INDUSTRY BIOSECURITY PLAN

FOR THE PAPAYA INDUSTRY

Threat Specific Contingency Plan

Papaya mealybug

Paracoccus marginatus

Plant Health Australia

September 2011

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1 Purpose and background of this contingency plan

This contingency plan provides background information on the pest biology and available control measures to assist with preparedness for an incursion into Australia of Papaya mealybug (*Paracoccus marginatus*). It provides guidelines for steps to be undertaken and considered when developing a Response Plan for incursion of this pest. Any Response Plan developed using information in whole or in part from this contingency plan must follow procedures as set out in PLANTPLAN (Plant Health Australia, 2010) and be endorsed by the National Management Group prior to implementation.

This contingency plan was funded by Horticulture Australia Limited (HAL) and developed for Papaya Australia. It is focussed on impacts on the papaya industry.

The information for this plan has been primarily obtained from documents as cited in the reference section. For each virus, information on background, life cycle, host range, distribution, symptoms and management/control is given.

2 Australian papaya industry

Papayas (*Carica papaya*) are predominately grown in Northern Queensland in the wet tropics of far north Queensland (Innisfail) and the Mareeba district in the Atherton Tablelands west of Cairns. Other growing areas include Proserpine and Yarwun in Central Queensland, Gympie and the Sunshine Coast district in South East Queensland as well as commercial production areas in Carnarvon and Kununurra in north Western Australia, the Darwin rural area in the Northern Territory and northern NSW.

Papaya fruit is produced as either red fleshed fruit from hermaphrodite trees, which the industry label as papaya or larger yellow fleshed fruit from dioecious trees which the industry label as papaw. Papaya trees have multiple sources of pollination (e.g. bees, hawkmoths etc) and some cultivars are self-pollinating. Papaws make up approximately 60% of the total production with the remainder of production based on red fleshed varieties. The crop is harvested and available all year round and can be purchased nationally from all major supermarkets and/or smaller independent fruit markets.

The value of Australian papaya production was estimated at approximately $20 million in 2005/2006 season, with $18.4M from North Queensland, $1.2M from Western Australia and the Northern Territory and $0.4M from Central and South East Queensland. Industry Research, Development & Extension issues are dealt with by the national representative body “Papaya Australia” in association with HAL. Papaya growers contribute a levy of 2c/kg for fresh fruit (24c per 12kg carton) for Research & Development and marketing.

3 Pest information/status

3.1 Pest details

Common names:	Papaya mealybug; La cochenille du papayer
Scientific name:	*Paracoccus marginatus* Williams and Granara de Willink
Taxonomic position:	Kingdom, Animalia; Phylum, Arthropoda; Class, Insecta; Order, Hemiptera; Family: Pseudococcidae

3.1.1 Background

The Papaya mealybug is believed to be native to Mexico or Central America but has since spread to the Caribbean and Florida (Millar 1999), the Pacific islands including Palau, Guam and Hawaii (Meyerdirk *et al.* 2004; Muniappan *et al.* 2006; Heu *et al.* 2007) and many parts of Asia (Muniappan *et al.* 2008). In its native habitat the Papaya mealybug is not a serious pest, possibly due to the presence of natural enemies (Walker *et al.* 2003).

The Papaya mealybug is small with males being 1 mm in size and the female 2 mm. Outside of its natural habitat, Papaya mealybug is a polyphagous pest, with hosts recorded from 25 plant families. On papaya, dense infestations of the mealybug occur along the veins of older leaves and on all parts of young leaves and fruit. The excretion of honeydew by the mealybug results in the development of sooty mould that covers leaves, stems and fruit, and heavy infestations can cause papaya trees to die within a few months. Heavy infestations are also capable of rendering fruit inedible due to the buildup of a thick white waxy coating.

Figure 1. *Papaya mealybug nymphs and adult females. From Bugwood.org*

3.1.2 Life cycle

The life cycle of the Papaya mealybug has not been well studied. *P. marginatus* are more active in warm, dry weather and the total life cycle is between one – two months depending on the season (Mahalingam 2010). Females usually lay 100 to 600 eggs in an ovisac over the period of one to two weeks (Walker *et al.* 2003), with the highest fecundity at around 25˚C (Amerasekare *et al.* 2008). Egg hatch occurs in about 10 days (though longer at lower temperatures), and nymphs, or crawlers, begin to actively search for feeding sites. Female crawlers have four instars, with the life cycle taking 24-26 days to complete at 25˚C (Tanwar *et al.* 2010). This development is temperature dependent, with females requiring 294 degree-days to complete development (Amerasekare *et al.* 2008). The adult male life cycle requires 303 degree-days (Amerasekare *et al.* 2008) and consists of five instars, the fourth of which is produced in a cocoon (pupal stage). The fifth instar of the male is the only winged form of the species capable of flight (Walker *et al.* 2003). A diagram of the life cycle of Papaya mealybug (taken from Tanwar *et al.* 2010*)* is shown in Figure 2.

Females are wingless (and therefore flightless) in all developmental stages, and move by crawling short distances or by being blown in air currents.

Factors that can contribute to high population build up include:

- The wax layers and fibres over the ovisac and body of nymphs and females protect them from environmental conditions and also from pesticides
- The wide host range
- Protection from predators by ants

