

PEST STATUS OF THE BROWN MARMORATED STINK BUG, *HALYOMORPHA HALYS* IN THE USA

Tracy C. Leskey^{1,2}, George C. Hamilton³, Anne L. Nielsen³, Dean F. Polk⁴, Cesar Rodriguez-Saona³, J. Christopher Bergh⁵, D. Ames Herbert⁶, Tom P. Kuhar⁷, Douglas Pfeiffer⁷, Galen P. Dively⁸, Cerruti R. R. Hooks⁸, Michael J. Raupp⁸, Paula M. Shrewsbury⁸, Greg Krawczyk⁹, Peter W. Shearer¹⁰, Joanne Whalen¹², Carrie Koplinka-Loehr¹², Elizabeth Myers¹², Douglas Inkley¹³, Kim A. Hoelmer¹⁴, Doo-Hyung Lee², and Starker E. Wright²

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Abstract

Since its initial discovery in Allentown, PA, USA, the brown marmorated stink bug (BMSB), *Halyomorpha halys* (Heteroptera: Pentatomidae) has now officially been detected in 38 states and the District of Columbia in the USA. Isolated populations also exist in Switzerland and Canada. This Asian species quickly became a major nuisance pest in the mid-Atlantic USA region due to its overwintering behavior of entering structures. BMSB has an extremely wide host range in both its native home and invaded countries where it feeds on numerous tree fruits, vegetables, field crops, ornamental plants, and native vegetation. In 2010, populations exploded causing severe crop losses to apples, peaches, sweet corn, peppers, tomatoes and row crops such as field corn and soybeans in several mid-Atlantic states. Damaging populations were detected in vineyards, small fruit and ornamentals. Researchers are collaborating to develop management solutions that will complement current integrated pest management programs. This article summarizes the current pest status and strategies being developed to manage BMSB in the USA.

Introduction

Native Geographic Distribution, Introduction and Spread. The brown marmorated stink bug (BMSB), *Halyomorpha halys*, is native to China, Japan, Korea and Taiwan (Hoebeke & Carter 2003). Early Asian literature refers to BMSB as the yellow-brown stink bug and as *H. picus* or *H. mista*. The first USA populations were discovered in the mid-1990s in or near

Allentown, PA. In 2001, Karen Bernhardt with Penn State Cooperative Extension recognized that the insect invading homes was probably not native and sent a specimen to Richard Hoebeke at Cornell University who identified it as BMSB (Hoebeke & Carter 2003). Today BMSB has been detected in 38 states and the District of Columbia (Figure 1) with isolated populations in Switzerland (Wermelinger *et al.* 2008) and Canada (Fogain & Graff 2011).

General Biology. Adults are distinguished from other brown stink bugs in the USA by their larger size, light colored banding on the antennae and legs and alternating light and dark bands around the abdomen (Figure 2). The term ‘marmorated’ means having a marbled or streaked appearance. Females emerge with undeveloped ovaries and must feed before mating. Once mated, females lay light green egg masses of ~28 eggs on the undersides of leaves. Depending



Figure 1. Distribution and impact of BMSB in the USA based on State records and BMSB Working Group assessments as reported by May 2012. In addition, at least one unofficial detection has been made in CO.

¹Corresponding Author; ²USDA-ARS, Appalachian Fruit Research Station, 2217 Wiltshire Road, Kearneysville, WV 25430. E-mail: tracy.leskey@ars.usda.gov; ³Department of Entomology, Rutgers University, 93 Lipman Drive, New Brunswick, NJ 08901; ⁴Dept. of Agricultural & Resource Management Agents, Rutgers University, 88 Lipman Dr. New Brunswick, NJ 08901; ⁵Department of Entomology, Virginia Tech, AHS AREC, 595 Laurel Grove Road, Winchester, VA 22602; ⁶Department of Entomology, Virginia Tech, Tidewater AREC, 6321 Holland Road, Suffolk, VA 23437; ⁷Department of Entomology, Virginia Tech, 216 Price Hall, Blacksburg, VA 24061; ⁸Department of Entomology, University of Maryland, 4112 Plant Sciences Building, College Park, MD 20742; ⁹Penn State University, Department of Entomology, Fruit Research and Extension Center, 290 University Drive, Biglerville, PA 17307; ¹⁰Oregon State University, Mid-Columbia Agricultural Research and Extension Center, 3005 Experiment Station Drive, Hood River, OR 97031-9512; ¹¹Department of Entomology and Wildlife Ecology, 250 Townsend Hall, University of Delaware, Newark, DE 19716-2160; ¹²Northeastern IPM Center, Insectary Building, Cornell University, Ithaca NY 14853; ¹³National Wildlife Federation, 11100 Wildlife Center Drive, Reston, VA 20190 USA; ¹⁴USDA-ARS, European Biological Control Laboratory, CS90013 Montferrier-sur-Lez, 34988 St. Gély du Fesc CEDEX, France



