites and when the ground is flooded have been seen moving brood (Way *et al.* 2002). Although there is no evidence in the literature it is likely that workers have a winged stage which aids in founding nests independently (Harris *et al.* 2005).

13.1.14. Prey items of *P. vaga*

Paratrechina vaga is omnivorous, feeding on scale insects and other honeydew producers, as well as feeding on small invertebrates.

13.1.15. Distribution of *P. vaga*

It is native to New Guinea and the western Pacific (Taylor 1987a & b). It occurs in Australia, and various islands in the Pacific (e.g. Morrison 1996; Reimer 1994). It is also reported in the Galapagos (Clark *et al.* 1982).

13.1.16. Biology of *T. simmillimum*

Tetramorium simillimum is predatory, and farms aphids on cocoa flowers and cherelles near the ground in its native African range. It also forms associations with soldierless termites. (Sands 1972) and preys on subterranean termites in Hawaii (Cornelius & Grace 1995). It has been recorded on coconut entering New Zealand from the Pacific Islands in interception records (QuanCargo Database 2008). *T. simillimum* is mainly diurnal or crepuscular, in summer there is more foraging at dusk, but in autumn workers become more nocturnal (Whitcomb *et al.* 1982). Colonies lack a soldier caste and appear to rely on small size and stealth to reach baits and food (Holldobler & Wilson 1980).

T. simillimum may form large, polygynous colonies (Reimer 1994). Its nests, in the introduced range of this species, are usually in soil in open areas, often around buildings, roads or parking lots and orchards (Whitcomb *et al.* 1982; Wojcik 1994; Deyrup *et al.* 2000). The ant occurs from sea level to about 1100 m in dry and mesic areas in Hawaii (introduced range) (Reimer 1994). It is limited to disturbed areas; in forested areas it is found along tracks (especially on hill tops) and roads. It has not been found in undisturbed forest (Reimer 1994). It is also able to establish (at least temporarily) in glasshouses in temperate climates (e.g. the U.K. – Bolton 1977).

13.1.17. Prey items of *T. simmillimum*

Tetramorium simillimum is predatory, and farms aphids. It also forms associations with soldierless termites on which it preys.

13.1.18. Distribution of *T. simmillimum*

Thought to originate in the old world tropics in Africa (Bolton & Collingwood 1975; Bolton 1980) *Tetramorium simillimum* has become a widespread tropical tramp species. It has been dispersed by commerce throughout the Americas, the Caribbean, Indian and Pacific Oceans and Australia (e.g., Wilson & Taylor 1967; Bolton 1977,1979; Clark *et al.* 1982; Wetterer & Wetterer 2004). It is also found in Japan (JADG 2003), India (Bolton 1979), and in greenhouses in the UK (Bolton 1977).

13.1.19. Biology of *W. auropunctata*

W. auropunctata is a generalist feeder on invertebrates, seeds, other plant material, and a large portion of its diet appears to consist of honeydew collected from honeydew producing insects (Clark *et al.* 1982; Torres 1984). Workers of little fire ant in New Caledonia tended native Margarodidae which promoted development of these hemipteran populations significantly larger than those attended by native ants (Le Breton *et al*. 2005). Some food is scavenged but active predation also occurs (Clark *et al*. 1982), and they pirate food from other ants (Brandao & Paiva 1994). They recruit in large numbers to abundant food sources and cooperate to carry large items (Clark *et al*. 1982; Tennant 1994). Foragers utilise plants with extra floral nectaries heavily when present (de la Fuente & Marquis 1999; Deyrup *et al.* 2000). It has been recorded once on coconut arriving from the Pacific in New Zealand (QuanCargo Database 2008).

Workers forage 24 hours a day in the arid zone in the Galapagos (Clark *et al.* 1982) and are more active at night in Puerto Rico (Torres 1984). Foraging is less affected by day/night, wind, rain, and direct sunlight than that of *S. geminata* and *P. longicornis* (Meier 1994). Workers are highly aggressive to other ant species, and in some locations where they have invaded are able to exclude other ant species completely (e.g., Jourdon 1997; Clark *et al*. 1982). In their native range they do not defend territories, but recruit to and defend food resources close to their nests (Torres 1984); the degree of monopolization can vary with the size of the food source (McGlynn & Kirksey 2000). In experiments studying agonistic interactions between the extremely invasive social termite *Coptotermes formosanus* and four adventive ant species to Hawaii, *W. auropunctata* showed the most aggressive behaviour (Kirschenbaum & Grace 2007).

Males are produced clonally, from fertilised eggs after the exclusion of maternal nuclear DNA, female queens by parthenogenesis, and female workers are produced sexually (Foucaud *et al.* 2006; Ohkawara *et al.* 2006). Both polygyne and monogyne colonies occur (Wetterer & Porter 2003). Errard and others (2005) suggest that *W. auropunctata* appears to behave as a single supercolony within its introduced range (study in New Caledonian little fire ant populations) and in its native range it acts as a multicolonial species. Uniformity of recognition cues in the New Caledonian ants may reflect the consequence of a single introduction event and subsequent aggressive invasion of the ecosystem (Errard *et al.* 2005). Colonies show low intraspecific aggression (unicolonial) and high interspecific aggression. Queens typically live about a year (Passera 1994). Sexuals are produced throughout most of the year (Passera 1994).

Clark *et al.* (1982) estimated densities of 1000–5000 workers/m2 in an area of abundance on Santa Cruz Island in the Galapagos. They do not have a defined nest but utilise any available space: under leaf debris, rotten limbs, stones, in the crotches of trees or clumps of grass, behind the sheaths of palms or palmettos, as well as spaces between plants and soil (Spencer 1941 cited in Ayre 1977; Clark *et al*. 1982). Colonies are highly mobile and will relocate if disturbed (Passera 1994). Colony densities are higher in areas in its introduced range where it has become a pest (0.75–2.7 aggregations/m2 in Galapagas, Lubin 1984; Ulloa, Chacon & Cherix 1990) than in its native range (0.05–0.13 nests/m2 in Panama: Levings & Franks 1982).

Two methods of dispersal have combined and helped the spread of *W. auropunctata* at local, regional, national and international scales: human-mediated dispersal, and budding. Most significant is human-mediated dispersal, without which the ant may never have reached its current locations. *W. auropunctata* is a 'tramp' ant (Passera 1994) renowned for transportation via human commerce and trade. In the absence of human-mediated dispersal, introduced populations of *W. auropunctata* are also believed to spread predominantly through budding (Clark *et al.* 1982). In favorable years the population may spread up to 500 m (Meier 1994). Some spread on floating vegetation/debris (particularly logs) during floods is also likely.

W. auropunctata has been described as a true generalist in its choice of nest sites (Le Breton *et al.* 2003). It occurs in a range of habitats from urban settlements (Delabie *et al.* 1995; Fowler *et al.*1990) and fields (Jeanne 1979) through to undisturbed forest (Jeanne 1979; Tennant 1994) although in more recent studies in Costa Rica the ant was found in extremely high abundance near disturbed sites and was not present in more pristine environments (Solomon & Mikheyev 2005). Generally, *W. auropunctata* nests in unstable microhabitats that favour species which can cope with frequent migrations (Passera 1994; Armbrecht & Perfecto 2003) and may occur in habitats that are wet or dry (Deyrup *et al.* 2000).

13.1.20. Prey items of *W. auropunctata*

Invertebrates, seeds, other plant material, and a large portion of its diet appears to consist of honeydew collected from Homoptera.

13.1.21. Distribution of *W. auropunctata*

Native to much of Central and South America, the little fire ant has been rapidly spreading throughout the world (Mikheyev & Mueller 2007). It is unclear how extensive the Neotropical range of *W. auropunctata* was before human spread (Wetterer & Porter 2003).

13.1.22. Hazard identification conclusion

There is evidence that both reproductives and winged individuals of ant species that occur in Tuvalu are arriving on coconut from other Pacific Islands (QuanCargo Database 2008), as well as larval and egg stages. Because of their highly invasive nature and the high impact consequences many of the 6 species would have on native ecosystems and urban environments, all ant species above are considered potential hazards in this risk analysis.

13.2. Risk assessment

13.2.1. Entry assessment

It is generally accepted that the most common way of starting a new ant colony for most species is either through the transportation of the entire colony or of those individuals capable of producing offspring - primarily the queen. The interception records show that queens of 3 ant genera found in Tuvalu have been intercepted arriving on commercial coconut consignments from the Pacific Islands to New Zealand. *Monomorium* sp. *Paratrechina* sp. and *Anoplolepis gracilipes*. *Paratrechina longicornis* and *Paratrechina* sp. have been intercepted as winged males. A larva of *Monomorium minutum* has also been recorded on coconut. The genus *Paratrechina* is particularly complex taxonomically and it is difficult to distinguish species in this group (Don 2008, D. Gunawardena pers. comm. 2007). Nesting characteristics of the species assessed here and their dispersal mechanisms are considered, to determine which species are likely to enter the country (Table 4).

There are two ways that ants could be associated with the coconuts arriving in New Zealand. Typically as hitchhikers with a random pattern of workers, queens or other adult life stages wandering onto the nuts while searching for food or a nestsite and being transported. The second way reflects an association between the ants and a major source of carbohydrate for them, the honeydew produced by scale insects or mealybugs which are themselves associated directly with the nut. (There is no direct way of proving the second association from interception records. This relationship on harvested coconuts in storage would need to be tested experimentally). Only one consignment of coconut in 2005 had both ants, and honeydew producing insects intercepted. A consignment of 4,500kg contained *Wasmannia auropunctata* eggs and larvae, the scale *Aspidiotus excisus* and the mealybug *Dysmicoccus brevipes*. The fact that larvae and eggs of *Wasmannia auropunctata* were present indicate the likely previous presence of adults and a queen.

Table 4: Nesting site and dispersal characteristics for ant species

Ant species	Nest Sites	Colony dispersal
Anoplolepis gracilipes	Includes cracks and crevices, bamboo sections and tree hollows, coconut trees	Budding off with a queen and workers
Monomorium destructor	Anywhere, forages in the crowns of coconut trees	Likely winged dispersal of inseminated queens
Paratrechina bourbonica	In soil	Winged males and queens but dispersal mode is unconfirmed
Paratrechina longicornis	Gaps in walls, thatching, dry litter, wood, trash and mulch	Males and queens winged but its unknown if they disperse by flying singly or in groups. Generally budding occurs.
Paratrechina vaga	In ground, monogynous colonies	Likely workers have winged stage which aids in founding nests independently
Tetramorium similimum	Soil, around buildings, roads, parking lots and orchards	Polygynous colonies, dispersal probably occurs via budding.
Wasmania auropunctata	Any available space, under leaves, stones, in trees, clumps of grass, spaces between plants and soil	Budding and human mediated dispersal.

Those species whose nesting sites tend to incorporate any available space, small cracks or crevices and organic material other than soil may have an increased likelihood of being associated with piles of coconuts. This includes *Anoplolepis gracilipes, Monomorium destructor*, *Paratrechina longicornis* and *Wasmannia auropunctata*. This non-specific nest site choice characteristic implies the exterior of husked and dehusked coconuts could provide suitable habitat for both foraging (if there were honeydew producing insects on the nuts) or colony dispersal. *W. auropunctata* is very small and has a very general nesting site preference, making it most likely to be undetected if it was to enter the country on coconuts. Where coconuts are stored in direct contact with soil and grass areas the likelihood of association for soil and ground nesting species such as *Tetramorium simillimum Paratrechina bourbonica* and *Paratrechina vaga* will be increased.

Anoplolepis gracilipes, Paratrechina bourbonica and *Monomorium destructor* have both been reported foraging or building nests directly in and on coconut trees. This could make an association with the coconuts themselves before export more likely. All life stages except eggs have been recorded on coconuts for *Monomorium* species. Mobile life stages primarily adult workers (mostly male) are commonly intercepted. Interception data has its limitations in telling us what the likelihood is of a particular species being more commonly associated with coconuts than any other species. The data resulting from inspections are most likely an under representation of what pests are occurring on each consignment.

The likelihood of entry for all ant species therefore is moderate to high

13.2.2. Exposure assessment

There would be no shortage of food plants or protein and carbohydrate sources for these exotic ants to utilise. In their current distributions nearly all species are predators of other invertebrates and tend homopterans for food sources. Honeydew producing insects occur in New Zealand and have been studied in beech forests in the northern South Island in relation to introduced vespulid wasps and on citrus trees and in Eucalyptus plantations (Clark 1938; Barr *et al*. 1996). The wasps compete for the honeydew resource to the exclusion of native fauna such as birds (the South Island Robin; *Petroica australis australis*) (Barr *et al.* 1996). It is highly likely that ant species coming into contact with this resource would utilise it, to the exclusion of other native fauna.

13.2.3. Establishment assessment

Three of the five genera found associated with coconuts in Tuvalu, are represented in New Zealand, namely *Tetramorium*, *Monomorium* and *Paratrechina*. Because species in the same genera are already established here it is likely that other members of the same genus could establish without being noticed particularly for *Paratrechina* species which are taxonomically difficult to distinguish.
There is little published data available for temperature tolerances or thermal thresholds for development of any ant species. The Biosecure climate modelling programme has been used to determine the likelihood of some ants establishing in New Zealand. This methodology compares the temperature ranges (mean annual temperature and mean minimum temperature) of the ants' native habitat, its introduced range and temperature data for New Zealand (Harris *et al.* 2005). This data has been used here to assess likelihood of establishment for 4 of the 7 species considered.