- Warmer, dry weather

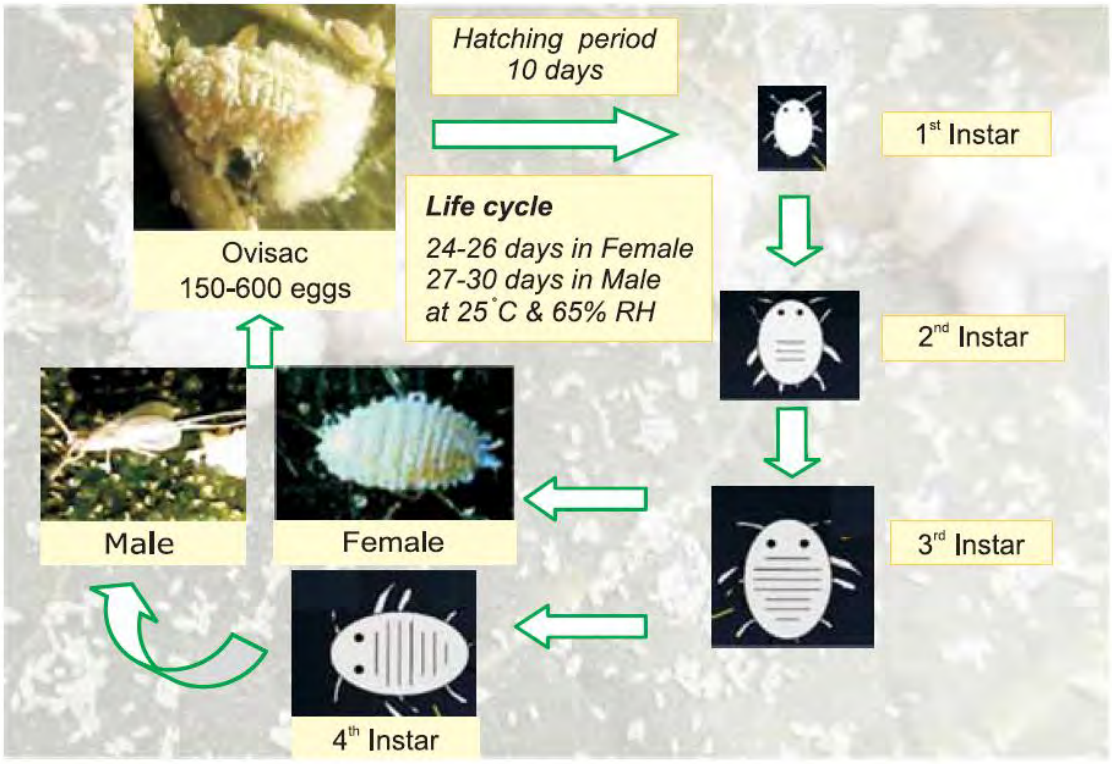

Figure 2. *Life cycle of Papaya mealybug. Taken from Tanwar et al. 2010*

3.2 Affected hosts

3.2.1 Host range

The Papaya mealybug has been recorded on over 55 species from 25 families (Walker *et al.* 2003), including a variety of economically important crops. Economically important crop hosts and weed hosts include papaya, hibiscus, avocado, citrus, cotton, tomato, eggplant, peppers, beans, peas, sweet potato, mango, cherry and pomegranate. The main hosts are detailed in Table 1.

Table 1. *Main crop and weed hosts of Papaya mealybug (information obtained from Tanwar et al. 2010)*

Botanical name	Common name
Cultivated crop species	
Capsicum annuum	Capsicum, peppers
Cajanus cajan L.	Redgram
Carica papaya L.	Papaya
Ceiba pentandra (L.) Gaertn.	Silk cotton
Citrus paradisi[1]	Grapefruit
Gossypium hirsutum L.	Cotton
Hibiscus rosa sinensis L.	Shoe flower
Jatropha curcus L.	Jatropha
Mangifera indica	Mango
Manihot esculenta Crantz	Sweet potato
Morus alba L.	Mulberry
Nerium oleander	Oleander
Persea americana	Avocado
Pisum sativum	Pea
Plumeria sp.	Frangipani
Prunus avium	Cherry
Psidium guajava L.	Guava
Punicum granatum	Pomegranate
Lycopersicon esculentum Mill.	Tomato
Solanaum torvum Sw.	Turkey berry
Solanum melongena L.	Eggplant
Tectona grandis L.	Teak

[1] Only reference available for citrus as a host appears to be *Citrus paradisi* Miller and Miller (2002)

Botanical name	Common name
Weed species	
Abutilon indicum L.	Country mallow
Achyranthus aspera L.	Latjira
Canthium inerme (L.f.)	Kuntze Turkey-berry
Cleome viscosa L.	Wild mustard
Commelina benghalensis L.	Spider wort
Convolvulus arvensis L.	Chandvel
Euphorbia hirta L.	Asthma plant
Leucas aspera (Willd)	Dronapushpi
Ocimum sanctum L.	Tulasi
Parthenium hysterophorus L.	Congress grass
Phyllanthus niruri L.	Hazardani
Trianthema portulacastrum L.	Pig weed
Tridax procumbens L.	Ghamra

3.2.2 Current geographic distribution

P. marginatus is native to Central America but has since spread throughout the Caribbean and through parts of Mexico and the USA. More recently the pest has been detected in South East Asian and islands of the Pacific. Papaya mealybug has been confirmed in countries listed in Table 2.

Table 2. *Current distribution of P. marginatus*

Asia Pacific	India, Indonesia, Guam, Hawaii, Northern Marianas, Sri Lanka, Thailand, Bangladesh, Maldives
North America	Mexico, USA
Central America	Cuba, Haiti, Dominican Republic, Puerto Rico, Belize, Guatemala, Costa Rica, Caribbean (St. Martin, Guadeloupe, St. Barthelemy, Antigua, Bahamas, British Virgin Islands, Cuba, Dominican Republic, Haiti, Puerto Rico, Montserrat, Nevis, St. Kitts, and the U.S. Virgin Islands)
South America	French Guiana

3.2.3 Symptoms

Papaya mealybug is a sucking insect that injects a toxic substance into the leaves while feeding. Mealybugs are generally observed as clusters of cotton-like masses on leaves, stems or fruit (Walker *et al.* 2003) and symptoms caused by infestation are as follows:

- Leaf chlorosis, deformation or crinkling due to toxins
- Premature aging of leaves, flowers and fruit causing these plant parts to drop under severe infestation
- Fruits may fail to develop normally and may be unusually small. Affected fruit may shrivel and drop.
- Flowers may be distorted or fail to open. Petals may be malformed or blemished.
- Sooty mould formation due to honeydew excretions by mealybugs
- Thick, waxy coating on leaves, stems and fruit under heavy infestation

Figure 3. *Heavy infestation of Papaya mealybug on papaya fruit. From Bugwood.org*

Figure 4. *Infestation of Papaya mealybug on papaya leaf. From Bugwood.org*

3.3 Diagnostic information

A nationally endorsed diagnostic protocol is not available for *P. marginatus*. A detailed description of all life stages of both sexes of the Papaya mealybug is given in Miller and Miller (2002) and a key for diagnosis of common mealybugs associated with Hibiscus as well as information on protocols for slide mounting are outlined by Hodges and Hodges (2005). Walker *et al.* (2003) outlines the following general characteristics:

Male adults

- Adults are pink, especially during pre-pupal and pupal stages but appear yellow in the first and second instars.
- They are approximately 1 mm in length with an elongate oval body that is widest at the thorax (0.3 mm). They also have 10-segmented antennae, a distinct aedeagus, lateral pore clusters, a heavily sclerotised thorax and head and well-developed wings.
- Adult males may be distinguished from other related species by the presence of stout fleshy setae on the antennae and the absence of fleshy setae on the legs.

