Contingency Plan for Brown Marmorated Stink Bug *(Halyomorpha halys)*

Prepared by Plant Health Australia

May 2017

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In referencing this document, the preferred citation is:
Plant Health Australia Ltd (Version 1, May 2017) Contingency Plan for Brown Marmorated Stink Bug

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1 Purpose and background of this Contingency Plan

This Contingency Plan provides background information on brown marmorated stink bug (BMSB), *Halyomorpha halys,* to assist in determining requirements for the initial response to a detection of this exotic stink bug in Australia. Only key information for immediate response is provided in this document. More detailed information can be found in the following supporting material:

- Guide to the identification of Brown marmorated stink bug, *Halyomorpha halys*, and other similar bugs (**www.agriculture.gov.au/SiteCollectionDocuments/biosecurity/import/cargo/pests/guide-identification-brown-marmorated-stink-bug.pdf**)
- Pest Risk Assessment (draft due for release in early 2017) prepared by the Department of Agriculture and Water Resources (DAWR). This document provides background information on BMSB, and an analysis of projected entry, establishment, spread and economic impact of this pest for Australia.
- Pest Risk Assessment (2015) prepared by DPIPWE. This document provides background information on BMSB, and an analysis of projected entry, establishment, spread and economic impact of this pest for Tasmania.
- Awareness material such as the brown marmorated stink bug fact sheets from DAWR, PHA and state jurisdictions.
- Overseas websites e.g. **www.StopBMSB.org**
- Appendix 1 – Impact on agricultural hosts
- Appendix 2 – Information on monitoring tools for BMSB

2 Impact of brown marmorated stink bug

- BMSB feeds on >100 host plants in 45 families (Lee 2015) and feeding damage can affect fruit, kernels, buds, stems and bark (Haye *et al.* 2015). Appendix 1 provides information on the impact on important host species.
- The ability of BMSB to feed on such a wide range of hosts has seen it become a significant problem across 41 states in the United States since its first detection in the late 1990s (Hoebeke and Carter 2003; Leskey *et al.* 2015, Lee 2015). BMSB appears to be a particular threat as it will move readily to different food sources as crop species ripen, making it a difficult pest to manage across landscapes.
- In addition to its impact on commercially important plant species, BMSB is a severe nuisance pest in urban areas as it is attracted in very high numbers to refuges in buildings in its overwintering phase. It produces an unpleasant odour when disturbed (Inkley 2012).
- Damage in crops can result from direct production losses due to fruit drop, reduced fruit set, reduction in yield as well as quality issues due to feeding damage and contamination that make

affected products unsaleable (Rice *et al.* 2014). Feeding by BMSB can also introduce pathogenic bacteria or fungi, resulting in fruit rot (Rice *et al.* 2014).

- In the United States, control of BMSB has added significantly to the cost of production. Establishment of BMSB has been estimated to have resulted in a four-fold increase in chemical sprays for apple crops resulting in an abandonment of Integrated Pest Management programs and increase in secondary pests (Rice *et al.* 2014; Joseph *et al.* 2015; Leskey *et al.* 2015).
- BMSB is a hitchhiker pest that can move long distances on items such as vehicles, shipping containers, timber and luggage, particularly as they enter their overwintering phase as temperatures cool and day length decreases (Haye *et al.* 2015).

3 Biology

For detailed aspects of the biology of BMSB, refer to the Pest Risk Assessment (2017)[1]. Information deemed to be of most significance to the immediate response are outlined below:

- Like many stink/shield bugs, BMSB is dormant in cooler winter temperatures and emerges when temperatures increase in spring. In the United States, BMSB begins mating about two weeks after emerging from its overwintering dormancy. In this two week period, adults need to feed and do not appear to respond to aggregation or sex pheromones.
- Diapause appears most strongly controlled by day length, with a threshold of 14.8 -15.5 hours day length required to break diapause (Rice *et al.* 2014). While records have indicated four to possibly six generations per year in parts of sub-tropical China, evidence from Korea and the United States indicates 1-2 generations are more likely (Penn State Entomological Notes, 2013; Ingels *et al.* 2015; Lee 2015). In the Northern United States (e.g. New Jersey), one generation per year is more common, while in West Virginia, it appears to undergo two generations per year (Leskey *et al.* 2015). Where two generations occur in the United States, overwintering adults emerge in May and lay eggs. These develop into first summer generation adults, which mature around mid-late July, then lay eggs which develop into adults early September (Leskey *et al.* 2015). The minimum temperature for development is 14.1 ^{o}C (Nielsen *et al.* 2008; Basnet *et al.* 2015).
- In the eastern United States, decreasing day length and temperature in late August triggers adults to congregate on plant hosts prior to seeking refuge sites for their overwintering phase (Leskey *et al.* 2012a).
- When mean winter temperatures average about 4°C, every 1°C increase can increase winter survival rates of BMSB by about 16% (Kiritani 2006; 2007).
- Eggs are laid on the underside of leaves and egg hatch is strongly influenced by temperature. At 30^{o}C egg hatch can occur in as little as 3-4 days, while at cooler temperatures (15^{o}C) egg hatching takes 22-26 days. Eggs do not hatch at temperatures >35^{o}C (Lee 2015).
- BMSB has 5 nymphal stages. Early stage nymphs are more brightly coloured than adults.

[1]Full citation for the Pest Risk Assessment will be provided once this document is released

3.1 Hosts and symptoms

BMSB has a very wide host range and symptoms (and types of damage) differ between hosts. Images of symptoms on many hosts are available from **www.Stopbmsb.org**. Highly preferred hosts and/or important crops in Australia are described in the following sections, however it should be noted many other plant species are affected and Appendix 1 describes impact on hosts and symptoms for many host species.

3.1.1 Pome fruit (apple and pear)

In the United States, severe damage has been observed on apple crops and an outbreak of BMSB was estimated to cause US $37 million in losses in 2010 (Rice *et al.* 2014).

3.1.2 Summerfruit and cherries

Peaches can be severely impacted by BMSB as a result of feeding injury (Nielsen and Hamilton, 2009). It has been suggested that while peaches (and apples) may not be optimal hosts for reproduction, adult BMSB use these crops as a food source after they emerge from diapause and again just before fruit harvest as the insects prepare to enter diapause (Nielsen and Hamilton, 2009).

Cherry trees are considered a major crop

3.1.3 Grain crops

Edible soybean (edamame) can have very high levels of BMSB during seed development (BMSB SCRI CAP; **www.stopbmsb.org**) soybean has been listed as a host in both the United States and Japan (Pennsylvania State University Entomological Notes, 2012).

