Brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae), detections in Western Sydney, New South Wales, Australia

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**Abstract**

Brown marmorated stink bug (BMSB), *Halyomorpha halys* Stål, 1855, is a polyphagous agricultural insect pest which causes serious production losses. BMSB also has human lifestyle impacts which arise from its habit of overwintering in homes. The invasiveness of BMSB and the harm it causes is making it a pest of increasing global importance. Over the past 30 years, the bug has spread from its native range in East Asia to North America and Europe. On November 2017 and January 2018, BMSBs were found at two Western Sydney locations in goods imported from northern Italy. While BMSB detections in imports are common in Australia, these encounters were significant because of sightings of bugs outside the infested premises, indicating possible spread into the local environment. Measures undertaken in Western Sydney to contain and eradicate BMSB included fumigation of infested goods, insecticide treatment of the warehouse site and surroundings and delimiting surveillance. Before commencing widespread surveillance, a vegetation survey was conducted to identify known host and potential BMSB host plants around the infested premises. ESRI Collector for ArcGIS™ was used to compile host plant location data which served as the basis for pheromone trap deployment and physical inspection. Surveillance continued until May 2018. No live BMSBs were detected. DNA analysis of dead BMSBs collected from infested goods discerned the presence of two different haplotypes (H): H1 (previously detected in North America, Europe and China) and H23 (North America and Japan).

**Key words**

biosecurity, emergency response, haplotype, invasive species.

**INTRODUCTION**

Brown marmorated stink bug (BMSB), *Halyomorpha halys* Stål, 1855, is a polyphagous insect which causes serious production losses to a wide variety of fruit and vegetables including tomato, apple, peach, capsicum, beans and corn (Rice et al. 2014). The native range of the pest is East Asia (China, Japan and Korea) (Xu et al. 2013). Due to human-assisted introductions, the bug has spread to other parts of the world including North America and Europe (Rice et al. 2014; Haye et al. 2015; Kriticos et al. 2017; Rot et al. 2018). The invasiveness of BMSB is making it a pest of increasing global importance, particularly where it encroaches on areas of agricultural production (Rice et al. 2014). The bug also has human lifestyle impacts which arise from its habit of overwintering in homes and releasing an unpleasant odour when disturbed (Inkley 2012).

BMSB poses a high biosecurity risk to Australia due to its tendency to hitchhike on imported goods (e.g. containers and vehicles) and the climatic suitability of many parts of the country, especially along the eastern rim of the continent which is home to some key areas of agricultural production (Kriticos et al. 2017). BMSBs are strong fliers (Rice et al. 2014), which, along with human-assisted movement, make them capable of widespread dispersal. As it does in other parts of the world, the bug would cause yield losses and negative social impacts in areas of host plant production. Established populations would be difficult and expensive to manage. Broad-spectrum insecticides are required for chemical control, and these can cause environmental problems such as disrupting integrated pest management programs (Leskey et al. 2012).

BMSB is frequently intercepted by border officials in a number of countries including New Zealand (Duthie 2012) and Australia (Walker 2009). Since 2014, large numbers of live BMSB have been detected by the Department of Agriculture and Water Resources (DAWR) inspectors in goods arriving in Australia from overseas, especially from the USA (DAWR 2017a). In 2016–2017, imports from Italy emerged as the major source of live BMSB (DAWR 2017a). To deal with this threat, risk management measures such as mandatory offshore heat treatment and fumigation of imported goods have been implemented. Preventing an incursion is a priority for government and industry in Australia. BMSB is included in the National...
Priority Plant Pest List endorsed by the Australian Plant Health Committee (DAWR 2016).