Female adults

- Adults are yellow, covered in a white waxy coating, and wingless.
- They are approximately 2.2 mm in length and 1.4 mm in width.
- Ovisac position is beneath and behind the body and can be as much as twice as long as the body.

- Female adults also possess a series of short waxy caudal filaments less than a quarter of the length of the body around the margin.
- Two characteristics that are important in distinguishing *P. marginatus* adult females from all other species of *Paracoccus* are the presence of oral-rim tubular ducts of one size and in conspicuous clusters dorsally restricted to marginal areas of the body, and the absence of pores on the hind tibiae.

Papaya mealybug can look similar to the Pink hibiscus mealybug (*Maconellicoccus hirsutus*) which is native to Australia, but they can also be distinguished by the colour of the body contents when crushed on white paper: *P. marginatus* is yellow; *M. hirsutus* is pink.

When preserved in 80% alcohol, *P. marginatus* turn black within 24–48 hours, whereas *M. hirsutus* specimens turn darker brown but do not go black.

When adult females are mounted on microscope slides, the species can be easily distinguished: *P. marginatus* has eight-segmented antennae and dorsal oral rim ducts located only in marginal areas; *M. hirsutus* has nine-segmented antennae and rows of dorsal oral rim ducts across all the body segments.

3.4 Pest risk ratings and potential impacts

Papaya mealybug is not known to be present in Australia. Within this contingency plan, a pest risk analysis has been carried out on this pest, taking into account the entry, establishment and spread potentials, together with the economic and environmental impact of establishment. A summary of these ratings are shown in Table 3. Based on this information, Papaya mealybug is considered a **High** overall risk to Australia.

Table 3. *Pest risk ratings for Papaya mealybug*

Potential or impact	Rating
Entry potential	Medium
Establishment potential	High
Spread potential	High
Economic impact	High
Environmental impact	Negligible
Overall risk	**High**

3.4.1 Entry potential

Rating: Medium

The entry potential of *P. marginatus* is considered to be **Medium** as Papaya mealybug is established in neighbouring countries (e.g. Indonesia) and could potentially enter via wind currents or in fruit or plant material transferred between northern communities. Entry via other means is not considered as likely as import of nursery stock requires post entry plant quarantine which should detect the presence of mealybugs. Import of fresh fruit is either prohibited or allowed only with a permit.

The rating would also be higher if there was an inadvertent entry (intentional or unintentional with traveller's' goods).

3.4.2 Establishment potential

Rating: High

The establishment potential of *P. marginatus* in areas where papaya are grown in Australia is considered to be **High** due to the widespread availability of hosts and the fact that this pest survives in a wide range of countries with similar environments to Australia.

3.4.3 Spread potential

Rating: High

The spread potential of *P. marginatus* in Australia is considered to be **High.** There is a wide host range and widespread availability of these hosts throughout tropical areas suited to development of *P. marginatus*, however most life stages (except adult males) are flightless. Localised spread (between trees and within farms) can occur as a result of crawling of instars and by insects such as ants. Longer distance spread can also readily occur from infested plants by wind, water and through human assisted movement. Vehicles moving through a crop, or pruning and harvesting activities, can help carry crawlers from one plant to another.

3.4.4 Economic impact

Rating: High

P. marginatus causes significant damage to cassava in Central America, and has the capacity to cause serious damage to papaya, other tropical fruit and ornamentals such as *Annona* and *Hibiscus* spp. (Miller *et al*. 2001). Mealybugs suck sap and infestations can cause crinkled and twisted leaves, reduced fruit development or reduced quality of fruit. Heavy infestations excrete honey dew, resulting in development of sooty mould which can also reduce yield and plant growth. Due to the potential damage on papaya and wide host range the economic impact is considered to be **High**.

3.4.5 Environmental impact

Rating: Negligible

There is **Negligible** potential to degrade the environment or otherwise alter the ecosystem by affecting species composition or reducing the longevity or competitiveness of wild hosts.

3.4.6 Overall risk

Rating: High

The overall rating is considered to be **High** given the likelihood of establishment and spread given the volume of susceptible hosts grown in Australia.

4 Pest management

4.1 Response checklist

The following checklist (Table 3) provides a summary of generic requirements to be identified and implemented within a Response Plan.

Table 3. *Checklist of requirements to be identified in a Response Plan*

Checklist item	Further information
Destruction methods for plant material, soil and disposable items	Section 5.1.1
Disposal procedures	Section 5.1.5
Quarantine restrictions and movement controls	Section 5.2
Decontamination and property cleanup procedures	Section 5.4
Diagnostic protocols and laboratories	Sections 3.3, 7.1, 7.2
Trace back and trace forward procedures	Section 5.5
Protocols for delimiting, intensive and ongoing surveillance	Sections 4.2.1, 5.5.1
Zoning	Section 5.3
Reporting and communication strategy	Section 7.3

For a range of specifically designed procedures for the emergency response to a pest incursion and a general communication strategy refer to PLANTPLAN (Plant Health Australia 2010). Additional information is provided by Merriman and McKirdy (2005)[2] in the Technical Guidelines for Development of Pest Specific Response Plans.