There is evidence that BMSB congregate in wheat, cotton, hops, sorghum and sunflower. Sunflower and sorghum in particular appear to be preferred hosts, and this is believed to be because they are tall, brightly coloured and have seeds high in protein (Zinati 2015). Little evidence of the impact of BMSB on wheat could be sourced, indicating it does not appear to be a significant host.

3.1.4 Vegetable crops

Sweetcorn, capsicum and okra are very susceptible to feeding injury (Kuhar *et al.* 2012; Rice *et al.* 2014). Green beans and eggplant are suitable for oviposition and nymphal development (Rice *et al.* 2014). Tomato appears less suitable for reproduction but suffers high levels of fruit damage (Rice *et al.* 2014).

In the United States, curcurbit and cruciferous species appear to suffer less damage, however it is not clear if this is because they are often grown near crops that are more attractive to BMSB (Kuhar *et al.* 2012).

3.1.5 Grapes

BMSB feeding can cause direct damage including berry drop, smaller cluster weights and soft or discoloured fruit (Nielsen *et al.* 2016).

3.2 Diagnostic information

An identification guide for brown marmorated stink bug (*Halymorpha halys* and other similar bugs) has been developed by the Department of Agriculture and Water Resources and can be found at **www.agriculture.gov.au/pests-diseases-weeds/plant/brown-marmorated-stink-bug.**

The Pest and Disease Image Library provides information on diagnostic notes and images at **www.padil.gov.au/pests-and-diseases/pest/main/136188.**

There are a number of stink bug species similar to BMSB in Australia, as well as several species that are exotic to Australia. Each species has characteristic features that can be identified by experienced personnel. A nationally endorsed diagnostic protocol has not been developed.

A summary description of BMSB (adapted from the University of Florida Featured Creatures website) is as follows:

- Adult BMSB has a shield-shaped body (Figure 1) and emits a pungent odour when disturbed. Adult females are 14.4 mm mean body length and adult males are 12 mm mean body length. Average length is given as a range of 12-17 mm long (Lee 2015).
- Adults and late stage nymphs are mottled brown. Both males and females have characteristic alternating dark and light bands across the last two antennal segments that appear as a single white band. The exposed lateral margins of the abdomen have alternate bands of brown and white in both nymphs and adults.
- Nymphs lack fully developed wings and have been described as tick-like in appearance, ranging in size from 2.4 mm (1st instar) to 12 mm (5th instar). First instars are orange or red (Figure 2).

Figure 1 Adult Brown Marmorated Stink Bug (image courtesy Bugwood.org: D.R. Lance, USDA APHIS


UGA1460048

Figure 2 Brown marmorated stink bug egg mass and newly hatched nymphs (image courtesy Bugwood.org: G. Bernon, USDA, APIS)

3.3 Dispersal of BMSB

- Adult BMSB are strong fliers when temperatures increase over 20°C (adults do not fly when temperatures are <16°C). While they can fly distances of up to 117 km in 22 hours, they more commonly fly distances of <5 km (Wiman *et al.* 2014; Lee, 2015). In spring and summer, adults will fly in search of a food source and will preferentially seek mature fruit crops (Martinson *et al.*, 2015).
- As day length decreases in autumn and winter and temperatures cool, adults will seek sheltered sites to overwinter.
- Long distance dispersal of stink bugs occurs by human-assisted means, particularly as they seek refuge as part of their overwintering strategy in autumn and winter. They are capable of hitchhiking in cargo, packing crates, aircraft, machinery, vehicles and personal luggage (Haye *et al.* 2015).
- In summer, adults may be active at night and will fly if temperatures are over 20°C.
- Dispersal in summer occurs as adults fly to seek new mates or food sources and although they will feed on many plant species, they are strongly attracted to ripened fruit and

vegetables and will move readily in search of these food sources. In summer, BMSB may seek shade within trees.

- Nymphs don't fly but are active walkers, especially when temperatures are >25ºC. Nymphs will move readily between gardens, paddocks and orchards in search of a food source. Under laboratory conditions, nymphs have been shown to disperse at 3 m per hour (Lee *et al.* 2014b).
- Both adults and nymph behaviour is described as very defensive and insects will drop or move quickly when disturbed (Leskey *et al.* 2015).

Potential BMSB population and behavioural patterns in the northern hemisphere compared to Australia are provided in Table 1, noting that this is a general guide and actual patterns would depend on the region/climate.

Table 1. Potential BMSB population and behavioural patterns in the northern hemisphere compared to Australia (drawn from information provided by the NZ Ministry for Primary Industries)

	Northern hemisphere	Australia
January	Overwintering	Activity
February	Overwintering	Activity
March	Overwintering	Activity/Aggregation
April	Emergence	Aggregation
May	Emergence/Activity	Overwintering
June	Emergence/Activity	Overwintering
July	Activity	Overwintering
August	Activity	Overwintering
September	Activity/Aggregation	Overwintering
October	Aggregation	Emergence
November	Overwintering	Emergence/Activity
December	Overwintering	Emergence/Activity

3.4 Management of Risk Pathways

The following section outlines the major High Risk Pathways for BMSB and the points at which control measures could be applied.

<table>
<tr><th>Risk Pathway</th><th>Description</th><th>Potential Domestic Control Measures</th></tr>
<tr><td>Soil</td><td>There are Nil expected pathways for BMSB in soil for adults, eggs or nymphs.</td><td>Not applicable</td></tr>
<tr><td>Seed</td><td>Feeding may occur on seed however, given harvesting procedures, seed may be considered a low risk.</td><td>Visual inspection of seed for the presence of adults or nymphs may be required if it is suspected hitchhiking insects may be present in seed consignments.</td></tr>
<tr><td>Nursery Stock</td><td>Egg are laid on the underside of leaves.</td><td>No information is available on efficacy of chemicals for control of BMSB eggs.

While it may be possible to encourage egg hatch[2] to allow treatment of nymphs/adults with chemicals, no information is available on the efficacy of this approach as part of control measures for limiting dispersal of BMSB.

Soapy water appears effective in killing adults, however no information is available on use of washing or soapy water for physical removal or control of BMSB eggs.</td></tr>
<tr><td>Fruit</td><td>Adults and nymphs feed on developing and ripe fruit.

Unlikely to be associated with fruit when harvested. May be considered a low risk.</td><td>Visual inspection of fruit for the presence of adults or nymphs.

If movement of BMSB is considered a risk in transport in fruit, investigation would be required for disinfestation using physical methods such as washing or chemical treatments to determine efficacy of control measures and damage to fruit.</td></tr>
<tr><td>Plant material including debris and waste from previous crops</td><td>Feeding may occur by adults and nymphs on leaves shoots, stems and bark.