Figure 2. BMSB life stages.

on temperature, eggs hatch in 3–4 days. Nymphs go through 5 instars. First instar nymphs are reddish and black in color and stay with the egg mass until they molt to the second instar at which time they seek food sources. Nymphs darken and express pronounced light and dark banding on their legs and antennae (Hoebeker & Carter 2003).

In temperate Asia, BMSB completes one generation per year, but is reported to have a partial second generation in sub-tropical regions (Fujiie 1985) and up to 5–6 generations in southern China (Hoffmann 1931). In Allentown, PA, BMSB completes one generation per year (Nielsen *et al.* 2008, Nielsen & Hamilton 2009a). Further south in WV, two complete generations were documented (Leskey *et al.* 2012a). In the mid-Atlantic region, summer adults appear from early July to early September. Development occurs on a variety of host plants with leaves, stems, fruit, pods, or seeds used as resources. Adults readily move between hosts coinciding with the presence of fruit, but can complete development on a single species such as *Paulownia* (Chung *et al.* 1995, Funayama 2004). Beginning in late August, decreasing day length and temperature trigger adults to congregate in large numbers on hosts prior to entering overwintering sites including human-made structures (Hamilton 2009, Inkley 2012), dead, standing trees, and rocky outcroppings in wooded areas (Lee, *unpubl. data*). In spring when temperatures and day length increase, adults emerge from overwintering sites to locate host plants.

Pest status

Orchard Crops. In Asia, BMSB is an outbreak pest of tree fruit (Funayama 2002). Damage to tree fruit in the USA was first detected in Allentown, PA and Pittstown, NJ (Nielsen & Hamilton 2009b). In orchards where BMSB is established, it quickly becomes the predominant stink bug species and, unlike native stink bugs, is a season-long pest (Nielsen & Hamilton 2009b, Leskey *et al.* 2012b). In 2008–2009, increasing BMSB populations in WV and MD caused late-season problems to fruit crops (Leskey & Hamilton 2010a). In southern PA and VA, BMSB was not a recognized pest until the 2010 season. However, injury to apple (Figure 3) was probably mistaken for physiological disorders such as cork spot and bitter pit. Severe pest pressure in 2010 resulted in \$37 million in losses to mid-Atlantic apples alone (American/Western Fruit Grower 2011) with some stone fruit growers losing > 90% of their crop (Figure 4, Leskey & Hamilton 2010b). In 2011, damage, though not as severe, was observed



Figure 3. Internal injury to 'Pink Lady' apple as a result of BMSB feeding.

throughout the mid-Atlantic states. Damage may have been mitigated by ~4-fold increase in insecticide applications against BMSB in some MD and WV orchards (Leskey *et al.* 2012b). Intervention depended heavily on broad spectrum-insecticides, especially pyrethroids. This practice disrupted IPM programs, causing outbreaks of secondary pests such as European red mites, wooly apple aphids and San Jose scale, that are normally controlled by natural enemies. In 2010 and 2011, BMSB was detected in areas close to major fruit growing districts in OR, WA, NY, and MI (2011 only). Cherries and hazelnuts, important crops in MI and OR, respectively, are also at risk.