The following provides a summary of generic requirements to be identified and implemented within a Response Plan:

- Destruction methods for plant material, soil and disposable items
    - Destruction of plant material would need to ensure that destruction of mealybugs in leaves, stems, flowers and fruit occurred
    - Destruction would be by normal Australian Quarantine and Inspection Service (AQIS) approved methods and/or by those approved by the Consultative Committee on Emergency Plant Pests (CCEPP)
- Disposal procedures
- Quarantine restrictions and movement controls

[2] Available on the PHA website (**www.planthealthaustralia.com.au/go/phau/biosecurity/general-biosecurity-information**)

  - Need to potentially consider the flight characteristics of the male adult, plus contaminated soil and any movement of plant host material or contaminated machinery and equipment

- Decontamination and farm clean -up procedures
- Diagnostic protocols and laboratories
- Trace back and trace forward procedures
  - Tracing operations must consider the wide host range of tropical crop species and ornamentals
- Protocols for delimiting, intensive and ongoing surveillance
  - The wide host range of *P. marginatus* and difficulty of undertaking surveillance through tropical areas should be considered when developing surveillance protocols
- Zoning
- Reporting and communication strategy

4.2 Delimiting survey and epidemiology study

Delimiting surveys should comprise local surveys around the area of initial detection concentrating on areas of poor growth. Surrounding crops would then be surveyed. The extent of the survey beyond the initial infested crop should be guided by the test results from surrounding crops. Farmers should be encouraged to scout their crops and report mealybug detections which could then be followed up with collections and diagnosis. Laboratory diagnosis will be required to confirm detection.

4.2.1 Sampling method

Once initial samples have been received and preliminary diagnosis made, follow up samples to confirm identification of the pest will be necessary. This will involve sampling directly from the infected crop, and sampling crops over a larger area to determine the extent of the pest distribution. A system of sample identification should be determined early in the procedure to allow for rapid sample processing and accurate recording of results. Follow up samples will be forwarded to the nominated diagnostic laboratories for processing.

Samples should be initially collected over a representative area of the infected crop to determine the pest distribution. All personnel involved in crop sampling and inspections must take precautions to minimise the risk of spread between crops by decontaminating between paddocks.

Any personnel collecting leaf or mealybug samples for assessment should notify the diagnostic laboratory prior to submitting samples to ensure expertise is available to undertake the diagnosis. General protocols for collecting and dispatching samples are available within PLANTPLAN, Appendix 3 (Plant Health Australia 2010a).

4.2.1.1 HOW TO COLLECT

Where a quarantine situation occurs, special authority will be needed to remove live exotic insects or infested plant material from the quarantine area. On receipt of the samples the diagnostic laboratory

should follow strict quarantine and processing guidelines. In keeping with ISO 17025 refer to PLANTPLAN (Plant Health Australia, 2010).

The following information for factors to be considered for sampling has been taken from McComie (2001). Scientific advice may be needed to determine appropriate sampling strategies depending on the nature of a potential incursion into Australia.

- Determine host plants to be sampled
- Identify sample units. For example:
    - Leaves – Papaya and Frangipani (plants with large leaves)
    - Shoots – Hibiscus, Jathropha and Eggplant
    - Shoots and leaves – Acalypha (an ornamental of the Euphorbiaceae family)
    - Fruits – Soursop
- Selection should be biased to borders of a field or orchard, following any predominant wind direction or where human assisted spread may have been likely

Examine new growth on hosts. In general inspect hosts that appear to be unhealthy (although different hosts may express different symptoms)

Look for signs of mealybugs i.e. whitish specks on host or terminals and leaves covered with white egg masses, nymphs and adults. Ants actively running up and down and forming trails may also indicate presence of mealy bugs. Presence of sooty mould may indicate mealybugs.

Collect samples by taking entire leaves, buds, flowers or fruit.

Samples should be collected into plastic Ziplock bags then sealed in rigid containers to prevent escape of mealybugs. Disinfest the outside of plastic bags and containers with 70% ethanol to kill instars that may be on the exterior. It is recommended that a dry paper towel be added to each bag during shipping however specific advice on sampling may be required in the event of an incursion.

Where host plants are not in new flush – examine underside of leaves and crevices of branches and also examine secondary hosts such as weeds.

General protocols for collecting and dispatching samples are available within PLANTPLAN, Appendix 3 (Plant Health Australia, 2010).

4.2.1.2 NUMBER OF SPECIMENS TO BE COLLECTED

A minimum of 5 samples should be collected per site. It is advisable to collect a large number of specimens of all life stages within each sample to assist in diagnosis. Host material should be included as removal of mealybugs from plant material may result in damage.

Collect specimens that are clean and in good condition (i.e. that are complete with appendages such as antennae, wings and legs).

Record the identity of the host plant where the insects were collected. Record the location, preferably as GPS co-ordinates, or alternatively, a map reference or distance and direction from a suitable landmark. If the land is privately owned, record the owner's details including contact telephone numbers.

4.2.1.3 HOW TO PRESERVE INSECT SAMPLES

Adults and larvae can be preserved by placing in 70% ethanol and stored indefinitely, although their colour fades gradually with time. Specimens required for molecular diagnostic work should be killed and preserved in 95-100% ethanol or frozen (-80˚C).

4.2.1.4 HOW TO TRANSPORT INSECT SAMPLES

Live insects (any life stage) should not be transported unless it is considered essential, and then such that containers are only opened in PC3 or QC3 containment facilities. For detailed information on transport and packaging requirements for suspect emergency plant pests refer to PLANTPLAN (Plant Health Australia 2010).

4.2.1.5 HOW TO COLLECT PLANT SAMPLES IF REQUIRED

Plant samples associated with collection of mealybugs may be required as part of the delimiting survey (see Section 4.2).

Leaf samples containing nymphs and if possible adults are to be placed in a specimen container and then placed in a portable fridge or insulated container with cool packs to prevent the insect and leaf samples from drying out.

All sample containers should be clearly labelled with the name, address and contact phone number of both the sending and receiving officers. In addition containers should be clearly labelled in accordance with the requirements of PLANTPLAN (Plant Health Australia 2010; Appendix 3). Containers should then be carefully sealed to prevent loss, contamination or tampering of samples. The Chief Plant Health Manager will select the preferred laboratory. Additional labelling includes the identification of plant species/parts affected, location of affected plant (where available include GPS reading) as well as symptoms and an image if available.

Refer to PLANTPLAN for packing instructions under IATA 650.

4.2.2 Epidemiological study

The extent of infestation on a property or within a region will depend on the initial population size of the introduction and whether conditions have been favourable for the pest to spread from the initial location. Sampling should be based upon the origins of the initial suspect sample(s). Factors to consider will be:

- The proximity of other host plants to the initial infestation source. *P. marginatus* has a wide host range and many host plant types may be present within a property (especially in the case of a nursery) or a region. Ornamental hosts in nearby gardens or used as landscape plantings will need to be surveyed.
- Machinery or vehicles that have been into the infested area or in close proximity to the infestation source
- The extent of human movements into and around the infested area. A possible link to the recent importation of plant material from other regions should also be considered
- The source of nursery stock propagation material
- Depending on the temperature and environmental conditions the total life cycle is 1-2 months indicating populations can build up quickly

4.2.3 Models of spread potential

No models of spread potential for *P. marginatus* currently exist.