Adults potentially attracted to wood piles, cut/stored timber or bales of hay over winter.</td><td rowspan="3">Given the propensity of BMSB to seek shelter when overwintering, treatment of infested material would be required using either heat treatment or fumigation (Section 5.3.5).</td></tr>
<tr><td>Conveyances (includes crates, boxes, bins, pallets)</td><td>This pathway provides a refuge for aggregations of adults over winter as a hitchhiker on packaging crates, machinery, vehicles and personal luggage.</td></tr>
<tr><td>Tools, equipment, machinery</td><td>Tools, equipment, machinery used on farm in the vicinity of host plants.</td></tr>
</table>

[2] Increasing temperature to 30ºC can encourage egg hatch to occur in as little as 3-4 days. At cooler temperatures (15ºC) egg hatching takes 22-26 days.

Risk Pathway	Description	Potential Domestic Control Measures
Transport vehicles	Vehicles in the vicinity of host plants.	Given the propensity of BMSB to seek shelter when overwintering, treatment of potentially infested vehicles may be required using either heat treatment or fumigation (Section 5.3.5). Use of steam or washing may also be considered for vehicles, however may not be effective if all parts of vehicles cannot be reached.

4 Surveillance and collection of samples

Information provided in the following sections provides a framework for key points of consideration for development of early detection and delimiting surveys for stink bugs.

4.1 Surveillance

4.1.1 Technical information for planning surveys

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

Initial surveillance priorities for BMSB should consider the following:

- In spring, summer and potentially into autumn, stink bugs will be feeding. BMSB seek sugar sources and particular focus should be on ripe/ripening fruit such as apples, pears, berry crops and summerfruit or vegetables such as tomatoes, capsicums, sweetcorn and eggplant (see Section 3.1 and Appendix 1).
- BMSB prefer edges of crops and orchards and these should be targeted in surveillance activities. For example, in corn and soybean, it has been noted that no BMSB were found greater than 25 m into the field (Venugopal *et al.* 2015).
- Ornamental trees such as the weed species Tree of Heaven (*Ailanthus altissima*) and Princess tree (*Paulownia tomentose)* as well as English holly (*Ilex aquifolium)*, Magnolia (*Magnolia grandiflora)* and Chinese pistachio (*Pistacia chinensis*) have been observed as preferential hosts for BMSB (Lee *et al.* 2013).
- Red sorghum and sunflower have been used as trap crops in the United States possibly as they are tall, brightly coloured and have seeds that are good protein sources (Zinati 2015). In broadacre situations in the northern cropping areas, these crops may therefore be useful ones to monitor or undertake surveillance.
- In cooler conditions (<16^{o}C), stink bugs will be in an overwintering state and focus for BMSB surveillance should be on:
    - Large (>60 cm diameter), dead trees with porous dead tissue and peeling bark (Lee *et al.* 2014a).
    - Refuges such as buildings or structures. In the United States, BMSB appear to aggregate in darker locations for their overwintering sites (Lee *et al.* 2013).

- If undertaking visual surveillance in plant crops, BMSB may be difficult to observe as a result of defensive behaviour which causes them to drop to the ground when disturbed.
- There is some evidence that BMSB prefers to aggregate (and feed) at tree tops, although little information is available on whether this refers to all tree species or whether there is a time of year or temperature component to this preference (Leskey *et al.* 2012b). It has been suggested that this tendency for aggregation at tree tops will make ground-based surveillance difficult in established orchards or within larger trees in backyards (Leskey *et al.* 2012b).

4.1.1.1 Surveillance tools

- The most effective traps trialled in the eastern United States were 1.5 m tall black pyramid traps placed on the ground (Leskey *et al.* 2012c; Leskey *et al.* 2015; Figure 3). It is believed that darker colour traps are effective as they mimic trunks of trees and BMSB have a natural tendency to climb upwards (Leskey *et al.* 2012c).
- Lures have been investigated for both traps and sticky strips with a two component aggregating pheromone (100 mg) and the synergist pheromone methyl (2*E*,4*E*,6*Z*)-decatrienoate (MDT) (66 mg) proving to be effective (Ingels *et al.* 2015; Leskey *et al.* 2015). Commercial lures are available from the United States (see Appendix 2 for examples of sources of monitoring tools).
- Research undertaken in the eastern states of the United States has focussed on management of BMSB using traps and attractants i,e, not for eradication or delimiting surveillance purposes. There is evidence that there is a linear relationship between attractant dosage and efficacy i.e. higher concentrations of attractants (up to 500 mg of methyl (2*E*,4*E*,6*Z*)-decatrienoate (MDT)) attract more BMSB (Leskey *et al.* 2012c; Leskey *et al.* 2015).
- Pheromone traps are not attractive to newly emerged adults, as insects need to reach sexual maturity first. To reach sexual maturity, adults require food for 1-2 weeks, average daily temperatures >16^{o}C and 13.5 hours or more of daylight.
- Research is required on the optimum lure dosage, trap placement and trap type for early detection, eradication or delimiting surveillance.
- Trapping grids of 20-25 m apart have been used within management programs in the United States (Quarles, **www.stopbmsb.org/managing-bmsb/management-overview**) however a wider trapping array may be possible with higher dose lures. No information is available on the use of traps within eradication programs as no country or region has attempted to eradicate BMSB.
- Lures with incorporation of kill strip in traps, resulted in increased collection of BMSB (Ingels *et al.* 2015). Lures should be replaced every 4-6 weeks and fresh kill strips are more likely to be effective than 3 week old strips (Joseph *et al.* 2013).
- There is evidence that sticky strips embedded with pheromone lures may also be effective (Ingels *et al.* 2015) for placement within trees. New Zealand research being conducted in the United States has shown that clear sticky traps embedded with pheromone are as effective at detecting all life stages of BMSB as pyramid traps. Use of clear sticky traps (compared with yellow sticky traps) has the advantage of limit other insect bi-catch. To be effective, sticky traps should be mounted on a post to allow insects to climb to reach the trap. Insects caught in sticky traps can suffer predation from birds and should be checked regularly in a delimiting surveillance program.

- Foliage should be inspected within 1 - 2 m of lures traps as BMSB may be attracted to the lure but not enter the trap (Ingels *et al.* 2015).
- BMSB is attracted to light sources and light traps can be used for detection (Nielsen *et al.*, 2013). Night time temperatures below 15ºC will limit the usefulness of light traps however, as insect movement is reduced in cooler conditions. At night, adults will only fly when temperatures are >20ºC. A simple light trap can be made by shining a light into an aluminium tray filled with soapy water.
- Beat sheets placed under trees (then tap or hit tree limbs to cause BMSB to drop) have been used as a surveillance tool however stink bugs can be difficult to detect due to hiding behaviour, nocturnal activity or presence higher in the tree (Nielsen and Hamilton, 2009).
- In the United States, detector dogs have been used to assist detection of overwintering populations of BMSB. Use of detector dogs, coupled with visual identification of key tree characteristics by surveillance personnel, increased detection efficiency to 84% in woodland situations (Lee 2014a).