Grapes. Although the degree of impact is unclear, more insight into the importance of BMSB in vineyards is emerging (Pfeiffer *et al.* in press). Issues include impact on grape cluster yield and quality, the effect of malodorous insects on crushed clusters and potential contamination of juice and wine, resulting in “stink bug taint”, analogous to previously reported “ladybug taint” resulting from crushed Asian ladybird beetles. BMSB feeding on ripening berries causes a progressive necrosis with fruit collapse. Though unconfirmed, BMSB feeding on the rachis may also cause abscission. Studies in NJ showed possible differential susceptibility of grape cultivars to BMSB infestation. Infestation levels of BMSB on Cabernet Sauvignon and Traminette were 2–3 times greater compared with those on Chambourcin. Future studies will focus on resistance of



Figure 4. 'Red Haven' peaches stripped from trees by a MD grower and left to rot because of ~100% BMSB injury in July, 2010.

a wider range of grape cultivars and possible mechanisms of resistance. Management programs in grapes that do not rely on pyrethroids are needed to avoid secondary outbreaks of grape mealybug, the vector of grapevine leafroll virus. As for potential taint of wine, controlled inoculation (as many as 25 BMSB/11.3 kg fruit) of juice/mush has not resulted in perceptible taint/aroma following fermentation; chemical analysis is in progress (J. Fiola, unpubl. data). Effective means to remove BMSB from clusters just before harvest were established in VA, lessening the risk of tainted wine. Additionally, large numbers of BMSB adults seeking overwintering sites damage the ambiance of commercial wine tasting rooms.

Small Fruit. Little is known about the impact of BMSB in small fruit crops. Research is underway to establish the impact of BMSB feeding, determine BMSB phenology, and to identify landscape and temporal risk factors associated with BMSB on small fruit crops. In blueberries, BMSB was first observed during the late-season in 2010, and many NJ blueberry growers have since reported it in and around structures and houses. Contamination risks are a great concern to blueberry growers who mechanically harvest and then sell to processors or ship to other countries and regions within the USA (Figure 5). During 2011, BMSB populations in NJ blueberry farms remained low and did not require control measures. In caneberries, stink bug species cause two types of injury. Although not thoroughly investigated, it appears that early



Figure 5. BMSB nymphs crawling from a container of machine-harvested blueberries highlighting the problem of contamination at harvest.

season feeding can cause death of buds. Late in the season, BMSB attack mature berries, inserting their stylets between the drupelets, and possibly feeding on the receptacle. This feeding causes discoloration and collapse of individual drupelets (Maxey 2011). In VA caneberries, BMSB accounted for 25% of the entire pentatomid community by the end of 2011.

Vegetables. The extent of BMSB damage and risk to vegetables has not been fully determined. Based on observations and initial research from the mid-Atlantic USA region, this pest will feed on and cause severe damage to a number of vegetables when densities are high (Kuhar *et al.* 2012). Sweet corn (*Zea mays*) appears to be a strongly preferred host crop, on which numerous nymphs and adults have been observed on a single ear and nearly 100% damage has been recorded in fields (Figure 6). The feeding stylets of BMSB are inserted through the husk and pierce the tender kernels, which may cause them to collapse and/or discolor. This damage is especially apparent after the ear is cooked. Bean crops such as *Phaseolus* species are also attractive hosts and feeding may result in scarred, flattened, and deformed pods. Vegetables such as pepper, tomato, eggplant, and okra also suffer heavy feeding damage, typically averaging more than 20% in research plots. Relatively less damage has been observed on other vegetable groups such as crucifers or cucurbits. However, because more than 200 species of plants are considered vegetables, more research is needed on this topic. Additionally, the risk of damage to a particular commodity may be heavily influenced by the presence of neighboring host plants.

Row Crops. BMSB has been found damaging soybean, wheat, and field corn. BMSB was first surveyed in soybean fields in 2006 near Allentown, PA (Nielsen *et al.* 2011). By 2010, the majority of soybean fields in western and central MD showed delayed maturity at field edges because of earlier feeding by BMSB, especially next to woodlots, with growers reporting > 50% yield loss. In 2011, BMSB surveys conducted in DE, MD, and VA revealed that highest populations were present on field edges. Treating just 12 meters into the field prevented further invasion and resulted in an 85–95% reduction in insecticide used compared with whole-field treatments. Follow-up studies will focus on defining specific protocols for



Figure 6. BMSB adult and nymphal feeding damage to sweet corn kernels.