4.2.4 Pest Free Area guidelines

Determination of Pest Free Areas (PFAs) should be completed in accordance with the International Standards for Phytosanitary Measures (ISPMs) 4, 8 and 10 (IPPC 1995, 1998a, 1999). Points to consider for this pest are:

- Mealybug instars can readily travel on wind currents so PFAs may need to be a considerable distance from the areas where *P. marginatus* was first detected
- The widespread availability of host plants throughout papaya growing regions makes the ongoing maintenance and certification of PFAs potentially very costly
- Surveillance should include records on absence of the pest
- Survey around transport routes of any machinery that may have inadvertently transported the pest

Additional information is provided by ISPM 4 (IPPC 1995) in Requirements for the Establishment of Pest Free Areas. This standard describes the requirements for the establishment and use of pest free areas as a risk management option for phytosanitary certification of plants and plant products. Establishment and maintenance of a PFA can vary according to the biology of the pest, pest survival potential, means of dispersal, availability of host plants, restrictions on movement of produce, as well as PFA characteristics (size, degree of isolation and ecological conditions).

4.3 Availability of control methods

4.3.1 General procedures for control

General procedures include:

- Keep traffic out of affected areas and minimise movement in adjacent areas
- Adopt best-practice property hygiene procedures to retard the spread of the pest between paddocks and adjacent properties
- After surveys are completed, destruction of the infested plant material is an effective control
- On-going surveillance of infested areas to ensure the pest is eradicated
- Do not use any material from infested plants for propagation

4.3.2 Control if small areas are affected

If only a small area is found to be infested (i.e. research plots, etc.) immediate crop destruction should be undertaken. It is likely that eradication of a small area infestation of adults and nymphs will only be achievable where insects have not been able to travel out of the area. In these circumstances severe control methods would be employed for quite small areas of incursion (e.g. an isolated area in an orchard, or a nursery and where small numbers of affected host plants are involved. Eradication

could still be achievable if mealybugs are detected in a wider field situation, though would require relatively swift action.

4.3.3 Control if large areas are affected

If large areas are infested and eradication is the goal, insecticides that target mealybugs should be considered. A range of active ingredients are available for mealybug control (listed in section 4.3.6) but none are registered specifically for Papaya mealybug. If eradication is no longer a possibility the focus should switch to integrated pest management relying on natural enemies and the possible introduction of biocontrol agents as the primary means of control.

4.3.4 Cultural control

Practices such as removal of host weeds, control of ants associated with the infestation and pruning and burning of infested branches may help manage Papaya mealybug once established.

4.3.5 Host plant resistance

There is no evidence to date of any host plant resistance to Papaya mealybug.

4.3.6 Chemical control

In general, chemical control is not particularly effective against mealybugs because of the waxy covering over their bodies. However, several active ingredients are registered worldwide for mealybug control (though not specifically Papaya mealybug) including: acephate, carbaryl, chlorpyrifos, diazinon, dimethoate, malathion, and white mineral oils. Higher rates are typically needed and multiple applications may be required for full control (Walker *et al.* 2003). Insecticide rotation is necessary to avoid the buildup of resistant populations.

4.3.7 Biological control

For long term management of Papaya mealybug should eradication be deemed not feasible, biological control is likely the best and most economically viable option. Several natural enemies of Papaya mealybug exist and are commercially available including the Australian mealybug ladybird (*Cryptolaemus montrouzieri*), other species of ladybirds, lacewings, hover flies, *Scymnus* sp. and some hymenopteran and dipteran parasitoids (Tanwar *et al.* 2010).

Four genera of encyrtid endoparasitoid wasps specific to mealybugs have been collected in Mexico as potential biological control agents: *Acerophagus papayae* (Noyes and Schauff 2003), *Anagyrus loecki*, *Anagyrus californicus* Compere, and *Pseudaphycus* sp. (Walker *et al.* 2003). A further species was later collected and identified as *Pseudleptomastix mexicana* (Noyes and Schauff 2003).

Release of the four parasitoid wasp species at research sites in the Dominican Republic and Puerto Rico resulted in 99.7% and 97% reductions in mealybug population density, respectively (Walker *et al.* 2003). Introduction of the parasitoids *Anagyrus loecki, Acerophagous papayae* and *Pseudleptomastrix mexicana* in Sri Lanka led to control of up to 95-100 % control (Tanwar *et al.*

2010). Release of these biocontrol agents into Australia in the event of *P. marginatus* becoming established may provide cheap and efficient control of the pest in papaya plantations.

5 Course of action- potential eradication methods

Additional information is provided by the IPPC (1998b) in Guidelines for Pest Eradication Programmes. This standard describes the components of a pest eradication programme which can lead to the establishment or re-establishment of pest absence in an area. A pest eradication programme may be developed as an emergency measure to prevent establishment and/or spread of a pest following its recent entry (re-establish a Pest Free Area) or a measure to eliminate an established pest (establish a Pest Free Area). The eradication process involves three main activities: surveillance, containment, treatment and/or control measures.

The decision to eradicate should be based both on the potential economic impact of host damage resulting from infestation of *P. marginatus* and on technical feasibility. Eradication costs must factor in long-term surveys to prove the success of the eradication program. A minimum of 2 years with no detections of the pest will be necessary before pest free status can be declared.

No specific eradication matrix has been determined for either pest. The final decision between eradication and management will be made through the National Management Group.

Note: Eradication is unlikely unless the pest is detected while still contained within a small or isolated area, given the dispersal capabilities of the pest and the widespread availability of host plants in agricultural, natural, and populated areas.