There has been no climate modelling done for *Tetramorium simillimum, Paratrechina bourbonica* or *Paratrechina vaga*. *P. bourbonica* is thought to be slightly more cold tolerant than some other ants introduced to the Hawaiian Islands but there are no data around thermal thresholds. Records of *P. vaga* established in Tauranga may in incorrect identifications, and could instead be *P. boubonica*. For *P. vaga* New Zealand has lower temperatures compared with the sites from which this species is reported. It is likely it would be restricted to human modified habitats and have few environmental consequences as a result (Harris *et al.* 2005). When the taxonomy for these species is reviewed and distribution records for New Zealand verified, these two species will be assessed again. For *T. simillimum* areas of suitable climate may be limited in New Zealand outside of urban areas (Harris *et al.* 2005).

The remaining 4 species have varying likelihoods of establishment based on the climate modelling undertaken.

Anoplolepis gracilipes: There is no overlap in mean annual temperature and minimal overlap for the average minimum temperature of the coldest month. It is unlikely that winters would restrict the distribution of this species, but rather that summers would not be sufficiently hot. The lack of summer heat is likely to restrict the development of brood, allowing few generations in summer (Harris *et al.* 2005).

Monomorium destructor: The mean minimum temperature of the coldest month shows some overlap with northern New Zealand and coastal areas in the southern North Island. The native and introduced range overlaps with most of the country. Outside heated buildings summers in New Zealand will probably be too cold for *M. destructor* brood to develop and populations to be maintained (Harris *et al.* 2005).

Paratrechina longicornis: The native range plus the introduced ranges show some overlap with all of New Zealand for mean annual temperature and mean temperature of the coldest month, because of distribution records from heated buildings in very cold climates. Eg. Quebec (Harris *et al.* 2005). Minimum temperatures are unlikely to restrict establishment over most of lowland New Zealand.

Wasmannia auropunctata: The mean annual temperatures overlap for northern New Zealand. Overlap of the native range data and New Zealand for minimum temperature of the coldest month is considerably wider. The lack of sufficiently high temperatures over summer for foraging and colony development is likely to severely limit the potential of this species establishing permanently outdoors in New Zealand (Harris *et al.* 2005). The species has not been reported from inside factories and hospitals in temperate locations. The habit of survival in urban areas does not appear to be as common for *W. auropunctata* as it does with some other species (e.g. *Paratrechina longicornis* and *Monomorium pharaonis*) (Harris *et al.* 2005).

The likelihood of exposure to suitable hosts and food sources is high for all species. The likelihood of establishing permanent populations outside of human modified environments is low for Paratrechina bourbonica, Paratrechina vaga and Tetramorium simillimum and moderate for establishment. The likelihood of establishment is low for A. gracilipes, and W. auropunctata, moderate for Monomorium destructor and high for Paratrechina longicornis.

13.2.4. Consequence assessment

13.2.4.1. Economic

Anoplolepis gracilipes could become a nuisance to domestic stock on farms. In abundance *A. gracilipes* can prey on newborn pigs, dogs, cats, rabbits, rats and chickens (Haines *et al.* 1994). The ant is capable of removing roots around plants, increasing honeydew producing scales, and causing build up of sooty mould on fruit and foliage, which would result in reduced plant photosynthesis and growth, and subsequent reduced crop yields and quality (e.g. Haines *et al.* 1994; Wood *et al.* 1988). Such impacts are unlikely to be significant in conventional orchards that use insecticides. Any detrimental impacts will be in part offset by the beneficial impacts of the ant as a predator of other pest species. *A. gracilipes* has been used in biological control trials (Entwistle 1972; Room 1975; Room & Smith 1975).

Monomorium destructor nests in heated buildings and there would be a high likelihood of damage to electrical equipment (Harris *et al.* 2005).

Paratrechina bourbonica is occasionally a minor nuisance in outdoor eating areas, can be abundant in gardens, and occasionally enters houses, but rarely in great numbers (Deyrup *et al.* 2000). It has been identified as one of the key pests in commercial and household premises requiring pest control in Florida (Klotz *et al.* 1995). It is likely to be restricted to human-modified habitats and have few environmental consequences.

Paratrechina longicornis is primarily a pest of urban areas where it can become abundant indoors (Lee 2002). It may be associated with honeydew-producing insects in large numbers (Wetterer *et al.* 1999), but is likely to reach large densities and be a pest only in glasshouse environments which are not considered further here. A limited economic impact assessment in New Zealand estimates potential treatment expenditure by affected sectors to be relatively small (up to $18,274 Anon 2004).

Paratrechina vaga may have the most significant impacts on other adventive ants with which it would compete. It is considered unlikely this ant would attain higher densities or have detrimental impacts beyond those of *Paratrechina* species already established in New Zealand.

Tetramorium simillimum is able to establish (at least temporarily) in glasshouses in temperate climates (e.g., the UK – Bolton 1977). It also appears able to persist in small numbers in *L. humile* infested gardens (Heterick *et al.* 2000) and will invade houses (Delabie *et al.* 1995). The presence of other adventive *Tetramorium* in New Zealand could allow it to establish unnoticed. It is unlikely to have much impact outside urban areas.

Wasmannia auropunctata is a significant horticultural pest in many areas. It stings field labourers and enhances populations of honeydew producing homopterans, which are a pest themselves, and encourage the build up of sooty mould (e.g. cocoa and citrus in Brazil Fowler *et al.* 1990), citrus in Puerto Rico (Michaud & Browning 1999) and cocao in Cameroon (de Souza *et al.* 1998). The association between *W. auropunctata* and Homoptera may increase the occurrence of diseases, including viral and fungal infections (Harris *et al.* 2005).

13.2.4.2. Environmental

International data point to the potential for *Anoplolepis gracilipes* to impact significantly on a whole range of indigenous fauna. It is likely it would invade natural habitats as it has overseas (Harris *et al.* 2005).

Monomorium destructor has the potential to establish in urban areas, but these generally have low native biodiversity values, and the ant will principally be found in buildings. It is unlikely to compete directly with native species of ant for resources, as native ants tend to be restricted to forested areas.

In Hawaii, *P. bourbonica* are found in low-growing vegetation and in undisturbed forest (but within 200 m of a road) (Wetterer 1998). Other authors record it up to 1800m altitude (Reimer 1994). It is likely to be restricted to human-modified habitats including roadsides and have few environmental consequences (Harris *et al.* 2005).

Available data suggest *Paratrechina longicornis* is generally not an ecologically dominant species, but is highly opportunistic, with its success centring on its ability to find food rapidly before other ant species. It is omnivorous and will take whatever food is available. It does best in highly disturbed or artificial environments where other species are less suited; in such locations it can become the numerically dominant ant (MacArthur & Wilson 1967; Jaffe 1993; Wetterer *et al.* 1999) displacing other ants and affecting invertebrates generally (Wetterer *et al.* 1999). Highly disturbed native habitats in New Zealand would include coastal dunes, intertidal and geothermal areas and perhaps coastal scrub (Harris *et al.* 2005). If *P. longicornis* was to establish in native habitat it would probably do so in the far north of New Zealand and on northern offshore islands, all of which have a milder subtropical climate. It would impact negatively the native fauna, particularly the invertebrate community, with many species declining and localised extinctions being possible. Invertebrate species with severely limited distributions would be most at risk. No native ants would be at risk of extinction, as they are widely distributed and present in forests that would serve as refuges (Harris *et al.* 2005).

Paratrechina vaga has not been recorded in undisturbed sites (Reimer 1994). New Zealand has low temperatures compared with the sites from which this ant is reported. It is likely it would be mostly restricted to human-modified habitats and have few environmental consequences. The main impacts may be on other adventive ants with which it would compete, and it is considered unlikely this ant would attain higher densities or have detrimental impacts beyond those of *Paratrechina* species already established in New Zealand (Harris *et al.* 2005).

Tetramorium simillimum occurs from sea level to about 1100 m in dry and mesic areas in Hawaii (introduced range) (Reimer 1994). It is limited to disturbed areas; in forested areas it is found along tracks (especially on hill tops) and roads. It has not been found in undisturbed forest (Reimer 1994). The presence of other adventive *Tetramorium* in New Zealand could allow it to establish unnoticed (Harris *et al.* 2005).

Wasmannia auropunctata is an ant of tropical climates, where it causes significant impacts to indigenous fauna, and can occupy a range of habitats from open fields (Jeanne 1979) to intact forests (Tennant 1994; Kaspari 1996; Vasconcelos 1999; Le Breton *et al.* 2003). Soil surface temperature would probably be an important factor determining where habitats were suitable for colonisation. In New Zealand during summer, soil and air temperatures inside forested habitats are several degrees colder than for pasture (Young & Mitchell 1994; Davies Colley *et al*. 2000). This would be likely to severely restrict foraging activity and colony development on the ground for this tropical ant. Optimal foraging temperatures (up near 30ºC Bestelmeyer 2000) would not occur. In northern areas of North Island New Zealand, habitats such as coastal dunes, grassy areas, and perhaps open forest margins would be most at risk of colonisation by *W. auropunctata*.

13.2.4.3. Health

Anoplolepis gracilipes was considered a medical problem on Christmas Island in the Indian Ocean, causing acute distress by entering ears, nose, eyes and open wounds, especially in the young and old (O'Dowd *et al.* 2003). In large populations of the ant it's possible for people coming into contact with large numbers of the ant to sustain formic acid burns (K. Abbott pers. comm. in Harris *et al.* 2005). They spray acid as a defence mechanism rather than bite.

Monomorium destructor does have a sting and has been reported to bite *en masse* and could be a significant nuisance to humans if it established in heated buildings. It would probably have a role in the spread of micro-organisms in kitchens and commercial food preparation areas (Smith 1965; Lee 2002) as do other building invading ants (Fowler *et al.* 1993).

Crazy ant (*Paratrechina longicornis*) may transmit diseases. It was the second most common species in three Brazilian hospitals, and at least 20% of foragers carried pathogenic bacteria (Fowler *et al.* 1993).

Wasmania auropunctata has a venomous sting, and wherever it establishes in urban and horticultural areas, it occasionally causes injury to humans and domestic animals. Multiple stings are likely to require some people to seek medical assistance (Harris *et al.* 2005). No reports of severe, systemic allergic reactions were found. Establishment in tropical glasshouses would likely result in gardeners being regularly stung as is reported in Canada (Naumann 1994). Despite being recorded as a house pest and in hospitals in Brazil, there has been no documented evidence of *W. auropunctata* causing health problems relating to disease transmission or stinging patients (Fowler *et al.* 1993).

Paratrechina bourbonica P. vaga, and *T. simillimum* appear to have no recorded human health effects in the literature.

The consequences of establishment of P. bourbonica P. vaga and T. simillimum are low for economic and environmental impacts with no human health consequences reported. For A. gracilipes and P. longicornis consequences would be moderate to high for economic and environmental and low for human health impacts. M. destructor has the potential for high economic, medium human health and low environmental consequences.
W. auropunctata is likely to have the highest impact of all species, with moderate to high impacts across all categories.

13.2.5. Risk estimation

As all 7 ant species show likelihoods of being able to enter the country, become established, at least in human modified environments and urban areas, and cause some level of unwanted consequences, the risk estimate for all species is non negligible.

Therefore A. gracilipes, M. destructor, P. bourbonica, P. longicornis, P. vaga, T. simillimum and W. auropunctata are classified as hazards on the commodity and risk management measures can be justified.

13.3. Risk management

The ant species above have been found on coconuts in interception records as hitchhikers. They don’t have a direct association with the drupe to complete any part of their lifecycle. Except where the calyx is chosen as a nest site for a small colony. These ants are likely to be either looking for the scale insects and mealybugs which produce honeydew on the outside of the coconut, or just foraging in the area and find either suitable nesting sites, or food incidentally.

Site hygiene is important for contamination prevention when the coconuts are in storage. Habitat reduction is the main reason for site hygiene. Keeping building materials, rubbish, coconut husks and crab cages etc. away from the outside of the warehouses will reduce the likelihood of ants finding nest sites and then foraging inside the warehouse to look for food. Other food items stored in the same warehouse, should be kept to a similar high standard of cleanliness as the coconuts. This will prevent contamination across products. The length of time between harvest and transportation on the export pathway should be kept to a minimum, to reduce contamination. Temporal and spatial aspects are important considerations for commodity storage.

Reducing the population of ants with a clearly designed programme of baiting and monitoring 2-3 weeks prior to export will reduce the likelihood of any pest associations being formed with the commodity. A specialist consultant in this area could be employed to formulate a control programme train and undertake baiting at the time of the first export shipment. Any programme should include both baiting and residual insecticide spraying. A residual spray can be applied several days prior to the arrival of the first consignment. Control should be applied to both the interior and exterior areas of the warehouse. More applications are likely to be required in high foot traffic zones. As *Waimannia auropunctata* is very small, could easily go undetected and would cause significant negative impacts were it to establish in New Zealand, this species should be a major focus of any baiting programme (P. Lester *pers comm.* September 2008).

The programmes should be site and species specific. Possible baits include Exterminant® which contains boric acid and MaxForce® for which the active ingredient is Hydramethylion. For more detail around chemical controls of ants see Chapter 5 Review of Management Options. It has been demonstrated that a programme of baiting around sea containers reduced contamination up to 98%. Multiple baiting systems would be required for any control approach in Tuvalu. Different ants have different preferences for sugar and carbohydrates, and these preferences can vary during the year according to colony status e.g. when reproducing they need more protein (P. Lester *pers comm*. September 2008).

13.3.1. Options

Pest management systems in coconut stands, screening measures and pre export visual inspection are considered to be part of each disinfestation treatment option given below.

Green coconut

Option 1. Scrubbing and washing of fruit surface after removal of calyx and waxing the cut surface immediately, following good hygiene practice to prevent recontamination, and then cold storage of coconuts in transit

Option 2. Option 1 plus baiting and monitoring programme to reduce risk of ants to negligible levels.

Brown coconut

Option 1. De-husking, following good hygiene practice to prevent recontamination, and cold storage of coconuts in transit

Option 2. Option 1 plus baiting and monitoring programme to reduce risk of ants to negligible levels.