On 17 November 2017, 38 live adult BMSB (12 male and 26 female) were detected in a shipping container packed with electrical components at Glendenning in Western Sydney. The goods were imported from northern Italy where BMSB has been present since the early 2000s (Rice et al. 2014). Items in the container had been classified as low risk by quarantine authorities and had not been inspected or treated. The warehouse manager at the infested premises (IP1) reported the presence of exotic bugs to DAWR. DAWR officers inspected IP1 on the day of the detection and made the initial identification of the pest as BMSB. While BMSB detections in imported goods are not uncommon in Australia (DAWR 2017a), this encounter was significant because a BMSB was found on a wall outside the warehouse entrance, raising the possibility of other bugs having spread into the local environment.

A second detection of BMSB in Western Sydney was made on 19 January 2018 at a warehouse at Horsley Park (IP2). Three dead bugs were present on bricks imported from Italy. This detection was unrelated to the first at IP1. Employees at the site informed DAWR officials that BMSBs were seen crawling and flying away from an earlier consignment, also from Italy, which arrived on December 2017.

Here, we report on the emergency response procedures implemented to deal with the potential BMSB incursions in Western Sydney. The primary objective of these procedures was to detect and delimit potential BMSB escapes from the infested premises. Here also, the authors provide details of the first comprehensive survey of BMSB host plants in Australia. The survey aim was to identify plants that may be harbouring potential BMSB escapes from IP1. Known plant hosts of BMSB (DAWR 2017a) were targeted, but a factor confounding the installation of a comprehensive surveillance network was the lack of knowledge about the host suitability of a large portion of plants, especially those around IP1. These included native species, ornamentals (e.g. street trees and shrubs) and environmental weeds, many of which do not occur in BMSB-infested areas in the northern hemisphere. To counter this knowledge gap, an intensive visual survey of vegetation within a radius of approximately 1 km around IP1 was carried out from 5 to 29 December 2017. Subsequently, most BMSB surveillance activities around IP1 were carried out near known host, and potential host plants identified in the vegetation survey.

Finally, molecular approaches are now often used to supplement conventional interception and trapping data to determine the genetic diversity and geographic origin of exotic pests (Gariepy et al. 2014). This paper also reports on the results of haplotype analysis of BMSB in the infested consignment at IP1 and comparisons made with potential source populations.

**MATERIALS AND METHODS**

**Initial response activities**

Following the detection of BMSB in Glendenning, a containment and eradication campaign was initiated under the Emergency Plant Pest Response Deed, which is a legally binding contract between Plant Health Australian (PHA), the Australian Government, all state and territory governments and national plant industry peak body representatives (PHA 2018). The emergency response was guided by PLANTPLAN (PHA 2017a), a generic response plan which provides nationally consistent guidelines for managing exotic plant pest incursions.

Infested items at IP1 were covered with shrink wrap, repacked into a container on 20 November and dispatched for fumigation. At that time, two other containers from the same consignment that were still offshore were subsequently fumigated upon arrival in Australia as a precaution. BMSBs found in all three containers were dead. On 21 November, owners of IP1 contracted a pest controller to treat the interior of the warehouse with insecticide (bifenthrin surface spray and pyrethrum fog). On 22 November, five panel traps modified for BMSB (AlphaScents™) and baited with Alphascents™ BMSB pheromone lures were installed inside the IP1 warehouse and in surrounding gardens. The lures contained methyl(2E,4E,6Z)-decaatrieneoate (MDT) and isomers of 10,11-epoxy-1-bisa bolen-3-ol(murgantiol), which are male-produced aggregation pheromones of two other pentatomids, the brown-winged green stink bug, Plautia stali Scott, and the harlequin bug, Murgantia histrionica (Hahn). BMSB has been shown to be cross-attracted to both pheromones (Lee 2015). On 24 November, vegetation around IP1 and adjoining properties was sprayed with bifenthrin, which has been identified as an efficacious active ingredient for controlling BMSB (Leskey et al. 2012). One dead BMSB was found in skylight cobwebs inside IP1 on 27 November. As an added precaution against other BMSB possibly inhabiting IP1, the interior was fogged with deltamethrin (20 g/L) on 30 November, 8 December and 15 December.