5.1 Destruction strategy

5.1.1 Destruction protocols

General protocols:

- No plant material should be removed from the infested area unless part of the disposal procedure
- Disposable equipment, infested plant material or growing media/soil should be disposed of by autoclaving, high temperature incineration or deep burial
- Any equipment removed from the site for disposal should be double-bagged
- Machinery used in destruction processes need to be thoroughly washed, preferably using a detergent or farm degreaser
- Farm machinery used in destruction processes need to be thoroughly washed, preferably using a detergent
- Destruction of smaller amounts of material e.g. specimens, can be accomplished by freezing samples for a minimum of 48 hours

5.1.2 Decontamination protocols

Machinery, equipment and vehicles in contact with infested plant material or growing media/soil, or present within the Quarantine Area, should be washed to remove plant material and growing media/soil using high pressure water or scrubbing with products such as a degreaser or a bleach solution (1% available chlorine) in a designated wash down area. When using high pressure water, care should be taken not to spread plant material. High pressure water should be used in wash down areas which meet the following guidelines:

- Located away from crops or sensitive vegetation
- Readily accessible with clear signage
- Access to fresh water and power
- Mud free, including entry and exit points (e.g. gravel, concrete or rubber matting)
- Gently sloped to drain effluent away
- Effluent must not enter water courses or water bodies
- Allow adequate space to move larger vehicles
- Away from hazards such as power lines
- Waste water, growing media/soil or plant residues should be contained (see Appendix 18 of PLANTPLAN [Plant Health Australia 2010])
- Disposable overalls and rubber boots should be worn when handling infested plant material or growing media/soil in the field. Boots, clothes and shoes in contact with infested plant material or growing media/soil should be disinfected at the site or double-bagged to remove for cleaning
- Skin and hair in contact with infested plant material or growing media/soil should be washed

5.1.3 Priorities

Specific priorities for eradication or containment:

- Confirm the presence of the pest
- Limit movement or people and prevent movement of vehicles and equipment through affected areas
- Stop the movement of any plant material that may be infested with mealybugs
- Determine the strategy for the eradication/decontamination of the pest and infested host material
- Determine the extent of infestation through survey and tracing

5.1.4 Plants, by-products and waste processing

- Any growing media/soil or infected plant material removed from the infected site should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial (in a non-cropping area)

5.1.5 Disposal issues

- Particular care must be taken to minimise the transfer of infested plant material from the area
- Host material including leaf litter should be collected and incinerated or double bagged and deep buried in an approved site

5.2 Quarantine and movement controls

Consult PLANTPLAN (Plant Health Australia 2010) for administrative details and procedures.

5.2.1 Quarantine priorities

- Plant material at the site of infestation to be subject to movement restrictions.
- Machinery, equipment, vehicles and disposable equipment in contact with infested plant material or present in close proximity to the site of infestation to be subject to movement restrictions.

5.2.2 Movement control for people, plant material and machinery

Once established *P. marginatus* will be difficult to eradicate. Therefore, any zoning, quarantine or movement controls will usually pertain to containment and management unless detection occurs soon after establishment.

If Restricted or Quarantine Areas are practical, movement of equipment or machinery should be restricted and subject to movement conditions. The industries affected will need to be informed of the location and extent of the pest occurrence.

Movement controls need to be put in place to minimise the potential for transport of the pest, and this will apply to all plant material, growing media and other items within the quarantined area.

Movement of people, vehicles, equipment and plant material, from and to affected properties or areas, must be controlled to ensure that the pest is not moved off-property. Movement controls can be achieved through the following; however specific measures must be endorsed in the Response Plan:

- Signage to indicate quarantine area and restricted movement into and within these zones
- Fenced, barricaded or locked entry to quarantine areas
- Movement of equipment, machinery, plant material or growing media/soil by permit only. Therefore, all non-essential operations in the area or on the property should cease
- Where no dwellings are located within these areas, strong movement controls should be enforced
- Where dwellings and places of business are included within the Restricted and Control Areas, limitation of contact with infested plants should be enforced
- Clothing and footwear worn at the infested site should either be double-bagged prior to removal for decontamination or should not leave the site until thoroughly disinfected, washed and cleaned

- Plant material or plant products must not be removed from the site unless part of an approved disposal procedure
- All machinery and equipment should be thoroughly cleaned down with a high pressure cleaner (see Section 5.1.2) or scrubbing with products such as a farm degreaser or a 1% bleach (available chlorine) solution, prior to leaving the affected area. Machinery should be inspected for the presence of insects and if found, treatment with insecticide may be required. The clean down procedure should be carried out on a hard surface, preferably a designated wash-down area, to avoid mud being re-collected from the affected site onto the machine. When using high pressure water, care should be taken to contain all plant material and mud dislodged during the cleaning process

5.3 Zoning

The size of each quarantine area will be determined by a number of factors, including the location of the incursion, biology of the pest, climatic conditions and the proximity of the infested property to other infested properties.

The National Management Group will determine this during the production of the Response Plan.

Further information on quarantine zones in an Emergency Plant Pest (EPP) incursion can be found in Appendix 10 of PLANTPLAN (Plant Health Australia, 2010). These zones are outlined below and in Figure 5.

5.3.1 Destruction Zone

The size of the destruction zone (i.e. zone in which the pest and all host material is destroyed) will depend on the ability of the pest to spread, distribution of the pest (as determined by delimiting surveys), climatic conditions, time of season (and part of the pest life cycle being targeted) and factors which may contribute to the pest spreading.

The entire crop or pasture should be destroyed after the level of infestation has been established. The delimiting survey will determine whether or not neighbouring host crops are infested and need to be destroyed. The Destruction Zone may be defined as contiguous areas associated with the same management practices as the infested area (i.e. the entire orchard, property or farm if spread could have occurred prior to the infestation being identified).

Particular care needs to be taken to ensure that plant material (including non-hosts) is not moved into surrounding areas.

5.3.2 Quarantine Zone

The Quarantine Zone is defined as the area where voluntary or compulsory restraints are in place for the affected property or properties. These restraints may include restrictions or movement control for removal of plants, people, growing media/soil or contaminated equipment from an infected property.

5.3.3 Buffer Zone

A Buffer Zone may or may not be required depending on the incident. It is defined as the area in which the pest does not occur but where movement controls or restrictions for removal of plants, people, soil or equipment from this area are still deemed necessary. The Buffer Zone may enclose an infested area (and is therefore part of the Control Area) or may be adjacent to an infested area.