Figure 3 Black pyramid trap for Brown marmorated stink bug

4.1.2 Delimiting surveys in the event of an incursion

BMSB has a very wide host range, and in spring and summer will disperse by walking and flying in search of food or mates. In winter BMSB will disperse to refuges (e.g. buildings and trees) in search of shelter.

Following BMSB detection, the following points are recommended for delimiting surveillance:

- Surveillance to delimit a detection of BMSB should take into account tracing information as outlined in Section 5.1 to determine potential pathways for movement of material from the site of the initial detection.
- Surveillance should occur within a 5 km zone[3] around the initial detection.
- Surveillance should be a combination of the following:
    - Visual inspection in high risk areas (e.g. edges of crops or orchards with mature fruit or vegetables)
    - Sticky traps or pyramid traps with pheromone lures for BMSB
    - If night time temperatures are > 20^{o}C, light traps should be deployed
    - Beat sheets for fruit trees may be an option
    - In winter, surveys in buildings and structures or large (>60 cm diameter), dead trees with porous dead tissue and peeling bark

[3] A 5 km zone has been proposed following discussion with experts and also in consultation with government agencies. This proposed zone distance is based on information from Section 3.3 that adult BMSB usually fly < 5 km in search of a food source, and as an area that will be feasible for initial surveillance within an incursion response.

- Surveillance should be accompanied with awareness material, signs and personal visits to households and businesses within the surveillance zone and buffer zones

4.1.3 General surveillance

4.1.3.1 Activities for general surveillance immediately following a detection

- Given the comparatively large size of adult BMSB (12-17 mm long), its impact as a nuisance pest in urban environments, and its damage to many commercial crops, BMSB will be a suitable target for general surveillance programs that request submission of images and/or samples. To establish a general surveillance program, the following will be required:
    - As there are native stink bugs that appear similar to BMSB, diagnostic laboratory(ies) should be considered to triage and diagnose images and samples submitted as part of a general surveillance program.
    - On-line or app reporting tools such as MyPestGuide to promote the submission of reports of suspected BMSB detections.
    - Factsheets to provide information on the pest, symptoms, impacts and reporting mechanisms
    - Media releases to describe the impact of the pest, surveillance programs and activities within the response program.
    - Information for industry communication channels including articles for industry newsletters, magazines and websites, information for Twitter feeds and Facebook and presentations for industry talks.
    - A website to provide information for the public and for commercial businesses and links to other relevant sites such as **www.StopBMSB.org**
    - Release and promotion of information on details for physical sample collection and submission, as well as information on how to take and submit images of stink bugs.
    - Broader awareness campaigns should consider literature (brochures and factsheets) in several languages.

An example of engagement with affected urban communities in the United States to assist with monitoring/trapping can be found at **www.njaes.rutgers.edu/stinkbug/**.

4.1.4 Stakeholder engagement

- Issues to be considered in engagement with stakeholders on BMSB includes:
    - BMSB's wide host range and its ability to move between crops.
    - The expected impact on crop production and potentially on trade. In the United States, Integrated Pest Management within crops has been effected as a result of increased sprays which have reduced numbers of beneficial insects or arachnids controlling secondary pests (Joseph *et al.* 2015).
    - Nuisance potential in homes and gardens (smell, invasive potential and difficulty of keeping out of structures, damage to fruit, vegetables and ornamentals).

  - o Given BMSB appear to congregate higher in trees (Leskey *et al.* 2012b), aerial sprays could be considered to achieve best coverage of host vegetation. Stakeholder engagement associated with aerial spray programs would need to be considered and may not be feasible for urban environments.
  - o Access to private properties for surveillance or treatment.

4.2 Collection and treatment of samples

- Follow the PLANTPLAN procedure for hard bodied pests.
- For stink bugs, United States protocols recommend that no ventilation holes are required for live insects (See **www.njaes.rutgers.edu/stinkbug/faq.asp** for an example of sample submission protocols from New Jersey Agricultural Experimental Station).

  For submission of samples for DNA analysis, stink bugs can be placed in 95% ethanol.

5 Course of action – immediate response to a detection

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 2014).

5.1 Tracing

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.

Extensive forward tracing may not be feasible or useful as BMSB adults can readily disperse by flying however if trace forwards are conducted, focus should be on high risk linkages such as:

- Premises linked directly with the initial detection, particularly where movements of vehicles or freight may have moved BMSB long distances.
- In spring/summer, linkages to commercial production, particularly areas where plant hosts are available.
- In autumn/winter, focus should be on premises that have received equipment, vehicles, machinery from the Infected Premise that may have received stink bugs as hitchhikers.

For trace-backs, focus should consider:

- Any material (products, equipment, machinery) received from overseas within a 12 month period.
- Note that BMSB is a hitchhiker and has been shown to be transported in personal effects.

5.2 Quarantine and movement controls

5.2.1 Movement controls

- If Restricted or Quarantine Areas are practical, movement of equipment or machinery should occur by permit. Movement controls should include visual inspection and potentially treatment for stink bugs. Disinfestation using heat treatment and/or fumigation has been used on larger complex machinery and equipment. If seeking refuge, BMSB can be difficult to locate using visual inspection.
- The size of the Restricted Area will be dependent on the type and scale of the incursion however a 5 km zone should be considered as the area in which surveillance should be undertaken to begin initial delimitation (Section 4.1.2).
- Voluntary movement control should be considered for urban/residential detections. Voluntary controls would involve negotiation with residents to undertaken inspection and treatment of goods prior to movement from Infested Premises. Residents should be advised on measures to minimise the inadvertent transport of the pest from the infested area to unaffected areas. Voluntary compliance is likely to be implemented for urban areas using awareness campaigns to highlight high risk goods/situations and appropriate treatments.

5.3 Destruction strategy

5.3.1 Physical exclusion and control of stink bugs

Physical methods for exclusion have been useful for management of BMSB in the United States. It should be noted these methods have only been implemented with respect to managing high numbers of BMSB and would need to be assessed for effectiveness and practicality within an eradication program e.g. used in conjunction with chemical sprays or in limiting spread from an initial detection as a component of eradication.

In organic vegetable production in the United States, exclusion netting has been used however maintaining netting is difficult and costly (Lee *et al.* 2013). Netting has also been used in combination with chemical sprays at the edges of orchards to stop stink bugs entering crops. For households in the United States, the following physical methods of exclusion have been reported (Anon, 2010):

- Physical sealing of structures to limit entry (or exit in the case of an eradication program) of stink bugs.
- Netting of 0.1 cm or mosquito netting treated with pyrethroids has been found to be useful for exclusion of stink bugs.