**Vegetation survey around IP1**

Vegetation surveillance was performed by teams including Greater Sydney Local Land Services (GSLLS) staff experienced in weed identification and qualified botanists. Due to high summer temperatures and the nature of the terrain, measures were required to counter the threats to the health and safety of surveillance teams, such as dehydration and the prevalence of venomous snakes. To the east of IP1 is the Western Sydney Parkland corridor, in which lie Eastern Creek and extensive areas of weed-infested bushland and parkland. The land to the west is predominantly industrial (e.g. factories, warehouses and parking lots). Approximately 300 ha was inspected by 10 different staff members in 3 weeks.

The criterion used for recording possible BMSB harbourages was if plants were either known hosts or potential hosts. Known host status was assigned according to a list of plants in the Draft pest risk analysis for brown marmorated stink bug (Halyomorpha halys) (DAWR 2017a), which cites BMSB hosts drawn from four sources (Bergmann et al. 2015, Bergmann et al. 2016, Lee et al. 2013, USDA-APHIS-PPQ 2010). Plants were categorised as potential hosts if they produced soft fruit, buds or pods, which could serve as a food source for BMSB (Bergmann et al. 2015). When feasible, plants were identified...
to species, but due to the size of the surveillance area and the strenuous nature of the work, it was not always practical to perform identifications in the field nor to collect specimens for later identification. Consequently, in some cases, plants were identified to genus only.

Geographic Information Systems software (ESRI Collector for ArcGIS™) uploaded onto tablets was used in combination with high-resolution aerial images from the ESRI ArcGIS ‘World Imagery’ online basemap to record host locations of both individual plants and groups of plants.

**BMSB surveillance**

Surveillance for BMSB was performed around IP1 and IP2, commencing on 22 November 2017 and 19 January 2018, respectively, until the emergency response stand-down on April 2018. Aspects of the surveillance program were drawn from the Contingency Plan for Brown Marmorated Stink Bug (PHA 2017b). Delimiting surveys employed the following: (1) pyramid traps (Fig. 1a), panel traps and sticky traps (Fig. 1b) with MDT/murgantiol pheromone lures for BMSB; (2) sweep-net sampling of host plant and visual observation of host plants; and (3) manual collection of specimens.

The bulk of BMSB surveillance activities around IP1 was carried out near known host and potential host plants identified in the vegetation survey. Although most known host and potential host plants were on the east of IP1, the warehouse opening, which was the only escape route accessible by BMSB, faced a westerly direction. Consequently, traps were placed to both east and west of IP1, with the majority of locations on the eastern side. Trap locations were recorded using ESRI Collector for ArcGIS™ (Fig. 2).

The Contingency Plan for Brown Marmorated Stink Bug (PHA 2017b) recommends delimiting surveys within a 5 km zone around the initial detection, based on the dispersal capabilities of BMSB (Wiman et al. 2014; Lee 2015). A comprehensive vegetation survey out to this distance was considered impracticable since a large portion of the land outside the 1 km zone was residential (Fig. 2). In view of this, an alternative strategy relying on programs of surveillance in community and private vegetable gardens and public engagement was adopted. Engagement activities included posts on social media, delivery of awareness material and media releases.

Four types of trap were installed around IP1 (number installed): 1.1 m black pyramid traps (74), 0.5 m green pyramid traps (16), panel traps (5) and clear sticky traps (76). All traps were used in combination with MDT/murgantiol pheromone lures. Visual inspection of hosts, manual specimen collection and trap deployment were also carried out near bright lights (a known insect attractant) in close proximity to IP1. An additional 22 black pyramid traps and 1 sticky trap were installed at IP2. A vegetation survey was not conducted around IP2 because the surrounding land contained considerably less vegetation than in IP1 as well as harsh environments including motorways and a landfill site. At IP2, trap locations and other surveillance activities were directed at known host and potential host plants and vegetable gardens within a 2 km radius.