Coconut apple

Option 1. De-husking, cutting off shoot and root material, waxing of cut surfaces, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

Option 2. Baiting and monitoring programme to reduce risk of ants to negligible levels

13.4. Assessment of uncertainty

There is some uncertainty around the likelihood of queens (the main reproductive units) entering the country on coconut for all species except *Anoplolepis gracilipes*. Queens from two other genera *Monomorium* and *Paratrechina* have been intercepted on coconut but not identified to species level. For *Tetramorium simillimum* and *Wasmannia auropunctata* no queens from either genus have ever been intercepted.

More information is needed about the colony dispersal mechanisms for both *Paratrechina* species and *Tetramorium simillimum*, as there is no published data in this area.

Clarification on which *Paratrechina* species are established in New Zealand is needed, particularly with regards to the *P. bourbonica* - *P. vaga* complex. The group is currently under review and when this has been completed further assessment may be undertaken.

13.5. References for chapter 13

Anderson, A N (1992) The rainforest ant fauna of the northern Kimberley region of Western Australia (Hymenoptera: Formicidae). *Journal of the Australian Entomological Society* 31: 187-192

Anderson, A N (2000) *Ants of Northern Australia: a guide to the monsoonal fauna.* Melbourne, CSIRO Publishing 106 p

Andersen, A N (2002) Common names for Australian ants (Hymenoptera: Formicidae). *Australian Journal of Entomology* 41: 285–293

Anon (2004) *Crazy ant (*Paratrechina longicornis*): economic impact assessment*. Unpublished report. Wellington, Ministry of Agriculture and Forestry. Pp7

Antweb (2007) *Paratrechina bourbonica* http://www.antweb.org/advancedsearch.do

Armbrecht, I; Perfecto, I (2003) Litter twig dwelling ant species richness and predation potential within a forest fragment and neighbouring coffee plantations of contrasting habitat quality in Mexico. *Agriculture, Ecosystems and Environment* 97: 107-115

Ayre, G L (1977) Exotic ants in Winnipeg. *Manitoba Entomologist* 11: 41–44

Barr, K; Moller, H; Christmas, E; Lyver, E; Beggs, J (1996) Impacts of introduced common wasps (*Vespula vulgaris*) on experimentally placed mealworms in a New Zealand beech forest. *Oecologia* 105(2): 266-270

Bestelmeyer, B T (2000) The trade off between thermal tolerance and behavioural dominance in a subtropical South American ant community. *Journal of Animal Ecology* 69: 998-1009

Bharti, M; Singh, D (2003) Insect faunal succession on decaying rabbit carcasses in Punjab, India. *Journal of Forensic Science* 48: 1-11

Bolton, B (1977) The ant tribe Tetramoriini (Hymenoptera Formicidae). The genus *Tetramorium* Mayr in the Melagassy Region and in the New World. *Bulletin of the British Museum (Natural History) Entomology series* 38: 129–181

Bolton, B (1979) The ant tribe Tetramoriini (Hymenoptera Formicidae). The genus *Tetramorium* Mayr in the Oriental and indo-Australian regions and in Australia. *Bulletin of the British Museum (Natural History) Entomology series* 36: 67–151

Bolton, B (1980) The ant tribe Tetramoriini (Hymenoptera: Formicidae). The genus *Tetramorium* Mayr in the Ethiopian zoogeographic region. *Bulletin of the British Museum (Natural history) Entomology Series* 40: 193-384

Bolton, B (1987) A review of the *Solenopsis* genus-group and revision of Afrotropical *Monomorium* Mayr (Hymenoptera: Formicidae). *Bulletin of the British Museum (Natural History) Entomology series* 54: 263–452

Bolton, B; Collingwood, C A (1975) *Hymenoptera, Formicidae. Handbooks for the identification of British Insects 6: part3c.* London, Royal Entomological Society of London

Brandao, C R F; Paiva, R V S (1994) The Galapagos ant fauna and the attributes of colonizing ant species. In Williams, D F (ed) *Exotic ants: biology, impact, and control of introduced species.* Westview Press; Boulder, pp 5–10

Carver, M; Inkerman, P A; Ashbolt, N J (1987) *Anagyrus saccharicola* Timberlake (Hymenoptera: Encyrtidae) and other biota associated with *Saccharicoccus sacchari* (Cockerell) (Homoptera: Pseudococcidae) in Australia. *Journal of the Australian Entomological Society* 26(4): 367-368

Clark, A F (1938) A survey of the insect pests of Eucalyptus in New Zealand. *New Zealand Journal of Science and Technology* 19(12): 750-761

Clark, D B; Guayasamin, C; Pazamino, O; Donoso, C; Paez De Villacis, Y (1982) The tramp ant *Wasmannia auropunctata*: Autecology and effects on ant diversity and distribution on Santa Cruz Island, Galapagos. *Biotropica* 14: 196–207

Collingwood, C A; Tigar, B J; Agosti, D (1997) Introduced ants in the United Arab Emirates. *Journal of Arid Environments* 37(3): 505-512

Cornelius, M L; Grace, J K (1995) Laboratory evaluations of interactions of three ant species with the formosan subterranean termite (Isoptera: Rhinotermitidae). *Sociobiology* 26(3): 291-298

Datta, S K; Raychaudhuri, D; Agarwala, B K (1982) Study on aphid tending ants in India. I. New records of aphid and ant species in their association. *Entomon* 7(3): 327-328

Davies-Colley, R J; Payne, G W; van Elswijk, M (2000) Microclimate gradients across a forest edge. *New Zealand Journal of Ecology* 24: 111-121

Davis, P R; Van Schagen, J (1993) Effective control of pest ants. *Journal of Agriculture, Western Australia,* 34: 92-95

Delabie, J H C; Do Nascimento, I C; Pacheco, P; Casimiro, A B (1995) Community structure of house-infesting ants (Hymenoptera: Formicidae) in southern Bahia, Brazil. *Florida Entomologist* 78: 264–270

De la Fuente, M A S; Marquis, R J (1999) The role of ant-tended extrafloral nectaries in the protection and benefit of a Neotropical rainforest tree. *Oecologia* 118: 192–202

Devi, C M; Singh, T K; Nilamani, L (2000) Aphidocolous ants (Hymenoptera: Formicidae) of Manipur, subfamily Formicinae. *Journal of Advanced Zoology* 21(2): 102-103

Deyrup, M; Davis, L; Cover, S (2000) Exotic ants in Florida. *Transactions of the American Entomological Society* 126: 293–326

Don, W (2008) Ants of New Zealand. Otago University Press, 240pp.

Dorow, W H O (1996) Review and bibliography of the ants of the Seychelles (Hymenoptera: Formicidae) *Journal of African Zoology* 110: 73-96

Entwistle, P F (1972) *Pests of cocoa*. London, Longman Gray Ltd. 779pg

Errard, C; Delabie, J; Jourdan, H; Hefetz, A (2005) Intercontinental chemical variation in the invasive ant *Wasmannia auropunctata* (Roger) (Hymenoptera: Formicidae): a key to the invasive success of a tramp species. *Naturwissenschaften* 92(7): 319-323

Fluker, S S; Beardsley, J W (1970) Sympatric associations of three ants: *Iridomyrmex humilis*, *Pheidole megacephala*, and *Anoplolepis longipes* in Hawaii. *Annals of the Entomological Society of America* 63: 1290–1296

Foucaud, J; Jourdan, H; Breton, J le; Loiseau, A; Konghouleux, D; Estoup, A (2006) Rare sexual reproduction events in the clonal reproduction system of introduced populations of the little fire ant. *Evolution* 60(8): 1646-1657

Fowler, H G; Bernardi, J V E; Delabie, J C; Forti, L C; Pereira da Silva, V (1990) Major ant problems of South America. In Vander Meer, R K; Jaffe, K; Cedeno, A (eds) *Applied myrmecology: a world perspective.* Westview Press, Boulder, pp 3-14

Fowler, H G; Bueno, O C; Sadatsune, T; Montelli, A C (1993) Ants as potential vectors of pathogens in hospitals in the state of Sao Paulo, Brazil. *Insect Science and its Application* 14: 367-370

Freitag, A; Dorn, K; Cherix, D (2000) First occurrence of the crazy ant *Paratrechina longicornis* (Latreille) (Hymenoptera: Formicidae: Formicinae) in Switzerland. *Bulletin de la Societe Entomologique* 73: 301-303

Haines, I H; Haines, J B; Cherrett, J M (1994) The impact and control of the crazy ant, Anoplolepis longipes (Jerdon) (Hymenoptera: Formicidae) in the Seychelles. In Williams, D F (ed) *Exotic ants: biology, impact and control of introduced species.* Boulder Westview Press Pp.206-218

Harris, R; Abbott, K; Barton, K; Berry, J; Don, W; Gunawardana, D; Lester, P; Rees, J; Stanley, M; Sutherland, A; Toft, R (2005) *Invasive ant pest risk assessment project for Biosecurity New Zealand.* Series of Internet published Landcare Research contract reports http://www.landcareresearch.co.nz/research/biocons/invertebrates/Ants/invasive_ants/documents/angora.pdf

Heinz, D J; Carlson, M K; Tabusa, R S (1980) *Annual report 1979 of the experiment station.* Report, Hawaiian Sugar Planters Association, pp 79

Heterick, B E; Casella, J & Majer, J D (2000) Influence of Argentine and coastal brown ant (Hymenoptera: Formicidae) invasions on ant communities in Perth gardens, Western Australia. *Urban Ecosystems* 4: 277-292

Hōlldobler, B; Wilson, E O (1990) *The ants.* Harvard University Press; Cambridge, Massachusetts,732 pg

Jaffe, K (1993) Surfing ants. *Florida Entomologist* 76: 182-183

Jaffe, K; Mauleon, H; Kermarrec, A (1990) Predatory ants of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) in citrus groves in Martinique and Guadeloupe, F.W.I. *Florida Entomologist* 73: 684–687

JADG (2003) *Japanese Ant image Database* http://ant.edb.miyakyo-u.ac.jp/E/Taxo/F40906.html

Jeanne, R L (1979) A latitudinal gradient in rates of ant predation. *Ecology* 60: 1211–1224

Jourdan, H (1997) Threats on Pacific islands: the spread of the tramp ant *Wasmannia auropunctata* (Hymenoptera: Formicidae). *Pacific Conservation Biology* 3: 61–64

Kalshoven, L G E (1937) Verdere aanteekeningen over de huismier, Monomorium destructor. *Jerd Ent. Meded. Nederlandsch-Indie* 3: 65-71

Kaspari, M (1996) Litter ant patchiness at the m² scale: disturbance dynamics in three neotropical forests. *Oecologia* 107: 265-273

Keall, J B (1981) *Interceptions of Insects, Mites and other animals entering New Zealand during 1973-1978.* Ministry of Agriculture and Fisheries. Plant Health and Diagnostic Station, Levin

Kirschenbaum, R; Grace, J K (2007) Agonistic interactions of four ant species occurring in Hawaii with *Coptotermes formosanus* (Isoptera: Rhinotermitidae). *Sociobiology* 50(2): 643-651

Klotz, J H; Mangold, J R; Vail, K M; Davis, L R Jr; Patterson, R S (1995) A survey of the urban pest ants (Hymenoptera: Formicidae) of Peninsular Florida. *Florida Entomologist* 78: 109-118

Lee, C Y (2002) Tropical household ants: pest status, species diversity, foraging behaviour and baiting studies. In Jones, S C; Zhai, J; Robinson, W H (eds). *Proceedings of the 4th International conference on urban pests.* Virginia, Pocohontas Press, Pg 3-18

Le Breton, J; Chazeau, J; Jourdan, H (2003) Immediate impacts of invasion by *Wasmannia auropunctata* (Hymenoptera: Formicidae) on native litter ant fauna in a New Caledonian rainforest. *Austral Ecology* 28: 204–209

Le Breton, J; Jourdan, H; Chazeau, J; Orivel, J; Dejean, A (2005) Niche opportunity and ant invasion: the case of *Wasmannia auropunctata* in a New Caledonian rain forest. *Journal of Tropical Ecology* 21(1): 93-98

Lester, P J; Keall, J B (2005) The apparent establishment and subsequent eradication of the Australian bulldog ant *Myrmecia brevinoda* Forel (Hymenoptera: Formicidae) in New Zealand. *New Zealand Journal of Zoology* 32(4): 353-357

Lester, P J; Tavite, A (2004) Long legged ants (*Anoplolepis gracilipes*) have invaded the Tokelau Atolls, changing the composition and dynamics of ant and invertebrate communities. *Pacific Science* 58: 391-402

Levings, S C; Franks, N R (1982) Patterns of nest dispersion in a tropical ground ant community. *Ecology* 63: 338–344

Lewis, T; Cherrett, J M; Haines, I; Haines, J B; Mathias, P L (1976) The crazy ant (*Anoplolepis longipes* (Jerdon) (Hymenoptera: Formicidae) in Seychelles, and its chemical control. *Bulletin of Entomological Research* 66: 97-111

Lim, S; Chong, A S; Lee, C (2003) Nestmate recognition and intercolonial aggression in the crazy ant, *Paratrechina longicornis* (Hymenoptera: Formicidae). *Sociobiology* 41: 295-305

Lubin, Y D (1984) Changes in the native fauna of the Galapagos Islands following invasion by the little red fire ant, *Wasmannia auropunctata*. *Biological Journal of the Linnean Society* 21: 229–242

MacArthur, R H; Wilson, E O (1967) *The Theory of Island Biogeography*. Princeton, N J Princeton University Press

Mallis, A (1982) *Handbook of pest control* (6th edition), Franzak and Foster, Cleveland, Ohio

McGlynn, T P; Kirksey, S E (2000) The effects of food presentation and microhabitat upon resource monopoly in a ground-foraging ant (Hymenoptera: Formicidae) community. *Revista de Biología Tropical*. 48: 629–642

Meier, R E (1994) Coexisting patterns and foraging behaviour of introduced and native ants (Hymenoptera Formicidae) in the Galapagos Islands (Ecuador). In Williams, D F (ed) *Exotic ants: biology, impact, and control of introduced species*. Westview Press; Boulder, pp 44–62

Michaud, J P; Browning, H W (1999) Seasonal abundance of the brown citrus aphid, *Toxoptera citricida* (Homoptera: Aphididae) and its natural enemies in Puerto Rico. *Florida Entomologist* 82: 424-447

Mikheyev, A S; Mueller, U G (2007) Genetic relationships between native and introduced populations of the little fire ant *Wasmannia auropunctata*. *Diversity and Distribution* 13(5): 573-579

Morrison, L W (1996) The ants (Hymenoptera: Formicidae) of Polynesia revisited: species numbers and the importance of sampling intensity. *Ecography* 19: 73–84.