5.3.2 Physical removal of BMSB

As noted in Section 5.3.1, physical methods for control have been useful for management of high numbers of BMSB, however it would need to be assessed for effectiveness and practicality within an eradication program e.g. used in conjunction with chemical sprays or in limiting spread from an initial detection as a component of eradication. Sargent *et al.* (2011) reports the following physical methods for removal of BMSB:

- Vacuuming up bugs and killing in soapy water.
- Using natural dropping behaviour to collect BMSB – place container under bugs and broom over the top of them. BMSB will tend to drop into the container and can be killed in soapy water.
- Collect and kill BMSB by creating a light trap – shine a light into an aluminium tray filled with soapy water. Note that BMSB will only fly at night if temperatures are >20^{o}C.
- Use of lure and kill traps. Sticky traps impregnated with lure pheromones have been used in the United States in management programs. No eradication has been attempted in the United States using lure and kill, and research would be required on trap distribution and pheromone concentration if considered for eradication purposes.

5.3.3 Removal of hosts

While not a common method of control in the United States, removal of specific hosts such as Tree of Heaven (*Ailanthus altissima*) has been listed as a cultural control method to limit numbers of BMSB and remove key hosts that provide a food source (**www.berriesnw.com/DisordersDetail.asp?id=151**).

Removal of hosts could be considered as part of an eradication program if it is suspected that egg masses may be present or if this will assist in limiting refuges. Egg hatch is strongly influenced by temperature and at 30^{o}C can occur in as little as 3-4 days (see Section 3), making host removal of limited effectiveness at these temperatures (Lee 2015). Lee (2015) observed that at cooler temperatures (15ºC), egg hatch takes 22-26 days, potentially increasing the potential for host removal to be an effective strategy

In contained situations such as glasshouses, removal of hosts could be considered to limit the availability of refuges for nymphs and adults however, as nymphs and adults are easily disturbed, unless coupled with insecticide control, movement of host material could cause insects to rapidly disperse.

Alternatively, maintenance of key hosts could be considered as sentinels within an ongoing surveillance program to declare area freedom.

5.3.4 Chemical control

Considerable work has been undertaken in the United States to identify control (but not eradication) methods for BMSB. Active ingredients that have been most effective include pyrethroids (bifenthrin, permethrin, fenpropathrin, beta-cyfluthrin), neonicotinoids (dinotefuran, clothianidin and thiamethoxam), carbamates (methomyl, oxamyl) organophosphates (acephate, dimethoate, methidathion, chlorpyrifos) and an organochlorine (endosulfan) (Lee *at al*. 2013; Rice *et al.* 2014).

Overwintered adults appeared more susceptible to insecticides than F1 adults that emerge later in the season (Lee *et al.* 2014a).

In the United States, the focus of control is on management and reduction of stink bug levels to levels that minimise commercial damage in crops rather than eradication. Three key challenges are noted with control of BMSB:

- The sheer number of individuals that are present in crops.
- Poor efficacy of many chemicals. Some chemicals e.g. neonicotinoids and pyrethroids can cause knockdown only, and up to 33% of BMSB can recover from chemical application. Residual activity of some chemicals is poor (there is greater residual effect on nymphs compared with adults).
- Disruption of Integrated Pest Management (IPM) systems is a major issue in the United States as more aggressive chemicals must be used more frequently. More frequent use of chemicals and disruption to IPM has resulted in secondary pests becoming more damaging or developing increased levels of chemical resistance (for example Green peach aphid) (Leskey *et al.* 2015; Joseph *et al.* 2015).

Table 2 details the pesticides for which applications have been made by the Department of Agriculture and Water Resources to the Australian Pesticides and Veterinary Medicines Authority (APVMA) for emergency permits.

Table 2. Australian Pesticides and Veterinary Medicines Authority Brown Marmorated Stink Bug Emergency Permit applications, 2016[4]

	Bifenthrin (Pyrethroid; Group 3)	Pyrethrins (Pyrethroid; Group 3)	Thiamethoxam (Neonicitinoid; Group 4)	Lambda-cyhalothrin (Pyrethroid; Group 3)	Imidacloprid + beta-cyfluthrin (Nicitinoid + Pyrethroid; Groups 3 and 4)
Assorted tropical fruit - edible peel		✓			
Assorted tropical fruit - inedible peel		✓			
Berry fruit	✓	✓	✓		
Brassica vegetables	✓	✓	✓	✓[5]	
Bulb vegetables		✓		✓[6]	
Canola	✓			✓	
Cereal grains		✓		✓	
Citrus fruit		✓	✓		
Cotton	✓	✓	✓	✓	
Cucurbit vegetables	✓	✓	✓		
Fruiting vegetables	✓	✓	✓	✓	
Grapes	✓				
Herbs	✓	✓			
Home garden		✓			
Hops	✓				
Leafy vegetables	✓	✓	✓		
Legume vegetables	✓	✓		✓	
Maize/sweet corn	✓			✓	
Olives		✓			
Ornamentals	✓	✓			
Peanuts	✓	✓		✓	
Pest control	✓			✓	✓
Pome fruit	✓	✓	✓	✓	
Pulse crops	✓	✓		✓	
Root and tuber vegetables	✓	✓		✓	
Stalk and stem vegetables	✓	✓			
Stone fruit	✓	✓	✓	✓	
Sunflower/ safflower		✓		✓	
Tree nuts	✓	✓	✓	✓	
Turf	✓				

[4] Emergency Permit applications have been submitted for the crops and chemical actives marked with a tick in the table. Should am incursion of BMSB occur in Australia, chemicals could be used for emergency measures associated with eradication.

[5] Flowerhead brassica

[6] Bulb onion and garlic

5.3.5 Control of stink bugs on buildings, goods, machinery or equipment

In the United States, commercial pesticide applicators have used deltamethrin, cyfluthrin, lambdacyhalothrin, cypermethrin, sumithrin and tralomethrin on building exteriors (Sargent *et al.* 2010).

Treatment conditions for control of stink bugs approved by the Australian Department of Agriculture and Water Resources for treatment of interception at the border in goods, machinery and equipment are:

- **Sulfuryl fluoride** – at least 48g/m^3 for 6 hours or longer or at least 16g/m^3 for 12 hours or longer both with an end point reading of 50% or more of the initial concentration and conducted at a temperature of 10°C or higher.
- **Methyl bromide** – at least 16g/m^3 for 12 hours or longer with an end point reading of 50% or more of the initial concentration and conducted at a temperature of 15°C or higher.
- **Heat** – at 50°C or greater for at least 20 minutes.

In addition, use of hot soapy water has been used for control of BMSB in the United States. Use of steam could be considered although it may disperse bugs if they cannot be contained.

5.3.6 Decontamination protocols

If decontamination procedures are required, machinery, equipment and vehicles infested with stink bugs or present within the Quarantine Area, should be treated as described in Section 5.3.5.