Traps were inspected weekly, and pheromone lures were replaced monthly. ESRI Collector for ArcGIS™ was configured to allow surveillance data to be recorded. In addition to inspecting traps, field teams carried out sweep-netting and visual surveillance of vegetation within 5 m of each trap. Field teams used the Guide to the identification of brown marmorated stink bug Halyomorpha halys, and other similar bugs (DAWR 2017b) to identify captured pentatomids. Adult specimens resembling BMSB were submitted for laboratory identification. Due to the dissimilarity between BMSB nymphs and adults, all pentatomid nymphal specimens were also retained for formal identification.

**DNA sequencing BMSB specimens**

Dead BMSB specimens were found in goods from the infested consignment at IP1 as they were being unpacked by warehouse staff. BMSBs collected between the months of November 2017 through February 2018 were used for subsequent haplotype analyses. Unfortunately, analyses excluded specimens from IP2 due to lack of access to samples from that location. On
May 2018, BMSB adult specimens (3 females and 1 male) were placed in 4 separate Sterilin™ Quickstart Universal Polystyrene 30 mL containers (Thermo Scientific™) containing 0.5 mL of molecular grade 100% ethanol along with a strip of filter paper (2.54 cm × 1.52 cm). Fixed BMSB specimens were transported via airmail to Washington State University in Prosser, Washington, for haplotype analysis.

DNA was extracted from all four BMSB adults using a Qiagen DNeasy Blood and Tissue Kit, and the quality and quantity of DNA were analysed using a Nanodrop 2000 Spectrophotometer. A 658 bp region of cytochrome C oxidase subunit 1 (CO1) was PCR amplified from each insect using the primers LCO1490 (GGT CAA ATC ATA AAG ATA TTG G) and HCO2198 (TAA ACT TCA GGG TGA CCA AAA AAT CA) (Folmer et al. 1994). Each 20 μL of reaction included Amplitaq Gold 360 Master Mix (Invitrogen, Carlsbad, California), 500 nM of each primer and 1 μL of template DNA. PCR conditions included an initial denaturation at 94 °C for 5 min, followed by 35 cycles of 94 °C for 60 s, 40 °C for 90 s and 72 °C for 90 s, and then a final extension at 72 °C for 7 min. The presence of amplicons was observed on a 1.5% agarose gel stained with ethidium bromide. Amplicons were excised from the gel, purified using GenElute EtBr spin columns (Sigma-Aldrich, St. Louis, Missouri) and cloned using a TOPO TA cloning kit with TOP10 Escherichia coli chemically competent cells (Invitrogen, Carlsbad, CA). Plasmid DNA was extracted from three selected colonies from each insect using a QIAprep spin mini prep kit (Qiagen, Valencia, California), and DNA clones were sequenced by MC Laboratories (San Francisco, California) after confirming PCR product insertion by EcoRI restriction digestion (Promega Corporation, Madison, Wisconsin). Forward and reverse sequences were aligned using Geneious 10 (Kearse et al. 2012; Geneious 2018), and the consensus sequences were compared with BMSB sequences obtained from the NCBI database and with CO1 sequences used for haplotype assignment by Gariepy et al. (2014). Sequences were deposited in the NCBI database under accession numbers MH796141–MH796145.

RESULTS

Vegetation survey

Vegetation survey teams identified 1541 sites with individual known host and potential host plant species and 611 areas with
multiple known host and potential host plant species (Fig. 2; Table 1). Many of the species identified were in bushland/parkland areas to the east of IP1 that were heavily infested with weeds. These sites contained approximately 80 plant species of interest, 24 of which were known hosts (DAWR 2017a). The top 20 known host and potential hosts identified in the survey are presented in Table 1.