Nauman, K; (1994) An occurrence of two exotic ants (Formicidae) species in British Colombia. *Journal of the Entomological Society of British Columbia* 91: 69-70

Nickerson, J C; Barbara, K A (2000) *Featured Creatures. Crazy ant Paratrechina longicornis*. University of Florida Institute of Food and Agricultural Services, and Florida Department of Agriculture and Consumer Services. http://entomology.ifas.ufl.edu/creatures/urban/ants/crazy_ant.htm

O'Dowd, D J (2004) *ISSG Global Invasive Species Database*: *Anoplolepis gracilipes*. http://www.issg.org/database/species/ecology.asp?si=110 Accessed 8/7/2008

Ohkawara, K; Nakayama, M; Satoh, A; Trindl, A; Heinze, J (2006) Clonal reproduction and genetic caste differences in a queen polymorphic ant, *Vollenhovia emeryi*. *Biology Letters* 2(3): 359-363

Passera, L (1994) Characteristics of tramp species. In Williams, D F (ed) *Exotic ants: biology, impact and control of introduced species.* Westview Press; Boulder, pp 23-43

Perrault, G H (1987) Ants of Tahiti. *Bulletin de la Societe Zoologique de France* 112(3-4): 429-446

QuanCargo Database (2008) *Interception Record Database*. Ministry of Agriculture and Forestry

Rao, N S; Veeresh, G K (1991) Some observations on the biology and behaviour of crazy ant, *Anoplolepis longipes* (Jerdon) (Hymenoptera: Formicidae). *Entomon* 16(4): 261-267

Reimer, N J (1994) Distribution and impact of alien ants in vulnerable Hawaiian ecosystems. In Williams, D F (ed) *Exotic ants: biology, impact, and control of introduced species.* Westview Press; Boulder, pp 11–22

Richardson, C A (1979) *Interceptions of Insects, Mites and other animals entering New Zealand 1966-1972.* Ministry of Agriculture and Fisheries. Plant Health and Diagnostic Station, Levin

Room, P M (1975) Relative distributions of ant species in cocoa plantations in Papua New Guinea. *The Journal of Applied Ecology* 12: 47-61

Room, P M; Smith, E S C (1975) Relative abundance and distribution of insect pests, ants and other components of the cocoa ecosystem in Papua New Guinea. *Journal of Applied Ecology* 12: 31-46

Sands, W A (1972) The soldierless termites of Africa. *Bulletin of the British Museum of Natural History, Entomology Supplement* 18: 1–244

Smith, M R (1965) *House-infesting ants of the eastern United States.* Technical Bulletin, Agricultural Research Service, U.S. Department of Agriculture, 1326

Solis, D R; Bueno, O C; Moretti, T C (2007) Immature development in the tramp ant species *Paratrechina longicornis* (Hymenoptera: Formicidae). *Sociobiology* 50(2): 499-512

Solomon, S E; Mikheyev, A S (2005) The ant (Hymenoptera: Formicidae) fauna of Cocos Island, Costa Rica. *Florida Entomologist* 88(4): 415-422

Spencer H (1941) The small fire ant *Wasmannia* in citrus groves: A preliminary report. *Florida Entomologist* 24: 6-14

Taylor, R W (1987a) *A checklist of the ants of Australia, New Caledonia and New Zealand (Hymenoptera: Formicidae)* CSIRO Division of Entomology Report No. 41: 1-92

Taylor, R W (1987b) *A checklist of the ants of Australia, New Caledonia and New Zealand (Hymenoptera: Formicidae) First Supplement.* 10 July 1987 CSIRO Division of Entomology Report No 41(Supplement 1): 1-5

Tennant, L E (1994) The ecology of *Wasmannia auropunctata* in primary tropical rainforest in Costa Rica and Panama. In Williams, D F (ed) *Exotic ants: biology, impact, and control of introduced species*. Westview Press; Boulder, pp 80–90

Teranishi, T (1929) Ants found in dwelling houses in Loochoo. *Kontyu,* March 3(1): 41-42

Torres, J A (1984) Niches and coexistence of ant communities in Puerto Rico: repeated patterns. *Biotropica* 16: 284–295

Townsend, J I (1984) *Interceptions of Insects, Mites and other animals entering New Zealand during 1979-1982.* Ministry of Agriculture and Fisheries. Plant Health and Diagnostic Station, Levin

Trager, J (1984) A revision of the genus *Paretrechina* (Hymenoptera: Formicidae) of the continental United States. *Sociobiology* 9: 51-162

Ulloa-Chacon, D; Cherix, D (1990) The little fire ant *Wasmannia auropunctata* (Roger) (Hymenoptera: Formicidae). In Van der Meer, R K; Jaffe, K; Cedeno, A (ed) *Applied myrmecology: a world perspective.* Westview Press; Boulder, pp 281–289

Vasconcelos, H L (1999) Effects of forest disturbance on the structure of ground foraging ant communities in central Amazonia. *Biodiversity and Conservation* 8: 407-418

Vargo, D L (2000) Soil Invertebrates of American Samoa. *Micronesica* 33: 1–10

Way, M J; Javier, G; Heong, K L (2002) The role of ants, especially the fire ant *Solenopsis geminata* (Hymenoptera: Formicidae), in the biological control of tropical upland rice pests. *Bulletin of Entomological Research* 92: 431-437

Way, M J; Cammell, M E; Bolton, B; Kanagaratnam, P (1989) Ants (Hymenoptera: Formicidae) as egg predators of coconut pests, especially in relation to biological control of the coconut caterpillar, *Opisina arenosella* Walker (Lepidoptera: Xyloryctidae), in Sri Lanka. *Bulletin of Entomological Research* 79: 219–233

Wetterer, J K (1998) Non-indigenous ants associated with geothermal and human disturbance in Hawaii Volcanoes National Park. *Pacific Science* 52(1): 40-50

Wetterer, J K; Porter, S D (2003) The little fire ant, *Wasmannia auropunctata*: distribution, impact, and control. *Sociobiology* 42: 1–41

Wetterer, J K; Walsh, P D; White, L J T (1999) *Wasmannia auropunctata* (Roger) (Hymenoptera: Formicidae), a highly destructive tramp ant, in wildlife refuges of Gabon, West Africa. *African Entomology* 7: 292.294.

Wetterer, J K; Wetterer, A L (2004) Ants (Hymenoptera: Formicidae) of Bermuda. *Florida Entomologist* 87: 212–221

Wheeler, W M (1910) *Ants: their structure, development and behaviour*. New York, Columbia, University Press 663p

Whitcomb, W H; Gowan, T D; Buren, W F (1982) Predators of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) larvae. *Florida Entomologist* 65: 150–158

Wilson, E O; Taylor, R W (1967) The ants of Polynesia (Hymenoptera: Formicidae). *Pacific Insects Monograph* 14: 1-109

Wojcik, D P (1994) Impact of red imported fire ant on native species in Florida. In: Williams, D F (ed) *Exotic ants: biology, impact and control of introduced species*. Colorado, Westview Press: 269-281

Wood, B W; Tedders, W L; Reilly, C C (1988) Sooty mould fungus on pecan foliage suppresses light penetration and net photosynthesis. *Hortscience* 24: 231-265

Young, A; Mitchell, N (1994) Microclimate and vegetation edge effects in a fragmented podocarp-broadleaf forest in New Zealand. *Biological Conservation* 67: 63-72

14. Pathogens

14.1. Hazard identification

Scientific name: *Phytophthora palmivora* Butler (Oomycetes: Pythiaceae)
Synonyms for P. palmivora: *Phytophthora palmivora* var. *palmivora*, *Phytophthora arecae, Phytophthora cactorum* var. *arecae, Phytophthora faberi, Phytophthora heveae, Phytophthora omnivora* var. *arecae, Phytophthora palmivora* var. *heveae, Phytophthora palmivora* var. *theobromae, Phytophthora theobromae, Pythium palmivorum* (Farr *et al.* 2008)

Scientific name: *Pseudoepicoccum cocos* (Stevens) Ellis

New Zealand Status: Neither pathogen occurs in New Zealand: (Pennycook & Galloway 2004; PPIN 2008)

14.1.1. Biology of *P. palmivora*

Phytophthora palmivora causes bud rot, fruit and immature nutfall, and causes significant coconut yield losses (Sudheesh & Sreekumar 2006). Green husked coconuts arriving from other Pacific Island countries have been observed with stem end rot when the calyx remains untrimmed (Grandison 2001). The disease cycle of this pathogen is complex with numerous routes and sources of transmission (Namaliu *et al.* 2006). *P. palmivora* is heterothallic, having an incompatibility system by which only genetically different strains can undergo nuclear fusion during sexual reproduction. There are two mating types of *P. palmivora* (A^1 and A^2), and both are found in many areas of the world (Zentmyer 1988).

Fallen fruit "attract" *P. palmivora* from the soil and sporulation is profuse under moist conditions. Sporangia can be dispersed at least 0.5m into the tree by rain splash.
Fruits approaching maturity are infected by the sporangia and zoospores this way. Secondary infections are then caused by sporangia spread through the tree by splashing water, windblown rain and, less commonly, by invertebrates such as snails beetles and ants (Taylor & Griffin 1981; Timmer *et al.* 2000; Graham & Menge 2000; Konam & Guest 2004).

Most infected fruit soon abscise but harvested fruit may not show symptoms until after they have been held in storage for a few days. Brown rot presents with a light brown discoloration initially, then a delicate white mycelium forms, accompanied by a distinctive pungent, rancid odour (Graham and Menge 2000). Soil populations are maintained by repeated infections of the fibrous roots and *P. palmivora* can persist in unfavourable conditions for some time as chlamydospores (Graham and Menge 2000).

Pod boring beetles (Coleoptera: Scolytidae and Nitidulidae) preferentially colonised cocao pod lesions caused by *P. palmivora* in Papua New Guinea (Konam & Guest 2004). The beetles were attracted to the lesions, where they rapidly generate and transmit secondary inoculum in epidemics of pod rot (Konam & Guest 2004). Several ant species including *Technomyrmex albipes*, *Crematogaster striatula*, *Pheidole megacephala* and species in the genera *Oecophylla* and *Macromischoides* are associated with spread of the disease in cocao (Muller *et al.* 1969; Adenuga 1975; Taylor 1977; Babacauh 1982; McGregor & Moxon 1985). The mealybug *Planococcoides njalensis* is a major hemipteran pest on the Ivory Coast and a vector of swollen shoot virus in Nigeria (Adenuga 1975; Babacauh 1982). The ants tending the mealybug include pieces of old diseased pods, soil containing spores and even bits of the actual fungus in the construction of shelters for the scale insects and thus help spread the disease (Babacauh 1982). *Crematogaster* and *Macromischoides* have been found to reduce populations of injurious Mirids (Heteroptera: Miridae) such as *Distantiella* and *Sahlbergella* spp which pierce pods and create damage (Adenuga 1975).

Erwin and Ribeiro (1996) state the minimum temperature for growth as 11˚C, the optimum between 27.5 to 30˚C, and the maximum near 35˚C. Optimal temperature ranges for infection and disease development on oranges in Florida was between 27 and 30˚C and the optimal temperature for sporangium production on the fruit surface was 24˚C (Timmer *et al.* 2000). Although inhibiting disease development, temperatures ranging from 10-22˚C would not prevent sporangium formation. Therefore sporangia are likely to be dispersed by rain with lesions developing when temperatures increased. Even at optimal temperatures sporangia development is slow on fruit, taking up to 72 hours (Timmer *et al*. 2000). In tropical areas with frequent rainfall and temperatures between 20-30˚C *P. palmivora* produces sporangia rapidly and has a short regeneration time (Erwin and Ribeiro 1996).

14.1.2. Hosts of *P. palmivora*

P. palmivora infects more than 200 species of economic, ornamental, shade and hedge plants including the following:
Anacardium occidentale (cashew nut), *Ananas comosus* (pineapple), *Annona*, *Antirrhinum majus*, *Areca catechu* (betelnut palm), *Areca lutescens*, *Artocarpus altilis* (breadfruit), *Capsicum annuum*, *Cattleya* sp., *Carica papaya* (papaw), *Citrus* sp., *Cocos nucifera*, *Colocasia* sp., *Crotalaria* sp., *Cymbidium* sp., *Dendrobium* sp., *Dianthus caryophyllus*, *Dieffenbachia* sp., *Durio zibethinus* (durian), *Elaeis guineensis* (African oil palm), *Euphorbia* sp. *Ficus carica* (fig), *Gossypium hirsutum* (Bourbon cotton), *Grevillea* sp., *Hedera* sp., *Hevea brasiliensis* (rubber), *Hibiscus* sp., *Howea* sp., *Lavandula* sp., *Lycopersicon esculentum*, *Macadamia integrifolia*, *Magnolia grandiflora*, *Manihot esculenta* (cassava), *Mangifera indica*, *Manilkara zapota* (sapodilla), *Myristica fragrans* (nutmeg), *Paphiopedilum* sp., *Peperomia* sp., *Persea americana*, *Petunia violacea, Phalaenopsis* sp., *Phaseolus* sp., *Philodendron* sp., *Piper nigrum* (black pepper), *Rhopalostylis baueri*, *Solanum tuberosum, Syzygium paniculatum, Theobroma cacao* (cocoa) (CPC 2007; Graham & Menge 2000; Farr *et al*. 2006-partial list).