BMSB will use defensive behaviour and if aggregating, will drop from plants or structures or rapidly disperse if disturbed.

Footbaths will not be useful for limiting the spread of stink bugs between premises/sites but should be considered if limiting the spread of fungal, bacterial or viral diseases that may be present.

5.4 Decision support for eradication

A summary of key activities associated with differing scenarios associated with a detection of BMSB is provided in Table 3. Differing physical detection scenarios have been chosen to highlight operational differences in urban compared with agricultural and horticultural environments.

Differing seasonal scenarios were also selected as the activity of BMSB changes between seasons. In spring and summer BMSB will be actively seeking mates and food sources, while in autumn and winter BMSB will be seeking refuge and overwintering.

A summary of factors to be considered for eradication or alternative action is provided in Table 4.

The decision to eradicate will be based on the potential economic impact of host damage, the cost of eradication and its technical feasibility.

Table 3 Recommended responses and considerations for differing scenarios of detection of brown marmorated stink bug

Scenario	Recommended eradication/ control treatments – see Section 5.4	Recommended Movement Controls – See Section 5.2.1	Recommended surveillance options – See Section 4.4.1

Commercial Glasshouse or QAP	- See 5.4 for eradication treatments for insects and equipment.
	- Destruction of hosts unlikely to be effective but within glasshouses, could be considered to limit food sources or refuges (see 5.4.2).
		- No movement of equipment or produce without permit.
		- Permits to include information on inspection, decontamination or destruction.
			- Minimum 5 km surveillance zone around the IP. Focus on known hosts or areas that provide refuge.
			- Surveillance at linked properties.
			- See Section 4 for points to consider when establishing surveillance program. Key points for glasshouses are:
			  - Undertake surveillance on all plants but target ripening fruit where available.
			  - Consider using traps and lures in larger glasshouses

Building/urban detection in autumn/winter – insects entering or in overwintering phase.	- Chemical sprays (or fumigation if feasible) to eradicate the pest. - Bait (lure and kill) traps - Physical removal of insects may be required in conjunction with chemical sprays or treatments. - Treatments within urban/ residential situations to focus on negotiation with residents to achieve voluntary compliance pending a confirmed validation of the pest.	- Inspection/decontamination of equipment moving from IP - Where feasible, destruction of packaging material - Movement controls undertaken by permit or as voluntary compliance (coupled with awareness campaign for urban areas).	- Minimum 5 km surveillance zone around the IP. In the autumn/winter period, focus on areas that provide refuge. BMSB appear to prefer darker locations when seeking refuge during overwintering. - Visual inspections of any remaining plant material/ facilities for insects during overwintering period.
Urban backyard in summer – insects feeding on fruit and vegetables	- Chemical sprays to eradicate nymphs and adults. - Surveillance within 5 km radius (visual and traps).	- Movement controls could be undertaken by permit or as voluntary movement controls (coupled with awareness campaign for urban areas).	- Surveillance on food sources (e.g. fruit and vegetable hosts) in 5 km zone around IP (noting adults likely to be more active and seeking food sources or mates in spring and summer. - Surveillance to be done in conjunction with awareness campaigns for households providing information on the pest and symptoms. - Pheromone traps/strips should be deployed in the 5 km zone. - Use of light traps should be deployed if night time temperatures are higher than 20ºC.

Scenario	Recommended eradication/ control treatments – see Section 5.4	Recommended Movement Controls – See Section 5.2.1	Recommended surveillance options – See Section 4.4.1
Port vicinity in spring/summer – insects emerging from diapause seeking food sources	- Chemical sprays (or fumigation of feasible) to eradicate nymphs and adults. - Surveillance within 5 km radius (visual and traps).	- Decontamination of equipment moving from IP - Visual inspection of plant material and equipment - Where feasible, fumigation of packaging &/or plant material. - Destruction using high temperature incineration (care taken in moving any potentially infested material off-site)	- Surveillance on food sources (eg fruit and vegetable hosts) in 5 km zone around IP noting adults likely to be more active and seeking food sources or mates. - Include awareness campaign for households within 5 km of the port area. - Pheromone traps/strips should be deployed in the 5 km zone. -Use light traps if night time temperatures are higher than 20ºC. - Surveillance at linked properties
Open agricultural/ horticultural setting in spring /summer – insects feeding on crops	- Sprays of detections pending outcomes of delimiting surveillance	- No movement of equipment or produce without permit. - Permits to include information on inspection, decontamination or destruction.	- Minimum 5 km surveillance zone around each IP although note that zone will require assessment depending on the property size and proximity to food sources for BMSB. - Pheromone traps/strips should be deployed in the 5 km zone. -Use light traps if night time temperatures are higher than 20ºC. - General surveillance awareness campaigns - Surveillance at linked properties
Open natural environment E.g. Detection on roadsides or national park in summer	- Treatment of detections in a 5 km zone pending delimiting surveillance	- Movement restrictions at state/ territory borders pending outcomes of delimiting surveillance	- Minimum 5 km surveillance zone around the IP. - General surveillance awareness campaigns

Table 4. Summary of factors to be considered in determining whether eradication or alternative action will be taken for an incursion of an exotic stink bug

Factors to consider regarding the technical feasibility of eradication
• **The population size and population structure associated with the initial detection** - Detections of large numbers of stink bugs (>1,000 individuals)[7] seeking refuge in structures as part of their over-wintering phase may indicate an established population in gardens or commercial production in the vicinity. - Large populations (>1,000 individuals)[8] in commercial production areas may indicate a population that has been established for a period of time. • **The cost effectiveness of recommended control technique options** - Multiple chemical applications may be required to eradicate stink bug populations. - Treatments other than chemical control may be an effective strategy but could be cost prohibitive or not feasible on larger scales. • **The ability to remove or destroy all stink bug individuals by the recommended control techniques** - Permission to enter private premises for surveillance and treatment must be considered. - Determination of whether treatments can effectively eradicate stink bug populations within premises or environments. • **The ability to remove stink bugs at a faster rate than they can increase until proof of freedom can be achieved** - Treatments are available for control of BMSB. Population size, time of season the detection occurs, area to be covered and ability for treatments to reach all individuals must be considered. • **The recommended control techniques are publically acceptable** - Chemical treatments (fumigation, sprays, bait trapping) in residences or backyards may not be acceptable or will require negotiation with residents. • **Whether Emergency Containment measures can effectively be put in place** • **Whether there are control methods, commonly employed for endemic pests that may prevent the establishment of the exotic stink bug species or be impacted by treatment for stink bugs** - In the United States, treatment for BMSB has resulted in significantly higher numbers of chemical sprays per season. 'Softer' chemicals such as pyrethroids have limited effectiveness, and application of a range of other chemicals has had an adverse effect on Integrated Pest Management programs, resulting in an increase of other secondary pest species that were previously well managed. • **Legislative impediments to undertaking an eradication response** - If not a prescribed pest, confirmatory diagnosis will be required under legislation in some jurisdictions before powers to enter premises and undertake treatments can be enacted. - Delimiting surveillance in urban environments may be restricted to backyards and environs rather than entry into premises (unless permission from the resident can be negotiated). - Emergency permits will be required for chemical treatments. Amendments to chemical labels will be required for longer term management of stink bugs.