BMSB surveillance

Traps placed around IP1 and IP2 were examined weekly over 5 and 4 month periods, respectively. No BMSBs were detected at either site. However, there was considerable bycatch including endemic pentatomid populations. Approximately 2600 bugs (adults and nymphs) were captured at both IPs. Green stink bug (GSB), Plautia stali (Heteroptera: Pentatomidae), comprised over 95% of collected pentatomids. Other trapped pentatomids included native genera Oncocoris sp., Platycoris sp., Poecilometis sp. and Theseus sp. as well as the introduced species Nezara viridula. Fifteen of the 20 traps with the highest numbers of captured GSB (Appendix I) were black pyramid traps. Plants near traps with the highest levels of GSB bycatch included blackberry (Rubus fruiticosus), mulberry (Morus alba), nightshades (Solanum sp.), privet (Ligustrum sp.) and green poisonberry (Cestrum parqui). While these plants may be preferred hosts for GSB, this relationship cannot be confirmed due to the wide range of plant species in the vicinity of most traps.

Sequence data and haplotypes

A 710 bp region of the DNA barcode region of the CO1 gene was amplified and sequenced from all four BMSB specimens submitted for analysis. These four specimens represented two BMSB haplotypes as described by Gariepy et al. (2014). The samples IP1–1, IP1–3 and IP1–4 shared identical sequences and were identified as H23, known to originate from Japan and to have been captured in North America (Table 2; Gariepy et al. 2014; Valentin et al. 2017). The CO1 sequence obtained from these specimens was also highly similar to that described from specimens established in Europe, including Italy (KY710433 and MF537248; Gariepy et al. 2015, Cesari et al. 2018). Two different clones were obtained from sample IP1-2 that differed by a single A-G SNP. Clone 1 did not match any BMSB sequences deposited in the NCBI database and may be the result of PCR or sequencing error. Clone 2 was identified as H1 first identified from Hebei/Beijing, China (Gariepy et al. 2014), and also collected in Italy (GenBank accession numbers KY930701 and KY710460; Cesari et al. 2018), North America, and several additional European locations including France, Greece, Hungary, and Switzerland (Gariepy et al. 2015).

DISCUSSION

Live BMSBs were neither seen nor trapped beyond IP1 and IP2. This result, following the intensive surveillance campaign conducted from November 2017 to May 2018, provides assurance that BMSB has not been established in Western Sydney. As BMSBs were seen flying from IP2, and evidently flew from infested goods at IP1, it is likely that bugs dispersed into the environment around both IPs. The reasons why BMSB was not detected were probably the limited numbers of escapees and response activities such as insecticidal treatment. Environmental factors including endemic insectivorous wildlife (e.g. spiders and birds), and climatic conditions may also have contributed to this outcome. Temperatures of 35 °C and above prevent development of all BMSB life stages (Haye et al.

Table 1 Findings of vegetation survey conducted within a 1 km radius of IP1 in Western Sydney: 20 most abundant known and potential hosts of brown marmorated stink bug

| Family            | Common name       | Scientific name       | Known (K) host or potential (P) host status† | % of sites present |
|-------------------|-------------------|-----------------------|-------------------------------------------|-------------------|
| Solanaceae        | African boxthorn  | Lycium ferocissimum   | P                                         | 8.2               |
| Solanaceae        | Green poisonberry| Cestrum parqui        | P                                         | 7.0               |
| Okeaeceae         | Narrow leaf privet| Liguastrum sinense    | K                                         | 6.6               |
| Gentianales       | Moth vine         | Araujia sericifera    | P                                         | 6.0               |
| Solanaceae        | Jerusalem cherry  | Solanum pseudocapsicum| P                                         | 5.9               |
| Fabaceae          | Cockspur coral    | Erythrina cristagalli | P                                         | 4.9               |
| Okeaeceae         | African olive     | Olea europea subsp. cupidate | P       | 4.7               |
| Solanaceae        | Nightshades       | Solanum sp.           | P                                         | 4.7               |
| Okeaeceae         | Broad leaf privet | Liguastrum lucidum    | P                                         | 3.2               |
| Loranthaceae      | Mistletoe         | Amyema sp.            | P                                         | 3.0               |
| Melliaceae        | White cedar       | Melia azedarich       | P                                         | 2.8               |
| Euphorbiaceae     | Chinese tallow    | Triadica sebifera     | P                                         | 2.6               |
| Cactaceae         | Prickly pear      | Opuntia stricta       | P                                         | 2.3               |
| Asparagaceae      | Asparagus fern    | Asparagus officinalis | P                                         | 2.3               |
| Solanaceae        | Tobacco bush      | Solanum mauritianum  | P                                         | 2.0               |
| Arecaceae         | Canary island palm| Phoenix canariensis   | P                                         | 1.9               |
| Rosaceae          | Blackberry        | Rubus fruiticosus     | K                                         | 1.5               |
| Moraceae          | Mulberry          | Morus alba            | K                                         | 1.5               |
| Rosaceae          | Rose              | Rosa sp.              | K                                         | 1.4               |
| Rosaceae          | Sweet briar       | Rosa rubiginosa       | P                                         | 1.4               |