14.1.3. Distribution of *P. palmivora*

P. palmivora is typically found in tropical and subtropical countries with high rainfall. It is present throughout Asia, parts of Europe, Africa, southern North America, Central and South America. It is found in Australia, is widespread in American Samoa, Fiji, French Polynesia, New Caledonia, Northern Mariana Islands, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu and Tuvalu (CPC 2007; Dharmaraju 1980).

14.1.4. Biology of *P. cocos*

There is little literature on the biology of this species. It is transmitted aerially, by airborne conidia (Hyde 1992). It is an occasional palm pathogen which has been recorded from coconut in Tuvalu (Hyde 1992). The symptoms are oval reddish brown zonate leaf spots (Hyde 1992). It is recorded commonly from leaves (Farr *et al.* 2008).

14.1.5. Hosts of *P. cocos*

Its hosts include *Areca* sp., *Cocos nucifera*, and *Elaeis guineensis* (Hyde 1992).

14.1.6. Distribution of *P. cocos*

It is found in Asia; India, Malaysia, Thailand, Pakistan, Indonesia, Sarawak and the Philippines, Africa in Tanzania, the Indian Ocean in Seychelles and Mauritius, the Caribbean in Jamaica, and is widespread in the Pacific, including Australia, Cook Islands, Solomon Islands, Kiribati, New Caledonia, Vanuatu, Niue, Papua New Guinea, Tonga, Tuvalu and Western Samoa (Hyde 1992).

14.1.7. Hazard identification conclusion

If coconuts are arriving dehusked there is a negligible risk of either *Pseudoepicoccum cocos* or *Phytophthora palmivora* being associated with the commodity, as long as good post harvest storage practices are maintained. If the coconuts are arriving with husks there may be a non negligible likelihood of association. *P. cocos* predominantly attacks leaves, and has a distribution restricted to tropical and subtropical areas, making it likely the climate in New Zealand would be a significant limitation to its establishment. *Pseudoepicoccum cocos* is therefore not considered further in this analysis.

Phytophthora palmivora commonly attacks fruit and has been recorded on the nut of *Cocos nucifera*. Its thermal thresholds for development are likely lower than *P. cocos* and for these reasons *P. palmivora* is considered a hazard on the pathway.

14.2. Risk assessment

14.2.1. Entry assessment

Infected fruit may not show signs of disease caused by *Phytophthora palmivora* for several days, which means this fungus could enter the country undetected. Given that transport times are likely to be relatively long however (at least a week by boat) which would increase the likelihood of disease expression before consignments arrived the likelihood of entry of *P. palmivora* to new Zealand is considered to be low to moderate.

The likelihood of P. palmivora entering the country therefore is low to moderate

14.2.2. Exposure assessment

The time from harvest in Tuvalu until distribution in New Zealand is estimated to be around 2 weeks. If there are green coconuts arriving with *P. palmivora* showing obvious symptoms, it is likely these nuts will be picked up during visual inspection and discarded. For nuts that do not have symptoms and with latent infection, there would be no shortage of host plants available for *P. palmivora* to utilise year round. Especially if husks are disposed of in compost heaps in gardens with host species. These include a range of ornamental and horticultural plants including *Capsicum*, *Citrus* spp., *Hibiscus*, tomato, *Magnolia*, macadamia, avocado and potato.

14.2.3. Establishment assessment

It is unclear if *P. palmivora* dies or becomes dormant at temperatures below 10-11˚C.
If *P. palmivora* dies below 10˚C it is unlikely to establish in New Zealand.
If *P. palmivora* becomes dormant under 10-11˚C there is a medium likelihood of it establishing in New Zealand, particularly the north of the North Island.

However, disease development occurs at higher temperatures (27-30˚C-Erwin and Ribeiro 1996, Timmer *et al*. 2000), and sporangia can take up to 72 hours to develop on *Citrus* at optimal temperatures (Timmer *et al*. 2000). The mean monthly minimum and maximum temperatures (in the period 1971-2000) for Kaitaia (35˚.08'S, 173˚.17'E) in February were 15.6˚C and 24.5˚C respectively (NIWA 2001). In the North Island it is unusual to have several days at temperatures of 27˚C or higher, and night temperatures would be much less, so there is a very low likelihood of *P. palmivora* developing pathogenicity in New Zealand.

The likelihood of exposure for P. palmivora is moderate, and likelihood of establishment low to moderate. Development of pathogenicity in New Zealand is considered low.

14.2.4. Consequence assessment

14.2.4.1. Economic

Phytophthora pod rot causes 10-30% annual losses in production of cocoa beans globally (McMahon & Purawantara 2004). *P. palmivora* attacked a variety of forest tree species in nurseries in India, where it was associated with leaf blight, damaged young seedlings and caused up to 90% defoliation of *Murraya azedarach* (Mehrotrotha & Mehrotrotha 2000). Nurseries in New Zealand would likely be affected by the same kinds of damage, but it is unknown how susceptible native flora would be to infection.

In some situations, for example *Diaprepes abbreviatus* (Coleoptera: Curculionidae) a root weevil attacks fibrous and structural roots of citrus, predisposing the root system to infection and girdling by *Phytophthora* in Florida (Graham *et al*. 2003). If there were already pests such as weevils or root nematodes associated with important crops like citrus in New Zealand, there is the potential for these associations to be created. Natural stresses such as drought, heavy rain or mist, insect attack or lack of cultural controls of diseased plant parts in cropping systems can predispose flora to outbreaks of the pathogen.

As *P. palmivora* has a broad host range and occurs in many kinds of environments it is likely some economic damage will be seen should it establish in New Zealand. But the likely levels are unpredictable given the complex array of ecological factors involved in disease expression.

14.2.4.2. Environmental

Phytophthora Taxon Agathis, originally described as *P. heveae* in 1972 when it was found associated with dying *Agathis australis* (kauri) trees in native forest on Great Barrier Island (Northern New Zealand) has been found more recently in other parts of northern mainland New Zealand attacking kauri and cherimoya an exotic fruit. Its taxonomy is not fully resolved but it is believed to pose a threat to kauri, leading to the possible loss of this cultural icon (Beever *et al.* 2007). This indicates there is a likelihood for even (unresolved taxonomically) native *Phytophthora*'s to negatively impact the environment.

P. palmivora has been recorded on several species represented by genera in the native flora including *Euphorbia*, *Hibiscus*, *Peperomia*, *Solanum* and *Syzygium* species (Farr *et al.* 2008). Most of the native plants in these genera are neither wide spread or common outside of natural habitats which include sand dunes, streamsides in forest and as understory herbs. *Solanum aviculare*, *S. laciniatum* and *S. americanum* may be more common in urban environments and could have a higher likelihood of being infected.

14.2.5. Risk estimation

The likelihoods of entry exposure and establishment in New Zealand for *Phytophthora palmivora* are low-moderate, moderate and low. The potential consequences economically and for the environment range from low to high depending on how the pathogen interacts with the complex suite of variables that give rise to disease expression.

Therefore P. palmivora is classified as a hazard on the commodity and risk management measures are justified.

14.3. Risk management

14.3.1. Options

Pest management systems in coconut stands, screening measures and pre export visual inspection are considered to be included with each disinfestation treatment option given below.

Green coconut

Option 1. Scrubbing and washing of fruit surface after removal of calyx and waxing the cut surface immediately, following good hygiene practice to prevent recontamination, and then cold storage of coconuts in transit

Brown coconut

Option 1. De-husking, following good hygiene practice to prevent recontamination, and cold storage of coconuts in transit

Coconut apple

Option 1. De-husking, cutting off shoot and root material, waxing of cut surfaces, following good hygiene practice to prevent recontamination and cold storage of coconuts in transit.

14.4. Assessment of uncertainty

The biology of *P. palmivora* whose aetiology is between that of an algae and a fungus is highly complex. Environmental variability plays a major role in influencing pathogenicity and incidence of many *Phytophthora* species. A high level of uncertainty will remain around the likely impacts *P. palmivora* could cause economically and to the natural environment. Host testing native plant species overseas to assess vulnerability could reduce this level of uncertainty.

14.5. References for chapter 14

Adenuga, A O (1975) Mutualistic association between ants and some Homoptera – its significance in cocoa production. *Psyche* 82(1): 24-28

Babacauh, K D (1982) Role of insect communities and water in the dissemination of *Phytophthora palmivora* (Butler) Butler ammended Bras. & Griff. in Cacao plantations in the Ivory Coast. *Café, Cacao, Thé* 26(1): 31-36

Beever, R E; Waipara, N M; Ramsfield, T D; Dick, M A; Horner, I J (2007) Kauri (*Agathis australis*) under threat from *Phytophthora*? *Proceedings 4th IUFRO working party on*

Phytophthoras in Forests and Native Ecosystems, 26-31 August 2007, Monterey, California, USA (submitted)

CPC (2007) *Phytophthora palmivora*. CABI-Crop Protection Compendium. CAB International,Wallingford, UK.
http://www.cabicompendium.org/

Dharmaraju, E (1980) Pest Problems of crops in Tuvalu. *Alafua Agricultural Bulletin* 5(4): 7-9

Erwin, D C; Ribeiro, O K (1996) Phytophthora *diseases worldwide.* APS Press, St Paul, Minnesota

Farr, D F; Rossman, A Y; Palm, M E; McCray, E B (2008) *Pestalotiopsis palmarum* specimens records. *Fungal Databases*, Systematic Mycology and Microbiology Laboratory, ARS, USDA http://nt.ars-grin.gov/fungaldatabases/

Graham, J H; Bright, D B; McCoy, C W (2003) *Phytophthora Diaprepes* weevil complex: *Phytophthora* spp. relationship with citrus rootstocks. *Plant Disease* 87(1): 85-90.

Graham, J H; Menge, J A (2000) *Phytophthora*-induced diseases. In Timmer, L W; Garnsey, S M; Graham, J H (eds) *Compendium of Citrus Diseases 2nd Edition.* American Phytopathological Society

Grandison, G (2001) *Progress Report for post harvest quality survey of fresh produce from Pacific Island countries.* For Ministry of Agriculture and Forestry, New Zealand
www.spc.int/pps/Other/PH%20NZ%20November%20report.doc

Hyde, K D (1992) *Pseudoepicoccum cocos. IMI Descriptions of Fungi and Bacteria*. Sheet 1129

Karthikeyan, A; Bhaskaran, R (1999) Incidence of leaf blight disease in relation to age, vigour of coconut seedlings and yield of palms. *Madras Agricultural Journal* 86(1/3): 80-82

Konam, J K; Guest, D I (2004) Role of beetles (Coleoptera: Scolytidae & Nitidulidae) in the spread of *Phytophthora palmivora* pod rot of cocoa in Papua New Guinea. *Australasian Plant Pathology* 33(1): 55-59

McGregor, A J; Moxon, J E (1985) Potential for biological control of tent building species of ants assocaited with Phytopthora palmivora pod rot of cocao in Papua New Guinea. *Annals of Applied Biology* 107(2): 271-277

McMahon, P; Puruwantara, A (2004) *Phytophthora* on cocoa. Diversity and Management of *Phytophthora* in Southeast Asia. *ACIAR Monograph* No. 114: 104-115

Mehrotrotha, A; Mehrotrotha, M D (2000) *Phytophthora* leaf blight of some forest trees. *Indian Journal of Forestry* 23(2): 142-148

Muller, R A; Njomou, S E; Lotode, R (1969) Field evaluation of fungicides against black pod rot of cacao casued by *Phytophthora palmivora*. Assessment of a rapid method. *Café-Cacao-Thé* 13: 34-54

Namaliu, Y; Vano, J T; Konam, J K (2006) A preliminary study of the epidemiological cycle of *Phytophthora palmivora*: integrated disease management of cocoa in relation to cocoa cropping cycle. *ACIAR Technical Reports Series* 62: 84-88

NIWA (2001) *Overview of New Zealand Climate.* National Institute of Water and Atmospheric research website http://www.niwa.cri.nz/edu/resources/climate/overview

Pennycook, S R; Galloway, D J (2004) Checklist of New Zealand "fungi", In McKenzie, E H C (ed) Introduction to fungi of New Zealand. *Fungi of New Zealand / Nga Harore o Aotearoa,* Volume 1. Fungal Diversity Press; Hong Kong, pp 401-488

PPIN (2008) *Plant Pest Information Network.* Database for the Ministry of Agriculture and Forestry, New Zealand

San Juan Bachiller, N (2004) Distribution and progression of *Phytophthora* bud rot disease of coconut in selected areas in the Philippines. *Diversity and Management of* Phytophthora *in Southeast Asia* 124-131

Stamps, D J (1985) *Phytophthora palmivora*. *IMI Descriptions of Fungi and Bacteria*. Sheet 831 (84) CAB International; Wallingford, UK

Subramanyan, K; Santha, K P (2007) Epidemiology of grey blight of coconut (*Cocos nucifera* L.). *Indian Coconut Journal* 38(2): 10-12

Sudheesh, K G; Sreekumar, V B (2006) Genetic variability in *Phytophthora palmivora* (Butler) using RAPD markers. *Journal of Phytopathology* 154(9): 542-544

Taylor, P A (1977) *Phytophthora* spp. in irrigation water in the Goulburn Valley, Victoria. *APPS Newsletter* 6(3): 41-42

Taylor, B; Griffin, M J (1981) The role and relative importance of different ant species in the dissemination of black pod disease of cocoa. In Gregory, P H; Madison, A C (eds) *Epidemiology of Phytophthora on Cocoa in Nigeria.* CAB International; Wallingford, UK, 132-144

Timmer, L W; Zitko, S E; Gottwald, T R; Graham, J H (2000) *Phytophthora* brown rot of *Citrus*: temperature and moisture effects on infection, sporangium production and dispersal. *Plant Disease* 84 (2): 157-163

Zentmyer, G A (1988) Origin and distribution of four species of *Phytophthora*. *Transactions of the British Mycological Society* 91(3): 367-378

Research priorities

There is a paucity of information on the efficacy of the available risk mitigation options in managing the biosecurity hazards associated with coconut fruit. This chapter identifies research priorities. This will enable us to validate the assumptions made in the risk analysis.