[7] Number estimated as representing a high level based on expert opinion of a recent incursion into Australia.

[8] Number estimated as representing a high level based on expert opinion of a recent incursion into Australia.

- **The ability to delimit the known area of infestation**
  - Determination of linked properties in an urban detection may be infeasible given the ability of stink bugs to disperse. High risk linkages such as travel to commercial production areas or facilities should be investigated.
- **The ability to identify and close the pathway for entry of the pest into Australia**
  - Pathways into Australia have been identified (and closed) as a result BMSB of hitchhiking on imported products.
- **The dispersal ability of the pest**
  - It is considered unlikely stink bugs will travel with harvested produce (unless as an accidental hitchhiker) as the process of harvesting or moving produce is likely to cause them to disperse.
  - In spring and summer, adult stink bugs may disperse widely in search of a food source or mate. Adults are strong fliers when temperatures are >20ºC. Nymphs are strong walkers when temperatures are >25ºC.
  - BMSB is a good hitchhiker that seeks refuge as part of overwintering behaviour triggered by shorter day lengths. Long distance spread (between and within countries) has resulted from human-assisted dispersal following aggregation in buildings, packaging, equipment and vehicles. Human assisted dispersal may occur between sites if insects have taken refuge from heat in summer in packing material or vehicles or if they seek refuge as part of over-wintering behaviour in colder temperatures
- **The capability to detect exotic stink bugs at very low densities for the purpose of declaring freedom, and that all sites affected by the pest have or can be found**
  - For BMSB, lures are available that combine a synergist and an aggregation pheromone. Insects take two weeks (providing they can access a food source) to become sexually mature following emergence from their over-wintering state, and in this period are not responsive to lures.
- **The ability to put into place surveillance to confirm proof of freedom**
  - Surveillance options are available for BMSB and include visual surveillance and lures (in insect traps and sticky strips). Detector dogs have also been used successfully in the United States.
- **Whether community consultation activities have or will be undertaken**
  - In an urban environment, community consultation critical to assist secure public support for delimiting surveillance and an eradication program.
  - Given the nuisance potential of this pest in urban environments, general surveillance activities should be implemented comprising awareness, media releases, web-based reporting tools and the exotic plant pest hotline.

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Appendices

Appendix 1: Impact on Agricultural Hosts

Symptoms caused by BMSB differs between hosts. On the leaves and fruit of many plants, small necrotic lesions develop. The table below describes the types of symptoms and damage seen on different hosts and also outlines whether the main impacts are on quality and/or production losses.

Host	**Affected plant part**	**Impact description**	**Quality or production losses**
Acacia[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	
Adzuki bean[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	
Almonds[3]		Reported to feed on almonds, no details about significance of this crop as a host plant (Haye *et al.* 2015).	
Apple[1]	Fruit	Feeding during petal fall can cause an increase in fruit abortion, feeding mid-season causes dimples to appear on the fruit, while feeding later in the season during fruit swell caused white or brown corking (puckering), dimpling or pitting near the skin surface, or water soaked lesions. Some orchards in the United States have reported >25% of fruit being damaged by BMSB and in some areas this was significantly higher (Nielsen and Hamilton 2009). Damage in the United States caused growers to increase their insecticide sprays to manage BMSB but this disrupted IPM programs and caused secondary pest problems (Leskey *et al.* 2012a).	Quality
Apricot[1]		Affected by BMSB (Haye *et al.* 2015)	
Asparagus[3]	Leaves and stems	Reported to be affected and damaged by BMSB (Lee *et al.* 2013). This was the first host that BMSB was reported on in Switzerland (Wermelinger *et al.* 2008)	Quality
Beet[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	
Blackberries[1]	Fruit and flowers	Feeding early in the season can cause death of buds. Late season feeding causes collapse of individual drupelets and the insects droppings can also cause fruit to taste (Rice *et al.* 2014).	Quality

Host	Affected plant part	Impact description	Quality or production losses
Blueberries[1]	Fruit	Feeding caused discolouration, necrosis of the internal tissue of the fruit and also resulted in reduced fruit weights. Some cultivars were more susceptible to damage than others (Wiman *et al.* 2015).	Quality
Capsicum[1]	Fruit	Feeding causes blemishes (discoloured spongy areas) on the skin as well as internal damage (Kuhar *et al.*, 2012).	Quality
Carrot[3]		Listed as a food source for rearing stinkbugs (Medal *et al.* 2013). No information available its status as a field host.	
Cherry[1]	Fruit	Cherry are affected by BMSB (Watanabe 1996; Haye *et al.* 2015). On cherry the adults feed on the young and ripening fruit. After feeding a significant areas of the fruit (20-60%) becomes brown and the fruit begins to collapse. Damaged fruit mostly abscise prior to harvest (Watanabe 1996).	Quality and production losses
Citrus[3]		Reported to feed on citrus, no details about significance of this crop as a host plant (Haye *et al.* 2015; Lee *et al.* 2013).	
Cotton[1]	Bolls	BMSB feeds on bolls, including large (>32mm) bolls that are usually not attacked by stinkbugs. Feeding can cause reduction in lint quality and yield (Kamminga *et al.* 2014)	Quality and production losses
Cucumber[1]	Fruit	Feeding causes damage to fruit (Lee *et al.* 2013)	Quality
Cucumber[3]	Fruit	Damage to up to 90% of cucumbers have been reported overseas (Lee *et al.* 2013).	Quality
Egg plant[1]	Fruit	Feeding causes blemishes (discoloured spongy areas) on the skin as well as internal damage (Kuhar *et al.* 2012)	Quality
Grapes – Table grapes/ Viticulture/ Dried Fruits[2]	Fruit	All life stages have been found in vineyards in the United States (Smith *et al.* 2015). BMSB feed on the grapes and causes abscission of the clusters and they can also hide in bunches and cause a taint to the juice of winegrapes (Basnet *et al.* 2015)	Quality and production
Hop[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	