†Known BMSB hosts listed in Department of Agriculture and Water Resources. 2017. Draft pest risk analysis for brown marmorated stink bug (Halyomorpha halys). Commonwealth of Australia.

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2014). On January 2018, the Western Sydney suburb of Penrith experienced a mean maximum temperature of 34.8 °C and a maximum daily temperature of 47.3 °C (Bureau of Meteorology 2018). Such records suggest that the harsh 2017/2018 summer climate in Western Sydney may have exceeded the temperature requirements of BMSB.

By surveying the vegetation around IP1, we were able to quantify the abundance of known host and potential host plants in the 1 km zone. In doing so, we provided a basis for conducting a comprehensive, evidence-based surveillance campaign for BMSB. The survey identified a large portion of the known host plants present in the 1 km zone around IP1. Because BMSB is not present in Australia, the only hosts known with certainty are those northern hemisphere species cited in the literature (DAWR 2017a). While these comprised a minority of the plant species in the region, their inclusion in the surveillance program was judicious given the lack of knowledge that exists in Australia about the host suitability of native plants and many of the weed species that were present around the IP1. In addition, the absence of BMSB from Australia obliged us to make assumptions about the host suitability of many plant species. This approach was justified by the fact that when BMSB has invaded new parts of the world, it has been known to increase its host range (Haye et al. 2015). Furthermore, given the wide phylogenetic separation of taxa known to be susceptible to BMSB, other new vulnerable hosts can be expected.

Another indication of potential BMSB host suitability of plants in Western Sydney was provided by GSB bycatch. While we have no knowledge regarding the species-specific attraction to known BMSB hosts, the plant species surrounding traps with the highest GSB bycatch included blackberry, mulberry and small-leaved privet, all of which are known BMSB hosts (DAWR 2017a). This finding suggests a degree of similarity in the food or host preferences of GSB and BMSB and could serve as a guide for targeting plant species for surveillance in the event of any subsequent BMSB incursions.

The invasiveness of BMSB, the arrival of imports from countries where it is established (e.g. Italy and USA) and suitability of climatic conditions (Kriticos et al. 2017) means Australia remains vulnerable to invasion, the risk of which has been increasing in recent years. In addition to events in Western Sydney over the course of summer 2017/2018, a detection was made at Jandakot, Western Australia, in January 2018 (Department of Primary Industries and Regional Development, Government of Western Australia 2019). Live BMSBs were detected in a container of imported electrical goods. Following fumigation of the site, one live BMSB was detected outside the warehouse. Surrounding bushland was sprayed with insecticide to reduce the risk of any further spread of BMSB. No further bugs have since been found at the site. During the 2018/2019 season, there have been seven post-border detections across Queensland, Western Australia and Victoria (DAWR 2019). Of these, the detection in a warehouse at Dandenong South in Victoria on imported goods from Italy was perhaps the most concerning, with two bugs found in separate traps outside the infested warehouse.