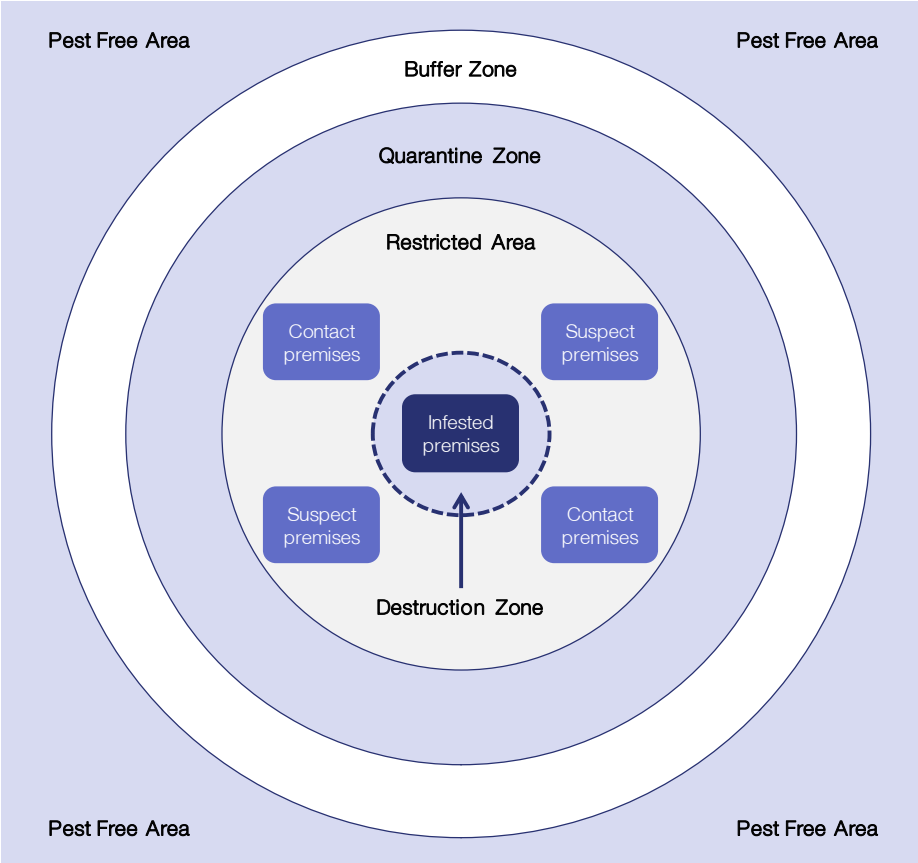

Figure 5. *Schematic diagram of quarantine zones used during an EPP incursion (not drawn to scale)*

5.3.4 Restricted Area

The Restricted Area is defined as the zone immediately around the infected premises and suspected infected premises. The Restricted Area is established following initial surveys that confirm the presence of the pest. The Restricted Area will be subject to intense surveillance and movement control with movement out of the Restricted Area to be prohibited and movement into the Restricted Area to occur by permit only. Multiple Restricted Areas may be required within a Control Area.

5.3.5 Control Area

The Control Area is defined as all areas affected within the incursion. The Control Area comprises the Restricted Area, all infected premises and all suspected infected premises and will be defined as the minimum area necessary to prevent spread of the pest from the Quarantine Zone. The Control Area

will also be used to regulate movement of all susceptible plant species to allow trace back, trace forward and epidemiological studies to be completed.

5.4 Decontamination and farm clean up

Decontaminant practices are aimed at eliminating the pathogen thus preventing its spread to other areas.

5.4.1 Decontamination procedures

General guidelines for decontamination and clean up:

- Refer to PLANTPLAN (Plant Health Australia 2010) for further information
- Keep traffic out of affected area and minimise it in adjacent areas
- Adopt best-practice property hygiene procedures to retard the spread of the pest between growing areas/fields and adjacent properties
- Machinery, equipment, vehicles in contact with infested plant material or growing media/soil present within the Quarantine Zone, should be washed to remove growing media/soil and plant material using high pressure water or scrubbing with products such as a degreaser or a bleach solution in a designated wash down area as described in Section 5.1.2
- If required as part of the decontamination, plant material should be destroyed using herbicide. Only recommended materials are to be used when conducting decontamination procedures, and should be applied according to the product label
- Infected or vector-infested plant material should be disposed of by autoclaving, high temperature (enclosed) incineration or deep burial

5.4.2 General safety precautions

For any chemicals used in the decontamination, follow all safety procedures listed within each MSDS.

5.5 Surveillance and tracing

5.5.1 Surveillance

Detection and delimiting surveys are required to delimit the extent of the outbreak, ensuring areas free of the pest retain market access and appropriate quarantine zones are established.

Initial surveillance priorities include the following:

- Surveying all host growing properties and businesses in the pest quarantine area
- Surveying all properties and businesses identified in trace-forward or trace-back analysis as being at risk
- Surveying all host growing properties and businesses that are reliant on trade with interstate or international markets which may be sensitive to the presence of *P. marginatus*

- Surveying commercial nurseries selling at risk host plants
- Surveying other host growing properties and backyards

5.5.1.1 CONSIDERATIONS FOR GROWERS, AGRIBUSINESSES AND WHOLESALERS/ RETAILERS

Producers of host crops, and the businesses that supply them and market their produce, should have information regularly made available through industry information sources. If Farm/Orchard Biosecurity Manuals are available, they should be widely promoted through the relevant producer associations.

5.5.1.2 CONSIDERATIONS FOR URBAN COMMUNITIES AND HOME GARDENERS

There is a likelihood that the initial site of incursion of *P. marginatus* could be in urban areas and if so, home gardeners and nurseries should be targeted in "community surveillance" programs. State Departments of Agriculture or Primary Industry that have information and/or technical services for urban target groups should have readily available information.

5.5.1.3 CONSIDERATIONS FOR QUARANTINE AUTHORITIES (AUSTRALIAN QUARANTINE AND INSPECTION SERVICE)

Information and training on *P. marginatus* should be available to AQIS inspectors. Of particular importance is knowledge of risk countries where these pests occur, and the risk pathways that could lead to their introduction. The aim of this approach is an awareness of what might be found during an inspection.

5.5.1.4 TARGETTED SURVEILLANCE

Targeted surveillance requires development of specific sampling plans based on knowledge of pest biology, accepted detection methods, and statistically defined methods that allow estimation of population presence, absence and / or size. The main role for targeted surveillance is to determine presence or absence for delimiting the incursion, providing evidence of absence for trade purposes or confirming an eradication response has been successful.