- Washing
  This is a simple and affordable treatment. Comparisons are needed between washing coconuts under a running tap; washing and brushing under running water; submersing in chlorinated water for a set time; submersing and brushing. Scrubbing and wiping the surface with a damp cloth or sponge and appropriate bleach+detergent.
  Efficacy needs to be tested for mealybugs, scales, mites, ants bugs and fungal pathogens.

- Coconut apple quality post harvest
  There is no published data on maintaining coconut apple (embryo) quality after harvest. There are estimates of 2 weeks around the time it can maintain texture and freshness suitable for consumption. Thorough testing is needed to ensure that the effort of harvesting, handling and transporting fruit will enable a quality product to enter the market in New Zealand. As this life stage of coconut is considered a delicacy it may prove to be popular, but further research is needed to confirm cost benefit of export.

- Produce disposal
  Scientific information regarding the disposal of bought fresh produce in New Zealand is required to determine the likelihood of associated pests being able to move from the commodity to another host. This is required particularly where coconuts are arriving into New Zealand with mature green husks. These may harbour scales insects, mealybugs and other surface pests. Some organisms such as *Chrysomphalus aonidum* has been found to survive up to 4 weeks on picked citrus fruit after harvest, and up to 17 days on the peels (Schweig & Grunberg 1936).

- Ant colonisation
  Hitchhiker species like ants are highly mobile and can be associated with products without having a direct use of the commodity to complete any part of their lifecycle. Winged males, queens and workers have been intercepted on coconuts coming from other Pacific Island pathways on a regular basis. It is not known however, how many individuals it takes to establish a colony here in New Zealand. The minimum number of individuals needed to colonise for key invasive ant species would be useful information. It is suggested that testing of this question be carried out.

- Mite fauna survey
  It is necessary to investigate and sample the mite fauna of Tuvalu. It is highly likely that there is more than one species of mite found in the atolls and islands of the group. However currently little literature or recorded data exist. Coconuts from other islands have a rich mite fauna in interception records particularly from the *Rhizoglyphus* genus (taro mites). These mites cause significant damage to crops where they occur and are a serious pest, currently with unwanted status in New Zealand. A survey of soil and of other crops such as taro could reveal these mites in the country and allow future more detailed assessment of the risk posed by mites to coconut exported from Tuvalu to New Zealand.

Appendix 1. Organisms considered in the risk analysis

Common name	Scientific name	In NZ?	Associated with coconut	Potential hazard	Hazard
Acari					
Vegetable mite, Mexican spider mite	*Tetranychus neocaledonicus* André (Acari: Tetranychidae)	N Zhang *et al.* (2002)	Y[1] Moutia 1958	N	N
Coleoptera					
Bark beetle	*Hypothenemus sp. nr. cassavaensis* Schedl (Coleoptera: Curculionidae)	N Leschen *et al.* (2003)	N[2]	N	N
Diptera					
House fly	*Musca domestica* Linneaus (Diptera: Muscidae)	Y Heine (1938)	N[3]	N	N
Hemiptera					
Coconut scale	*Aspidiotus destructor* Signoret (Hemiptera: Diaspididae)	N Charles & Henderson (2002)	Y Mariau (2001)	Y	Y See Chapter 6.1
Circular black scale	*Chrysomphalus aonidum* Linnaeus (Hemiptera: Diaspididae)	N Charles & Henderson (2002)	Y Maskew (1915)	Y	Y See Chapter 6.2
Dictyospermum scale	*Chrysomphalus dictyospermi* Morgan (Hemiptera: Diaspididae)	N Charles & Henderson (2002)	Y Fleury (1931)	Y	Y See Chapter 6.2
	Chrysomphalus propsimus Banks (Hemiptera: Diaspididae)	N Charles & Henderson (2002)	Y McKenzie (1939)	Y	N See Chapter 6.2
Brown soft scale	*Coccus hesperidum* Linnaeus (Hemiptera: Coccidae)	Y Clark (1938)	Y Fernando & Kanagaratnam (1987)	N	N

[1] In the main reference to its association with *Cocos nucifera* Moutia (1958) reports *T. neocaledonicus* as attacking coconut sporadically, causing no great damage. It is generally controlled by predatory mites such as *Typhlodromus caudatus* (Moutia 1958). There are no examples of any *Tetranychus* spp. associated with coconuts imported from the Pacific in interception records, and it is doubtful the mite infests mature nuts. It is therefore not considerd further in this analysis.

[2] *Hypothenemus* sp. nr. *cassavaensis* which is considered a synonym of *Hypothenemus seriatus*, by Wood & Bright (1992) breeds in the pith of twigs of a wide variety of plants. Although it was collected in the storage facility hitchhiker survey is not associated with coconut in the literature. No members of the genus are recorded on coconut from the Pacific in interception records.

[3] This fly was collected in the storage facility hitchhiker survey, inside the warehouse. But is not known to be associated with coconut, and also occurs in New Zealand.

Common name	Scientific name	In NZ?	Associated with coconut	Potential hazard	Hazard
Green coffee scale	*Coccus viridis* Green (Hemiptera: Coccidae)	N Hodgson & Henderson (2002)	Y De Lotto (1960)	N[4]	N
Angraecum scale	*Conchaspis angraeci* Cockerell (Hemiptera: Conchaspididae)	N Hodgson & Henderson (2002)	N[5]	N	N
Grey sugarcane mealybug	*Dysmicoccus boninsis* (Kuwana) (Hemiptera: Pseudococcidae)	N[6] Cox (1987)	Y Williams & Watson (1988)	Y	Y See Chapter 6.3
Pineapple mealybug	*Dysmicoccus brevipes* (Cockerell) (Hemiptera: Pseudococcidae)	N[7] Cox (1987)	Y Bindhu-Radhakrishnan *et al.* (2003)	Y	Y See Chapter 6.3
Pacific coconut mealybug	*Dysmicoccus cocotis* (Maskell) (Hemiptera: Pseudococcidae)	N Cox (1987)	Y Williams (1994)	N[8]	N
Tessellated scale	*Eucalymnatus tessellatus* (Signoret) (Homoptera: Coccidae)	N Hodgson & Henderson (2000)	Y Vesey Fitzgerald (1941)	N[9]	N
Striped mealybug	*Ferrisia virgata* (Cockerell) (Homoptera: Pseudococcidae)	N Cox (1987)	Y Williams & Ganara de Willink (1992)	Y	Y See Chapter 6.4
Latania scale	*Hemiberlesia lataniae* (Signoret) (Hemiptera: Diaspididae)	Y Blank *et al.* (1995)	Y Gowdey (1923)	N	N

[4] *Coccus viridis* is often found feeding from phloem along the main vein of the leaf and near the tips of green shoots in host plants. It is usually found on stems, leaves, and green twigs (Copland & Ibrahim, 1985). There is no record of it on the coconut drupe itself.

[5] This scale occurs in Tuvalu (Williams & Watson 1990; Ben-Dov *et al.* 2001) and has a fairly wide host range but has not been recorded on coconut there or elsewhere within its distribution.

[6] *D. boninsis* is erroneously recorded as being present in New Zealand in Ben-Dov *et al.* (2001) quoting Kirkaldy (1909). Kirkaldy's publication reviews the hemipteran fauna of Hawaii, not New Zealand

[7] *Dysmicoccus brevipes* was found in a plum orchard in Auckland in November 1997, but a subsequent survey in 1998 did not detect it. This suggests that it either failed to establish or that populations are currently below detectable levels on host crops (Richmond & Crowley 1998). No further records have been collected of the mealybug in New Zealand since 1997.

[8] There are only 3 recorded hosts for *Dysmicoccus cocotis*, pandanus, coconut and *Calophyllum inophyllum*, none of which occur in New Zealand. There would be no host material for the mealybug even if it were to enter the country it would be unable to establish and is not considered further in this analysis.

[9] This scale is usually found on leaves of its host plants (Williams & Watson 1990). There is no evidence for its occurrence on fruit.

Common name	Scientific name	In NZ?	Associated with coconut	Potential hazard	Hazard
Egyptian fluted scale	*Icerya aegyptiaca* Douglas (Homoptera: Margarodidae)	N Morales (1991)	Y Beardsley (1955)	Y	Y See Chapter 6.5
Seychelles scale	*Icerya seychellarum* (Westwood) Maskell (Hemiptera: Margarodidae)	N Cox (1987)	Y Lepesme (1947)	Y	Y See Chapter 6.5
Pandanus mealybug	*Laminicoccus pandani* (Cockerell) (Hemiptera: Pseudococcidae)	N Cox (1987)	Y[10] Vietch & Greenwood (1924)	N	N
Pink hibiscus mealybug	*Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae)	N Cox (1987)	Y Chang & Miller (1996)	N[11]	N
Nigra scale	*Parasaissetia nigra* Nietner (Hemiptera: Coccidae)	N Hodgson & Henderson (2000)	Y Nakahara (1981)	N[12]	N
Small snow scale	*Pinnaspis strachani* Cooley (Homoptera: Diaspididae)	N Charles & Henderson (2002)	Y Fernando & Kanagaratnam (1987)	Y	N See Chapter 6.6
Hymenoptera					
Yellow crazy ant	*Anoplolepis gracilipes* (Jerdon) (Hymenoptera: Formicidae)	N Don (2008)	Y O'Dowd (2004)	Y	Y See Chapter 6.9
	Cardiocondyla sp. nr. minutor Forel (Hymenoptera: Formicidae)	N[13] Don (2008)	N	N	N
Destructive trailing ant	*Monomorium destructor* (Jerdon) (Hymenoptera: Formicidae)	N Don (2008)	Y Way *et al.* (1989)	Y	Y See Chapter 6.9

[10] Early records of *L. pandani* causing damage to *Cocos nucifera* from the Society Islands and Fiji (Veitch & Greenwood 1924; Simmonds 1925) possibly refer to *L. vitensis* (Williams & Watson 1988). The mealybug lives on the leaves of its hosts, and is not recorded attacking fruit (Ben-Dov *et al.* 2008).

[11] There is only one record (Ben-Dov 1994) of this mealybug in Tuvalu. There is no literature cited around this record, and it is therefore unconfirmed. It is not considerd present in Tuvalu.

[12] This mealybug is distributed sporadically throughout New Zealand and is not a serious pest on the exotic plants it has been found on including *Citrus, Daphne, Feijoa sellowiana, Ilex, Iris germanica* and *Prunus armeniaca* (Hodgson & Henderson 2000).

[13] This ant which is thought to be a species near *Cardiocondyla minutior* was collected in the storage facilities hitchhiker survey, on the outside of the warehouse building. There is no evidence in the literature for an association with coconut, and it does not harvest honeydew from Hemipteran insects, being primarily ground dwelling. It is therefore not considerd a hazard in this risk analysis.

Common name	Scientific name	In NZ?	Associated with coconut	Potential hazard	Hazard
Robust crazy ant, flesh eating ant	*Paratrechina bourbonica* Forel (Hymenoptera: Formicidae)	N Don (2008)	Y Wilson & Taylor (1967)	Y	Y See Chapter 6.9
Slender crazy ant	*Paratrechina longicornis* (Latreille) (Hymenoptera: Formicidae)	N Don (2008)	Y QuanCargo Database (2008)	Y	Y See Chapter 6.9
Forrest parrot ant	*Paratrechina vaga* Forel (Hymenoptera: Formicidae)	N Don (2008)	Y Quancargo Database (2008)	Y	Y See Chapter 6.9
	Pheidole sexspinosa Mayr (Hymenoptera: Formicidae)	N Don (2008)	N[14]	N	N
Fire ant	*Solenopsis geminata* (Fabricius) (Hymenoptera: Formicidae)	N Don (2008)	N[15]	N	N
Guinea ant	*Tetramorium bicarinatum* Mayr (Hymenoptera: Formicidae)	Y Lester & Keall (2005)	N[16]	N	N
Similar groove headed ant	*Tetramorium simillimum* (Smith) (Hymenoptera: Formicidae)	N Don (2008)	Y Quancargo Database (2008)	Y	Y See Chapter 6.9
Little fire ant	*Wasmannia auropunctata* (Roger) (Hymenoptera: Formicidae)	N Don (2008)	Y QuanCargo Database (2008)	Y	Y See Chapter 6.9
Isoptera					
Coconut termite	*Neotermes rainbowi* Hill (Isoptera: Kalotermitidae)	N Philip *et al.* (2008)	Y Given (1964)	Y	N See Chapter 6.8

[14] There is very little literature available on this species. The type specimen for *Pheidole sexspinosa* is from Tuvalu (Ellis Islands). There was a *Pheidole* sp. collected in the storage facilities hitchhiker survey, but it had two spines rather than 6 which is distinctive for *Pheidole sexspinosa*.

[15] *Solenopsis geminata* has been reported as occuring in Tuvalu (Ward 2007) but was not found in the storage facilities hitchhiker survey in 2007, and has only been recorded once in interception records on coconut from Tonga between 1973-1978 (Keall 1981). Its relatively large size would suggest that were it on imported coconut it would be detected by inspectors. There is also no association with coconut in the literature and therefore it is not considered further in this analysis.