The polyphagous nature of BMSB and the rising concern that this pest can establish itself quite successfully in new habitats, as evidenced by its seemingly ever-increasing geographical distribution, raise considerable economic concerns for growers in the agricultural industry. Recently, there have been multiple new detections of BMSB around the world, such as in Slovenia and Croatia (Rot et al. 2018, Šapina and Jelaska 2018). These outcomes reinforce the pressing need to develop new approaches in identifying the invasion pathways, while intercepting potential pest threats by monitoring imports that might be harbouring BMSB (Valentin et al. 2017).

Generating genetic data on invasive BMSB populations can provide awareness about source areas and of invasion routes, as well as determining whether populations from some source regions are better adapted for establishing in exotic environments (Haye et al. 2015). Our results demonstrate a relatively high degree of genetic diversity amongst BMSB imported from Italy. Of particular concern was the identification of the H1 haplotype, which is believed to be highly invasive and damaging to horticultural produce (Valentin et al. 2017). Although only H1 has been officially recorded in Italy (Valentin et al. 2017), H23 may be a recent arrival there, possibly via similar pathways to those that brought BMSB into Western Sydney.

Identifying the source region for BMSB also has important control implications. For example, egg parasitoids (e.g. Trissolcus spp.) are important biological control agents. If BMSB becomes established in Australia, Trissolcus spp. could potentially play a key role in the containment of this pest. Should there be a desire to introduce such biocontrol agents, knowledge of the origin of BMSB would allow surveys for egg parasitoids to focus on the correct region (Xu et al. 2013; Haye et al. 2015). Interestingly, many sentinel BMSB egg mass surveys in North America have revealed adventive populations of Trissolcus japonicus (Hymenoptera: Platgyastridae) (Ashmead), the natural enemy of BMSB in its native range (Heraldly et al. 2016; Milnes et al. 2016).

Given the increasing risks posed by BMSB, enhanced control measures need to be implemented. DAWR has responded by

Table 2  DNA sequence results for specimens collected from IP1

| Sample ID | Date collected from IP1 | GenBank accession number | NCBI† matches | Haplotype‡ |
|-----------|------------------------|--------------------------|---------------|------------|
| IP1–1     | 25-Jan-18              | MH796143                 | KF273402 (100% pairwise identity) | H23        |
| IP1–2     | 17-Nov-17              | MH796141 (clone 1)       | KF273380 (99.8% pairwise identity) | H1         |
|           |                       | MH796142 (clone 2)       | KF273380 (100% pairwise identity) | H1         |
| IP1–3     | 20-Dec-17              | MH796144                 | KF273402 (100% pairwise identity) | H23        |
| IP1–4     | 21-Mar-18              | MH796145                 | KF273402 (100% pairwise identity) | H23        |

†National Centre for Biotechnology Information. Search was performed using a custom database consisting of haplotypes identified by Gariepy et al. (2014). ‡Gariepy et al. (2014).
reviewing its pre-border risk management activities (DAWR 2017a) and implementing measures that will provide an ‘acceptable level of protection’. For example, on 17 January 2018, DAWR imposed compulsory treatments on goods imported from Italy and the USA and have now introduced seasonal import measures applicable to a range of countries to manage the BMSB importation risk during the period from 1 Sept 2018 to 30 April 2019 (DAWR 2018). It would be appropriate for post-border risk management, which is generally the responsibility of state and territory governments, to be similarly upgraded. Insecticidal treatment has been the most widely used method for controlling BMSB in crops and tree fruits in the USA (Rice et al. 2014). The most efficacious active ingredients include bifenthrin, deltamethrin, permethrin, dimethoate, fenpropatrin and dinotefuran (Leskey et al. 2012; Rutgers New Jersey Agricultural Experiment Station 2018). Insecticidal treatment would be the main control and eradication strategy for a range of BMSB detection scenarios in Australia, including urban buildings and backyards, farms and bushland (Plant Health Australia 2017b). In advance of a possible BMSB incursion, to facilitate a rapid response, it is recommended that proactive spray plans are developed and prior arrangements are in place with suppliers of insecticides and spray equipment as well as with spray contractors. Finally, because there are currently no pesticides registered for controlling BMSB in Australia (Australian Pesticide and Veterinary Medicines Authority 2018), emergency use permits are a prerequisite to the use of efficacious insecticides in the envisaged scenarios.