Due to the nature of the symptoms caused by *P. marginatus* and the ability to visibly detect infestations of mealybugs, the most common and efficient method of determining the presence or absence of this pest is by visual examination of plant material.

5.5.1.5 EXOTIC PEST SURVEY

Although the potential for entry into Australia of *P. marginatus* is low, the most desirable situation for control is continued surveillance of imported commodities and people from infested regions entering Australia. Once established, eradication of this pest may be difficult, though remain feasible if early action is taken prior to any movement of significant numbers of insects out of the first site of infestation. Exotic pest surveys of regions to the north of Australia (e.g. islands) and monitoring spread in other overseas countries from where host plant material may come is desirable to assist with monitoring or surveillance measures.

5.5.2 Survey regions

Establish survey regions around the surveillance priorities identified above. These regions will be generated based on the zoning requirements (see Section 5.3), and prioritised based on their potential likelihood to currently have or receive an incursion of this pest. Surveillance activities within these regions will either allow for the area to be declared pest free and maintain market access requirements or establish the impact and spread of the incursion to allow for effective control and containment measures to be carried out.

Steps outlined in Table 4 form a basis for a survey plan. Although categorised in stages, some stages may be undertaken concurrently based on available skill sets, resources and priorities.

Table 4. *Phases to be covered in a survey plan*

Phase 1	Identify properties that fall within the buffer zone around the infested premise Complete preliminary surveillance to determine ownership, property details, production dynamics and tracings information (this may be an ongoing action)
Phase 2	Preliminary survey of host crops in properties in buffer zone establishing points of pest detection
Phase 3	Surveillance of an intensive nature, to support control and containment activities around points of pest detection
Phase 4	Surveillance of contact premises. A contact premise is a property containing susceptible host plants, which are known to have been in direct or indirect contact with an infested premises or infected plants. Contact premises may be determined through tracking movement of materials from the property that may provide a viable pathway for spread of the pest. Pathways to be considered are: • Items of equipment and machinery which have been shared between properties including bins, containers, irrigation lines, vehicles and equipment • The producer and retailer of infected material if this is suspected to be the source of the outbreak • Labour and other personnel that have moved from infested, contact and suspect premises to unaffected properties (other growers, tradesmen, visitors, salesmen, crop scouts, harvesters and possibly beekeepers) • Movement of plant material and soil from controlled and restricted areas • Storm and rain events and the direction of prevailing winds that result in air-borne dispersal of the pest during these weather events • Movement of plant material and growing media/soil from controlled and restricted areas
Phase 5	Surveillance of nurseries, gardens and public land where plants known to be hosts of pest are being grown
Phase 6	Agreed area freedom maintenance, pest control and containment

5.5.3 Post-eradication surveillance

The period of pest freedom sufficient to indicate that eradication of the pest has been achieved will be determined by a number of factors, including growth conditions, the previous level of infection, the control measures applied and the pest biology. As a guide, the following activities should be carried out following eradication of the pest:

- Establishment of sentinel plants at the site of infestation

- If symptoms or suspect insects are detected, authorities are to be contacted to determine further response
- Maintain good sanitation and hygiene practices throughout the year
- Targeted surveys for *P. marginatus* to be undertaken for a minimum of 2 years after eradication has been achieved

6 References

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6.1 Websites

CABI 2011 **www.cabicompendium.org/cpc/home.asp**

PLANTPLAN **www.planthealthaustralia.com.au/plantplan**

Service Featured Creatures Series **http://entomology.ifas.ufl.edu/creatures**

Bugwood **http://www.bugwood.org/**

7 Appendices

7.1 Appendix 1: Standard diagnostic protocols

For a range of specifically designed procedures for the emergency response to a pest incursion refer to Plant Health Australia's PLANTPLAN (Plant Health Australia, 2010), Appendices 2 and 3.

7.2 Appendix 2: Resources and facilities

Table 5 provides a list of diagnostic facilities for use in professional diagnosis and advisory services in the case of an incursion.

Table 5. *Diagnostic service facilities in Australia*

Facility	State	Details
DPI Victoria – Knoxfield Centre	Vic	621 Burwood Highway Knoxfield VIC 3684 Ph: (03) 9210 9222; Fax: (03) 9800 3521
DPI Victoria – Horsham Centre	Vic	Natimuk Rd Horsham VIC 3400 Ph: (03) 5362 2111; Fax: (03) 5362 2187
DPI New South Wales – Elizabeth Macarthur Agricultural Institute	NSW	Woodbridge Road Menangle NSW 2568 PMB 8 Camden NSW 2570 Ph: (02) 4640 6327; Fax: (02) 4640 6428
DPI New South Wales Orange Agricultural Institute	NSW	1447 Forest Road Orange NSW 2800 Ph: (02) 6391 3980, Fax: (02) 6391 3899
DPI New South Wales – Tamworth Agricultural Institute	NSW	4 Marsden Park Road Calala NSW 2340 Ph: (02) 6763 1100; Fax: (02) 6763 1222
DPI New South Wales – Wagga Wagga Agricultural Institute	NSW	PMB Wagga Wagga NSW 2650 Ph: (02) 6938 1999; Fax: (02) 6938 1809
SARDI Plant Research Centre – Waite Main Building, Waite Research Precinct	SA	Hartley Grove Urrbrae SA 5064 Ph: (08) 8303 9400; Fax: (08) 8303 9403
Grow Help Australia	QLD	Entomology Building 80 Meiers Road Indooroopilly QLD 4068 Ph: (07) 3896 9668; Fax: (07) 3896 9446

Facility	State	Details
Department of Agriculture and Food, Western Australia (AGWEST) Plant Laboratories	WA	3 Baron-Hay Court South Perth WA 6151 Ph: (08) 9368 3721; Fax: (08) 9474 2658

7.3 Appendix 3: Communications strategy

A general Communications Strategy is provided in Appendix 6 of PLANTPLAN (Plant Health Australia, 2010).

7.4 Appendix 4: Market access impacts

Within the AQIS PHYTO database, no countries appear to have a specific statement regarding area freedom from *Paracoccus marginatus* (April 2011). Should *P. marginatus* be detected or become established in Australia, some countries may require specific declaration. Latest information can be found within PHYTO, using an Advanced search “Search all text” for *Paracoccus marginatus*.