[16] *Tetramorium bicarinatum* was collected in the storage facility hitchhiker survey, but already occurs in New Zealand.

Common name	Scientific name	In NZ?	Associated with coconut	Potential hazard	Hazard
Lepidoptera					
Coconut flat moth	*Agonoxena argaula* (Meyrick) (Lepidoptera: Agonoxenidae)	N Dugdale (1987)	Y Simmonds (1922)	N[17]	N
Orthoptera					
Coconut stick insect	*Graeffea crouanii* Le Guillou (Orthoptera: Phasmidae)	N Jewell & Brock (2002)	Y Swaine (1969)	Y	N See Chapter 6.7
Fungal Pathogens					
Stem bleeding disease	*Ceratocystis paradoxa* (Dade) C. Moreau (Ascomycetes: Microascales) *Anamorph: Thielaviopsis paradoxa* (De Seynes) Höhn	Y[18] Pennycook & Galloway (2004)	Y Srinivsulu *et al.* (2006)	N	N
	Pseudoepicoccum cocos (Stevens) Ellis	N Pennycook & Galloway (2004)	Y Ben-Dov *et al.* (2008)	Y	N See Chapter 6.10
Grey blight	*Pestalotiopsis palmarum* (Cooke) (Xylariales: Amphisphaeriaceae)	Y[19] Pennycook & Galloway (2004)	Y Hyde (1992)	N	N
Coconut bud rot	*Phytophthora palmivora* Butler (Oomycetes: Pythiaceae)	N Pennycook & Galloway (2004)	Y Dharmaraju (1980)	Y	Y See Chapter 6.10

[17] The adults moths are found along the midrib of the coconut leaflets during day time, and larvae feed under loose webs spun on the lower surface of leaves. Pupation ocurs in a cocoon either along the rib of a leaflet or on a nearby low growing plant, or blade of grass (Simmonds 1922). There is no evidence *A. argaula* is associated with the drupe of *Cocos nucifera*.

[18] *Ceratocystis paradoxa* has been found twice in New Zealand since 1995, and is recorded from banana and wheat (PPIN 2008)

[19] *Pestalotiopsis palmarum* has been found on many exotic palm species in New Zealand, since it was first recorded in 1997 (PPIN 2008)

References for Appendix 1

Atkinson, T H; Peck, S B (1994) Annotated checklist of the bark and ambrosia beetles (Coleoptera: Platypodidae and Scolytidae) of tropical southern Florida. *Florida Entomologist* 77(3): 313-329

Beardsley, J W Jr (1955) Fluted scales and their biological control in United States administered Micronesia. *Proceedings of the Hawaiian Entomological Society* 15(3): 391-399

Beardsley, J W (1959) On the taxonomy of Pineapple mealybug in Hawaii, with a description of a previously unamed specis (Homoptera: Pseudococcidae). *Proceedings of the Hawaiian Entomological Society* 17(1): 29-37

Ben-Dov, Y; Miller, D R; Gibson, G A P (2001) *Conchaspis angraeci*. ScaleNet, Distribution http://www.sel.barc.usda.gov/scalecgi/distrib.exe?Family=Conchaspididae&genus=conchaspis&species=angraeci&subspecies=&intro=A

Bindhu-Radhakrishnan, Mathew, T B; Premila, K S; Priya-Mohan (2003) New report of mealybugs occurring inside the perianth of immature nuts in coconut. *Insect Environment* 9(2): 53-54

Blank, RH; Holland, P T; Gill, G S C; Olson, M H; Malcolm, C P (1995) Efficacy and persistence of insecticide residues on fruit of kiwifruit to prevent greedy scale (Hemiptera: Diaspididae) crawler settlement. *New Zealand Journal of Crop and Horticultural Science* 23: 13-23

Chang, L W H; Miller, C F (1996) In Animal and Plant Health Inspection Service, *Pathway risk assessment: Pink mealybug from the Caribbean.* U.S. Department of Agriculture 61pp

Charles, J G; Henderson, R C (2002) Catalogue of the exotic armoured scale insects (Hemiptera: Coccoidea: Diaspididae) in New Zealand. *Journal of the Royal Society of New Zealand* 32(4): 587-615

Copland, M J W; Ibrahim, A G (1985) Chapter 2.10 Biology of Glasshouse Scale Insects and Their Parasitoids. In Hussey, N W; Scopes, N (eds) *Biological Pest Control - The Glasshouse Experience*. Cornell University Press; Ithaca, New York, pp 87-90

Cox, J M (1987) Pseudococcidae (Insecta: Hemiptera). *Fauna of New Zealand* 11

Clark, A F (1938) A survey of the insect pests of Eucalyptus in New Zealand. *New Zealand Journal of Science and Technology* 19(12): 750-761

De Lotto, G (1960) The green scales of coffee in Africa south of the Sahara (Homoptera: Coccidae). *Bulletin of Entomological Research* 51(2): 389-403

Dharmaraju, E (1980) Pest problems of crops in Tuvalu. *Alafua Agricultural Bulletin* 5(4): 7-9

Don, W (2008) *Ants of New Zealand*. Otago University Press, 240pp

Dugdale, J S (1988) Lepidoptera - annotated catalogue and keys to family group taxa. Fauna of New Zealand Series #14 Manaaki Whenua Press Landcare Research. 264 pages

Fernando, L C P; Kanagaratnam, P (1987) New records of some pests of the coconut inflorescence and developing fruit and their natural enemies in Sri Lanka. *Cocos* (5): 39-42

Fleury, A C (1931) Plant Quarantine Service. *Monthly Bulletin of the Department of Agriculture California* 19(12): 811-831

Given, B B (1964) The coconut termite in the Cook Islands. *SPC quarterly Bulletin* 14(3): 25-26

Gowdy, C C (1923) *Report of the Government Entomologist*. Ann. Kept. Jamaica Department of Agriculture. pp: 23-24

Harris, R; Abbott, K; Barton, K; Berry, J; Don, W; Gunawardana, D; Lester, P; Rees, J; Stanley, M; Sutherland, A; Toft, R (2005) *Invasive ant pest risk assessment project for Biosecurity New Zealand.* Series of Internet published Landcare Research contract reports http://www.landcareresearch.co.nz/research/biocons/invertebrates/Ants/invasive_ants/documents/angora.pdf

Harris, R J; Berry, J A (2001) Confirmation of the establishment of three adventive ants (Hymenoptera: Formicidae) in New Zealand: *Cardiocondyla minutior* Forel, *Ponera leae* Forel, *Mayriella abstinens* Forel. *New Zealand Entomologist* 24: 53–56

Heine, E M (1938) Observations on the pollination of New Zealand flowering plants. *Transactions and Proceedings of the Royal Society of New Zealand* 67: 133-148

Hodgson, C J; Henderson, R C (2000) Coccoidea (Insecta: Hemiptera: Coccoidea), *Fauna of New Zealand* 41

Hyde, K D (1992) *Pseudoepicoccum cocos*. *IMI Descriptions of Fungi and Bacteria*. Sheet 1129

Jewell, T; Brock, P D (2002) A review of the New Zealand stick insects: new genera and synonomy, keys, and a catalogue. *Journal of Orthoptera Research* 11(2):189-197

Keall, J B (1981) *Interceptions of Insects, Mites and other animals entering New Zealand during 1973-1978.* Ministry of Agriculture and Fisheries. Plant Health and Diagnostic Station, Levin

Kirkaldy, G W (1909) Catalogue of the Hemiptera (Heteroptera) with biological and anatomical references, lists of foodplants and parasites, etc. Prefaced by a discussion on nomenclature, and an analytical table of families. *Cimicidae Berlin*: Felix L. Dames Vol. 1 xl 392 pp

Lepesme, P (1947) *Les insectes des palmiers.* Paul Lechevalier; Paris, 903pp

Leschen, R A B; Lawrence, J F; Kuschel, G; Thorpe, S; Wang, Q (2003) Coleoptera genera of New Zealand. *New Zealand Entomologist* 26: 15-28

Lester, P J; Keall, J B (2005) The apparent establishment and subsequent eradiacation of the Australian giant bulldog ant *Myrmecia brevinoda* Forel (Hymenoptera: Formicidae) in New Zealand. *New Zealand Journal of Zoology* 32: 353-357

MAF Biosecurity New Zealand Standard (2010) 152.02 Importation and clearance of fresh fruit and vegetables into New Zealand.

Mariau, D (2001) *The fauna of oil palm and coconut. Insect and mite pests and their natural enemies.* Translated from the French by Peter Biggins. Centre de coopération internationale en recherche agronomique pour le développement (CIRAD). Pp 89-90

Maskew, F (1915) Quarantine Division; Report for the Month of March 1915. *Monthly Bulletin of the State Commission for Horticulture* 4(5): 287-289

McKenzie, H L (1939) A revision of the genus *Chrysomphalus* and supplementary notes on the genus *Aonidiella* (Homoptera: Coccoidea: Diaspididae). *Microentomology* 4: 51-77

Migeon, A; Dorkeld, F (2006) *Spider Mites Web.* Centre de Biologie et de Gestion des Populations. Webpage: http://www.montpellier.inra.fr/CBGP/spmweb.

Morales, C F (1991) Margarodidae (Insecta: Hemiptera) *Fauna of New Zealand* 21

Moutia, L A (1958) Contricution to the study of some phytophagous acarina and their predators in Mauritius. *Bulletin of Entomological Research* 49: 59-75

Nakahara, S (1981) List of the Hawaiian Coccoidea (Homoptera: Sternorhyncha). *Proceedings of the Hawaiian Entomological Society* 23: 387-424

O'Dowd, D J (2004) *ISSG Global Invasive Species Database: Anoplolepis gracilipes*. http://www.issg.org/database/species/ecology.asp?si=110 Accessed 8/7/2008

Pennycook, S R; Galloway, D J (2004) Checklist of New Zealand "fungi". In McKenzie, E H C (ed) Introduction to fungi of New Zealand. *Fungi of New Zealand / Nga Harore o Aotearoa,* Volume 1. Fungal Diversity Press, Hong Kong. p401-488

Philip, B; Pearson, H; Bennett, S (2008) Australian termites in New Zealand. *Biosecurity* 82: 12-13

PPIN (2008) *Pestalotiopsis palmarum*. PHO/PHA Report. *Plant Pest Information Network Database*. Ministry of Agriculture and Forestry

QuanCargo Database (2008) *Interceptions Record Database*. Ministry of Agriculture and Forestry

Richmond, J E; Crowley, J M (1998) Pineapple mealybug in New Zealand? *Orchardist* 71(7): 71

Simmonds, H W (1922) Notes on the coconut leaf moth. *Agricultural Circular of the Department of Agriculture*, Fiji 3(3): 44p

Srinivasulu, B; Kumar, K V K; Aruna, K; Lakshmi, M V; Rao, D V R (2006) Biointensive IDM approach against basal stem rot and stem bleeding diseases of coconut. *Journal of Plantation Crops* 34(3): 502-507

Swaine, G (1969) The coconut stick insect *Graeffea crouani* Le Guillou. *Oléagineux* 24(2): 75-77

Veitch, R; Greenwood, W (1924) The food plants or hosts of some Fijian insects. Part II *Proceedings of the Linnean Society of New South Wales* 49: 153-161

Vesey-Fitzgerald, D (1941) Progress of the control of coconut feeding Coccidae in Seychelles. *Bulletin of Entomological Research* 32: 161-164

Wards, D F (2007) *The distribution and ecology of invasive ant species in the Pacific region.* PhD Thesis. Auckland University

Way, M J; Cammell, M E; Bolton, B; Kanagaratnam, P (1989) Ants (Hymenoptera: Formicidae) as egg predators of coconut pests, especially in relation to biological control of the coconut caterpillar, *Opisina arenosella* Walker (Lepidoptera: Xyloryctidae), in Sri Lanka. *Bulletin of Entomological Research* 79: 219–233

Williams, D J (1994) Distribution of the Pacific coconut mealybug *Dysmicoccus cocotis* (Maskell) and of a new related species on coconut in Southern Asia (Hemiptera: Coccoidea: Pseudococcidae). *Journal of Natural History* 28(2): 365-371

Williams, D J; Granara de Willink, M C (1992) *Mealybugs of Central and South America*, CAB International; Wallingford, UK

Williams, D J ; Watson, G W (1988) *The scale insects of the tropical South Pacific region. Part 2. The Mealybugs (Pseduococcidae).* CAB International Institute of Entomology, Wallingford, UK

Wilson, E O; Taylor, R W (1967) The ants of Polynesia (Hymenoptera: Formicidae). *Pacific Insects Monograph* 14: 1–109.

Wood, S L; Bright, D E (1992) A catalog of Scolytidae and Platypodidae (Coleoptera). Part 2: taxonomic index. *Great Basin Naturalist Memoirs* 13. 1553 pp

Zhang, Z-Q; Henderson, R; Flynn, A; Martin, N A (2002) *Key to Tetranychidae of New Zealand.* Landcare Research, Contract Report LC0102/144, Auckland

Appendix 2. Five most common organism groups in interception records (2003-2007)

Table 1 shows the five groups with the most representatives in Interception records of coconut from Pacific Island pathways. Table 2 shows the remaining groups represented in the Interception records. The number beside the organism shows the number of times it was recorded in the five year period looked at (2003-2007).

Table 1.