ACKNOWLEDGEMENTS

The authors thank the management and staff at IP1 and IP2 for their cooperation; James Clugston, Linda Dedovic, Dr Nicole Kerrie Gallahar, Annaliese Geddes, Nerida Gill, Lisa Goodchild, Lee Parker, Jenny Schable and Josh Topham (GSLLS) for vegetation mapping and BMSB surveillance; Paras Acharya (GSLLS) for configuring and managing ESRI Collector for ArcGIS®; Dr Elizabeth Beers (Washington State University) for allowing staff participation in the project; Dr Gregory Chandler (DAWR), Peter Ridgeway (GSLLS) and Dr Louise Rossiter (NSW Department of Primary Industries) for technical advice; and Dr Tara Gariepy (Agriculture and Agri-Food Canada), Dr Christine Stone (NSW Department of Primary Industries – Forestry), Dr Tewodros Wакie and Dr Kylie Swisher Grimm (United States Department of Agriculture, Agriculture Research Service) for comments on the manuscript.

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Accepted for publication 1 August 2019.
Twenty highest trap collection results for green stink bug, *Plautia stali* (Heteroptera: Pentatomidae), and associated known or potential host(s) of brown marmorated stink bug, within a 5 km radius of IP1 in Western Sydney.

| Number of green stink bugs collected | Trap type       | Common name         | Host                | Scientific name       |
|-------------------------------------|-----------------|---------------------|---------------------|-----------------------|
| 117                                 | Black pyramid trap | Blackberry          | Blackberry          | *Rubus fruticosus*    |
| 113                                 | Black pyramid trap | Blackberry          | Blackberry          | *Rubus fruticosus*    |
| 113                                 | Black pyramid trap | Mulberry            | Morus alba          | *Morus alba*          |
| 106                                 | Green pyramid trap | Blackberry          | Blackberry          | *Rubus fruticosus*    |
| 72                                  | Black pyramid trap | Mulberry            | Morus alba          | *Morus alba*          |
| 72                                  | Sticky trap      | Blackberry          | Mulberry            | *Morus alba*          |
| 59                                  | Black pyramid trap | Mulberry            | Ligustrum sp.       | *Ligustrum sp.*       |
| 59                                  | Black pyramid trap | Privet              | Ligustrum sp.       | *Ligustrum sp.*       |
| 58                                  | Black pyramid trap | Nightshades         | Solanum sp.         | *Solanum sp.*         |
| 53                                  | Black pyramid trap | Nightshades         | Solanum sp.         | *Solanum sp.*         |
| 52                                  | Green pyramid trap | Blackberry          | Rubus fruticosus    | *Rubus fruticosus*    |
| 50                                  | Black pyramid trap | Privet              | Cestrum parqui      | *Cestrum parqui*      |
|                                     |                 | Morning glory       | Ipomea sp.          | *Ipomea sp.*          |
| 48                                  | Black pyramid trap | Blackberry          | Rubus fruticosus    | *Rubus fruticosus*    |
| 47                                  | Black pyramid trap | Cockspur coral tree | *Erythrina crista-galli* |
| 46                                  | Black pyramid trap | Plum                | *Prunus sp.*        |                       |
| 45                                  | Black pyramid trap | Green poisonberry   | *Cestrum parqui*    |                       |
|                                     |                 | Privet              | Ligustrum sp.       | *Ligustrum sp.*       |
|                                     |                 | Oleander            | Nerium oleander     |                       |
| 38                                  | Panel trap       | White cedar         | Melia azedarach     |                       |
| 37                                  | Sticky trap      | Cockspur coral tree | *Erythrina crista-galli* |
|                                     | Black pyramid trap | Tree of heaven      | *Ailanthus altisima* |
|                                     |                 | Nightshades         | Solanum sp.         | *Solanum sp.*         |