Host	**Affected plant part**	**Impact description**	**Quality or production losses**
Hazelnut[1]	Nuts	Feeding causes blank nuts (i.e. kernels do not develop) kernel shrivelling, or corking of kernel (Hedstrom *et al.* 2014)	Quality and production losses
Kiwi[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	
Lettuce[3]		Listed as a food source for BMSB in laboratory studies only	
Lilac[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	
Lima bean[3]	Fruit	Causes discolouration and distortion of the pods (Rice *et al.* 2014)	Quality
Loquat[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	
Maize/sweet corn[1]	Ears	On sweet corn BMSB is reported to cause damage to kernels (described as sunken, collapsed or discoloured) even at low population levels and infections also caused a reduction in kernel numbers/ear and reduced ear length (Cissel *et al.* 2015). Damage to field corn (i.e. maize) is the same with collapsed grains occurring sue to feeding by BMSB (Rice *et al.* 2014).	Quality and yield losses
Maple[3]	Seeds	Nymphs reported on the seeds of maple in Switzerland (Wermelinger *et al.*, 2008).	
Millet (*Panicum miliaceum*)[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	
Nectarine and peach[1]	Fruit	Feeding causes corking injuries to peaches, which can be seen just under the surface of the skin. The fruit can also become distorted (Leskey *et al.* 2012b). Fruit abscission can also occur (Lee *et al.* 2013).	Quality
Okra[3]	Fruit	Feeding causes pods to become distorted/deformed or pimpled (Kuhar *et al.* 2012)	Quality
Olive[3]		Reported to feed on olives, no details about significance of this crop as a host plant (Haye *et al.* 2015).	
Ornamentals – various[3]	Various	Juneberry (*Amelanchier lamarckii*) and Butterfly bush (*Buddleja davidii*) were slightly affected. Japanese angelica tree (*Aralia elata*), Garden nasturtium (*Tropaeolum majus*), Dead man's fingers (*Decaisnea fargesii*)	Can cause plant death

Host	**Affected plant part**	**Impact description**	**Quality or production losses**
		and Japanese Stewartia (*Stewartia pseudocamellia*) were heavily infested by BMSB in Switzerland. Infestations reportedly lead to the death of a *Stewartia pseudocamellia* plant (Wermelinger *et al.* 2008)	
Paulownia[3]		BMSB vectors witches' broom phytoplasma (Yuan 1984).	Vector of phytoplasma
Pistachio[3]		Reported to feed on pistachio, no details about significance of this crop as a host plant (Haye *et al.* 2015).	
Pea[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	
Peanut[3]		Listed as a food source for rearing stinkbugs. No information on its status as a field host.	
Pear[1]	Fruit	Some orchards in the United States have reported >25% of fruit being damaged by BMSB and in some areas this was significantly higher (Nielsen and Hamilton 2009). Feeding causes depressions and corking, feeding damage is greater when BMSB feeds on fruit <30mm (Lee *et al.* 2013).	Quality
Pecan[3]		Pecan is reported as a host of this pest however no information was provided on its economic impact (USDA APIS 2010).	
Persimmon[3]	Fruit	Fruit becomes discoloured and distorted as a result of BMSB feeding (Kim and Park 2015; Lee *et al.* 2013). Fruit abscission can also occur (Lee *et al.* 2013).	Quality
Plum[3]		Listed by Lee *et al.*2013 as a host of BMSB. No details on impact.	
Quince [3]		Listed by Lee *et al.*2013 as a host of BMSB. No details on impact.	
Raspberries[1]	Fruit and flowers	In parts of the United States BMSB is replacing the endemic stink bugs feeding on raspberry. BMSB feeds on the fruiting structures (Basnet *et al.* 2014). The fruit often will not come free of the fruiting structures and will appear shrivelled. Feeding early in the season can cause death of buds. Late season feeding causes collapse of individual drupelets and the insects droppings can also impart a bad taste to fruit (Rice *et al.* 2014)	Quality
Soybean[2]	Fruit, Stay-green syndrome	BMSB damage appears as brown or black puncture wounds on stems, leaves and blooms. BMSB feed on the seeds by piercing the pods. This causes pods to become flattened and distorted or aborted. BMSB typically feeds on the edges of soybean paddocks and can produce a “stay green” syndrome where the infested plants	Production losses

Host	Affected plant part	Impact description	Quality or production losses
	affects leaves	remain green longer than non-infested plants (Pennsylvania State University Entomological notes, 2012). Also associated with delayed maturity and reduced yields due to see damage (Quaries 2014).	
Sorghum[3]		While there is no reference to damage or yield loss caused to sorghum, this crop is significant as it is listed as a trap crop in the United States i.e. BMSB are highly attracted to it (Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact).	
Strawberries[1]	Berries	80% yield losses due to BMSB damage reported in Lee *et al.* (2013)	
Sunflower[2]	Seed	Listed as having been used as trap crop as it is highly attractive to BMSB (Soergel *et al.* 2015). Listed by Lee *et al.* 2013) as a host of BMSB. No details on impact.	
Tea[3]	Leaves	Reported to feed on tea leaves (Lee *et al.* 2013)	
Tomato[1]	Fruit	Feeding causes blemishes (discoloured corkish or spongy areas) on the skin as well as internal damage (Kuhar *et al.*, 2012). Damage to ripe tomatoes appears as whitish yellow feeding sites. Damage to green tomatoes appears as a pinprick surrounded by a light discoloured area (www.stopbmsb.org).	Quality
Vegetable beans[3]	Fruit	Pods become distorted/deformed, with sunken areas forming around feeding sites. 10-15% of pods were affected in research plots in Virginia and Maryland (Kuhar *et al.* 2012)	Quality
Walnut[3]		Reported to feed on walnut, no details about significance of this crop as a host plant (Haye *et al.* 2015).	
Wheat[3]		Listed by Lee *et al.* 2013 as a host of BMSB. No details on impact.	

[1] Major host; high impact of BMSB on this host

[2] Moderate host; moderate impact of BMSB on this host

[3] Limited impact and/or limited information of economic damage on this host

Appendix 2: Additional information on monitoring tools for BMSB

- Brown Marmorated Stinkbug (BMSB) traps, lures and the methyl (2E,4E,6Z)-decatrieonate (MDT) adult-aggregation pheromone available from AgBio Inc., 877 268-2020.
- Dead-INN Pyramid Trap (4ft) with MDT 1x lure available from AgBio. Traps, **www.agbio-inc.com/dead-inn-pyramid-trap.html**. AgBio has worked directly with USDA to develop this commercial trap and lure.
- USDA recommends the Hercon Vaportape II kill strip (purchased from Gemplers, 800 382-8473 or **www.gemplers.com**). Insecticide strips are available for use in Australia (see **www.australianalmonds.com.au/documents/Industry/Fact%20Sheets/Carpophilus%20Monitoring%20Guidelines%20-%20Almonds%202014-15.pdf**)
- Further information on trap deployment for monitoring for BMSB is outlined in the Oregon State University Extension Service Factsheet (Wiman *et al.* 2016).