Scales	Ants	Flies	Beetles	Mites
Oceanaspidiotus pangoensis 1	*Paratrechina sp* 1	*Psychoda sp* 2	Curculionidae 3	Dolichocybidae 6
Aspidiotus pacificus 1	*Paratrechina vaga* 2	Syrphidae 1	Cerambycidae 1	*Rhyzoglyphus minutus* 1
Chrysomphalus aonidium 1	*Paratrechina longicornis* 1	Calliphoridae 2	*Atheta sp* 1	Tarsonemidae 1
Pseudalacaspis sp 1	*Tetramorium simillimum* 1	Cecidomyiidae 4	*Carpophilus maculatus* 1	Uropodidae 1
Aspidiotus excisus 1	*Tapinoma melanocephalum* 1	Sciaridae 1	*Aphanocorynes humeralis* 1	*Lorryia sp* 1
Pseudalacaspis cockerelli 1	*Tetramorium pacificum* 1	Phoridae 1	*Stentrupis marshalli* 1	*Tryophagus putrescentiae* 2
Pinnaspis strachani 2	*Pheidole fervens* 1	*Haptoncus ocularis* 1	Coleoptera 3	*Proctolaelaps sp* 8
Chrysomphalus propsimus 1	*Monomorium floricola* 1	*Megaselia sp* 1	*Periplaneta sp* 1	*Mesostigmata sp* 8
Diaspididae 1	*Monomorium minutum* 1	Stratiomyiidae 2	Porcellionidae 1	mite eggs 2
Hemiberlesia lataniae 1	*Monomorium sp* 1	Otitidae 1	Staphylinidae 1	*Tarsonemus sp* 1
	Tetramorium tonganum 1	Chloropidae 1	*Carpophylus sp* 1	*Tyrophagus sp* 1
	Tetramorium bicarinatum 1	Canthyloscelidae 1	*Urophorus humeralis* 2	Acaridae 3
	Solenopsis papuana 1	*Drosophila sp* 2	Nitidulidae 2	*Rhyzoglyphus setosus* 1
	Anoplolepis gracillipes 2	Drosophilidae 1	*Diocalandra taitensis* 2	*Parasitus sp* 1
	Ants	Muscidae 1	*Litargus sp* 1	Parasitidae 1
	Pheidole megacephala 1	*Canthyloscelus sp* 1	*Lophocateres pusillus* 1	*Sancassania sp* 2
	Monomorium pharaonis 1	*Nasonovia ribisnigri* 1	*Nanus sp* 1	Acscidae 5
	Wasmannia auropunctata 1	Psychodidae 1	Carabidae 1	*Asca sp* 2
		Lestremiinae 1	Anobiidae 1	Pyemotidae 3
		Miridae 1	*Psudophoecharis sp* 1	*Dendrolaelaps sp* 5
		Diptera 3	*Ortholomus sp* 1	Laelapidae 1
			Ulomops sp 1	*Dolichomotes sp* 5
			Alphitobius sp 1	Oribatida 3
			Lasiochilus sp 1	*Fuscuropoda sp* 1
			Eroctylidae 1	*Gamasellodes ericae* 1
			Cryptamorpha desjardinsi 1	*Scheloribates sp* 2
				Gamasellodes sp 1

				Dendrolaelaps moseri 1
				Histiostomatidae 1
				Digmasellidae 3
				Dolichocybe sp 1
				Acari phoretic mites 1
				Fractolaelaps sp 1
				Heterostigmata 1
				Thyreophagus sp 2

Table 2.

Mealybugs	Moths	Thrips	Spiders	Cockroaches	Hemiptera
Palmicultor brouni 1	Pyralidae 1	Thrips sp 1	Araneae 2	Blattidae 1	Hemiptera 1
Dysmicoccus cocotis 1	Tineidae 2	*Lepidocyrtus sp* 1		*Parcoblatta sp* 1	
Dysmicoccus brevipes 1	Lepidoptera 2	Entomobryidae 1			
Pseudococcidae 2	*Opogona sp* 1	*Ctenarytaina thysanura* 1			
	Opogona omoscopa 1				
	Tineola bisselliella 1				
Snails	Slaters	Psocids	Nematodes	Earwigs	
Gastropoda 1	*Armadillidium sp* 2	*liposcellis sp* 1	Rhabditidae 1	*Euborellia sp* 1	
			Diplogasteridae 3	Labiduridae 1	
			Aphelebnchoides sp 1		

Appendix 3. Review of post harvest handling and storage of coconut: Tuvalu November 2007.

A field trip was made to Funafuti Island in Tuvalu from the 13th-20th of November 2007. All aspects of coconut production were seen, from the growth and harvesting of green coconut, mature brown coconut and coconut apple to how coconuts for consumption are transported between the outer islands and the capital Funafuti. Currently no harvested coconuts are exported, but there is a high demand for the commodity domestically. Dehusking methods and post harvest handling were also seen. Other products apart from the nut itself are processed by the Tuvalu Copra Trade Cooperative (TCTC), including copra, coconut oil and toddy (Plates 1-8).

Plate 1. Mature green coconuts

Plate 2. Small coconut plantation, Funafuti

Plate 3.Coconut dehusking iron stake

Plate 4. Mature green coconut husks


Plate 5. De-husked coconut apple


Plate 6. Coconut apple interior


Plate 7. Coconuts at TCTC warehouse


Plate 8. Other coconut products displayed

A survey of the storage facilities hitchhiker fauna inside and around the warehouses where coconut is handled post harvest was undertaken (see Table 1 below). The inside and outside of the two buildings were sampled with sugar and protein baits in plastic containers. Baits were left at various locations around the buildings for up to an hour and then lids sealed on the containers and trapped individuals put in a freezer (Plates 9-12). In total 12 insect species were collected, 10 ant species 1 fly and a bark beetle. Hundreds of individuals were surveyed.

Plate 9. Baits used in the survey


Plate 10. Baited container at wharf warehouse

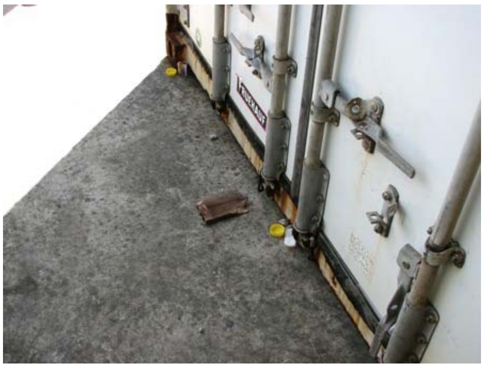


Plate 11. Replicated baiting


Plate 12. Baiting at TCTC warehouse

A total of 15 replicated samples at each site (15 protein baits and 15 sugar baits) meant 30 samples per site, therefore 60 samples for both warehouse sites combined. Tuvalu quarantine staff helped sort samples in Funafuti, which were later taken back to New Zealand for identification by the Identification and Diagnostic Centre (Ministry of Agriculture and Forestry) in Auckland.

Observations were also made around site hygiene of the boats transporting coconut from outer islands to the capital and of the warehouses and their surrounding environs. Several issues were observed. These photos illustrate potential risk areas for attracting hitchhikers which may provide them with a structurally complex environment where they could find suitable nesting sites (Plates 13-18). Having food items in or around the coconut storage areas will attract foraging worker ants or other organisms like beetles and flies. Building site materials along the warehouse walls could encourage queens and other reproductive ant stages to make nests and multiply, being a possible cause for recontamination of coconuts after post harvest handling. All issues can be remedied easily.


Plate 13. Pandanus leaves on coconut


Plate 14. Loose coconuts in the hold

Plate 15. Building site materials

Plate 16. Crab cage under window

Plate 17. Food and dead crabs in cage

Plate 18. Ants on outside of toddy bucket

Table 1. Storage facility hitchhiker survey results

Location		Bait Type	Vial ID	Identification	Number of ants
Copra Warehouse	Back Right 5m	Sugar	1	*Anoplolepis gracilipes*	12
				Paratrechina sp. C	1
		Protein	5	*Paratrechina sp. A*	4
				Tetramorium simillimum	1
	Back Left Wall	Sugar	11	*A. gracilipes*	1
				T. simillimum	1
		Protein	2	*T. simillimum*	16
	Back Right Wall	Sugar	7	*Paratrechina sp. B*	1
		Protein	22	*Pheidole sp.*	22
				A. gracilipes	1
	Back Left 5m	Sugar	20	*A. gracilipes*	52
		Protein	10	None	N/A
	Front Right wall	Sugar	19	None	N/A
		Protein	29	*A. gracilipes*	1
				Cardiocondyla sp. nr minutior	1
	Front Left Wall	Sugar	13	*A. gracilipes*	6
		Protein	16	*T. simillimum*	1
				Pheidole sp.	1
				A. gracilipes	1
	Front Left 5m	Sugar	4	*A. gracilipes*	36
				Paratrechina sp. A	1

Location		Bait Type	Vial ID	Identification	Number of ants
		Protein	28	*A. gracilipes*	3
				T. simillimum	1
	Front Right 5m	Sugar	6	*A. gracilipes*	13
		Protein	21	*A. gracilipes*	3
	Coconut Left	Sugar	8	None	N/A
		Protein	27	None	N/A
	Coconut Right	Sugar	26	None	N/A
		Protein	9	*A. gracilipes*	1
	Middle Big Room	Sugar	23	*Musca domestica*	N/A
		Protein	12	*Monomorium pharaonis*	1
	Front Door	Sugar	25	*T. simillimum*	40
		Protein	15	*T. simillimum*	26
	Toddy Big	Sugar	17	None	N/A
		Protein	24	*Paratrechina sp. A*	38
	Toddy Little	Sugar	18	None	N/A
		Protein	30	None	N/A
	Middle Toddy Room	Sugar	14	None	N/A
		Protein	3	None	N/A
Wharf Warehouse	Inside wall Left	Sugar	60	None	N/A
		Protein	31	*A. gracilipes*	3
	Coconut Bag 1	Sugar	40	None	N/A
		Protein	41	*A. gracilipes*	1
	Coconut Bag 2	Sugar	33	*A. gracilipes*	1
		Protein	35	None	N/A
	Coconut Bag 3	Sugar	32	*A. gracilipes*	1
				P. longicornis	1
		Protein	48	None	N/A
	Coconut Bag 4	Sugar	51	None	N/A
		Protein	39	None	N/A
	Front Left 5m	Sugar	37	None	N/A
		Protein	36	None	N/A
	Front Right 5m	Sugar	55	*A. gracilipes*	1
		Protein	57	*M. destructor*	2
				Paratrechina sp. A	1
	Front Left Wall	Sugar	45	*A. gracilipes*	10
		Protein	53	*Monomorium destructor*	72
	Front Right Wall	Sugar	49	*Scolytidae indet.*	N/A
		Protein	54	*Pheidole sp.*	2
	Back Right 5m	Sugar	59	*A. gracilipes*	1
		Protein	56	*A. gracilipes*	1
	Back Left Wall	Sugar	52	None	N/A
		Protein	44	*A. gracilipes*	1
				M. destructor	22
				Pheidole sp.	3
	Back Right Wall	Sugar	43	*A. gracilipes*	2
		Protein	58	*A. gracilipes*	3
	Back Left 5m	Sugar	38	None	N/A

Location		Bait Type	Vial ID	Identification	Number of ants
		Protein	34	*M. destructor*	5
	Middle Front Wall	Sugar	50	None	N/A
		Protein	42	None	N/A
	Middle Front 5m	Sugar	47	None	N/A
		Protein	46	None	N/A
	Outside combined	Sugar & Protein x6	61	*A. gracilipes*	2
				Paratrechina sp. B	1
				Pheidole sp.	75

Appendix 4. Glossary of definitions and abbreviations

Accidental Tourists	Organisms that happen to be in a particular place at a particular time purely by chance, and do not have a biological association with the object they are found on.
Brown Coconut	Mature coconut often fallen from the tree. The husk is brown and dry.
Coconut Apple	The growing embryo inside the nut. It has growing roots and stems coming out of the dry husk.
Coir	The fiber obtained from the husk of a coconut, used chiefly in making rope, matting and often used in potting compost as a partial or complete substitute for peat
Cotyledon	The first leaves sent out by the germinating seed; the seed leaves
CPC	Crop Protection Compendium. Internet Database
Drupe	Fleshy fruit with a single stone or pit
Endemic	Plants or animals indigenous to a specified area.
Endocarp	The hard inner (usually woody) layer of the pericarp of some fruits that contains the seed
Endosperm	The nutritive tissue within seeds of flowering plants, surrounding and absorbed by the embryo
Establishment	The point where a contaminating organism has a viable population on hosts or host material in New Zealand such that it could potentially spread in the future.
Exposure	The point where a contaminating organism becomes associated with a host in New Zealand in a manner that allows the organism to complete a normal life cycle.
Exotic	Organism belonging to another country.
Green coconut	Green coconuts not fully mature and contain a substantial amount of liquid inside. The outer husk is green.
Hitch-hiker pest	A species that is sometimes associated with a commodity but does not feed on the commodity or specifically depend on that commodity in some other way to complete its life cycle
IHS	Import Health Standard
Indigenous	Plant or animal born or produced naturally in a region.

Introduced	Organism not originally from the country it is found in, introduced there by humans.
Introduced range	Distribution range within an area where an organism has been introduced
IRA	Import risk analysis
MAFBNZ	Ministry of Agriculture and Forestry, Biosecurity New Zealand
Mature Coconut	The husk is brown and generally removed before export**.** Utilised for the hard flesh inside the nut and the water
Native range	Distribution range in an area where an organism occurs naturally
QuanCargo	Database of commercial consignments and interceptions of pests made by quarantine inspection.
Pericarp	The wall of a ripened ovary; fruit wall
PPIN	Plant Pest Information Network database. MAF
TCTC	Tuvalu Coconut Trade Cooperative
TDA	Tuvalu Department of Agriculture
TPPQS	Tuvalu Plant Protection and Quarantine Service
Regulated Pest	A pest of potential economic importance to New Zealand and not yet present here, or present but either not widely distributed and being officially controlled, having the potential to vector another organism, or a regulated non-quarantine pest.
Vector	Usually a pest organism such as a mite or insect that transmits a viral or other pathogenic agent between host plants.