Figure 7. BMSB feeding injury to the periphery of a soybean field illustrating the “stay green” effect and contrasting with the unaffected, normally senescing plants at the center of the plot.

perimeter treatments and identifying BMSB densities needed to cause delayed plant maturity, the “stay green effect” (Figure 7). Results from insecticide trials conducted in VA and MD indicate that most labeled products provide control though further information including residual activity is needed. Several wheat fields in MD were reported to contain very high BMSB adults and one field yielded egg masses. Most adults were near the field edge, adjacent to wooded borders. Research on native stink bugs indicates that the most susceptible stages of wheat development are the milk and soft dough stages (Viator *et al.* 1983). This coincides with the stage of the wheat fields containing large numbers of BMSB adults. Adults from those fields laid many eggs over a very short time in the laboratory. In the absence of a more highly preferred host, wheat may be susceptible to BMSB, though more studies are needed to determine if BMSB poses a significant risk. High populations (> 3 per ear) were found on corn plants after the ear had started to form especially within the first 12 meters of field margins in DE. Unlike soybeans, perimeter treatments are generally impractical for treatment of late-stage corn. A pilot investigation in MD to determine how the surrounding landscape influences densities in field corn suggests that corn fields bordered by woodlots, other crops, and buildings have higher populations compared with fields bordered by roads.

Ornamentals. In its native range, BMSB feeds on numerous ornamental plants (Hoebeke & Carter 2003). Ornamental crops in the USA are at risk because of the highly polyphagous nature, high mobility, and the observed direct and potential indirect damage by BMSB. Known ornamental hosts include woody and herbaceous plants in nurseries, urban landscapes, natural areas, and house plants (Raupp *et al. unpubl. data*). Currently, the host list of BMSB includes > 100 plants many of which are ornamentals (USDA APHIS 2010 and references therein). BMSB became an important pest and economic threat in commercial nurseries and landscapes with the large populations of 2010. By mid-summer in MD, BMSB was feeding on fruits of crabapples, hawthorns, and serviceberries, disfiguring fruits and wilting plants. By autumn, BMSB became very abundant feeding on the trunks of several trees

and shrubs (Figure 8). The resultant injury included copious sap flow, fluxes, and discolored bark at feeding sites. Death of herbaceous perennials has been reported. A 2011 field survey of trees and shrubs at a commercial nursery in MD showed 150 of 178 cultivars were used by BMSB. Top hosts included cultivars or species of *Syringa* (lilac), *Acer* (maple), *Cercis* (redbud), *Platanus* (London planetree), and *Prunus* (ornamental cherry). Certain host plants are used solely for feeding, whereas other hosts are used for feeding and oviposition (USDA APHIS 2010, Raupp *et al. unpubl. data*). There is concern that BMSB could vector pathogens to ornamental plants in the USA because in Asia it vectors the phytoplasma responsible for *Paulownia* witch’s broom (Bak *et al.* 1993, Yu & Zhang 2009). Ornamental hosts may contribute to damage in other ways. In natural and semi-natural areas, ornamental plants and other wild host trees may provide overwintering habitat allowing BMSB to populate crops easily, and they may support large BMSB populations that invade homes to overwinter.

Nuisance Problems. BMSB is a significant nuisance to homeowners and businesses because they will utilize attics, garages, offices, and other buildings to overwinter (Watanabe *et al.* 1994, Hoebeke & Carter 2003, Hamilton *et al.* 2008, Hamilton 2009, Inkley 2012). This problem is exacerbated in rural areas where forests and agricultural fields provide suitable habitat for BMSB to reproduce during the growing season. Surprisingly large numbers of BMSB overwinter in walls, insulation, attics and other suitable crevices that provide cool, dry refugia (Figure 9). One homeowner in rural Maryland collected 26,205 adult BMSB from January–June in 2011, of which 10,584 (40.4%) were found in first and second floor living space, with the remainder found in the attic (Inkley 2012). Throughout the winter and spring, especially on warmer days, BMSB become active indoors, often finding their way into living areas.

BMSB do not bite or sting humans and are not known to transmit human pathogens. Nonetheless, they are a nuisance because of the unpleasant odor they emit when disturbed, sheer numbers and daily presence, staining of walls and



Figure 8. Adult BMSB feeding on the trunk of a London plane tree, *Platanus × acerifolia*.

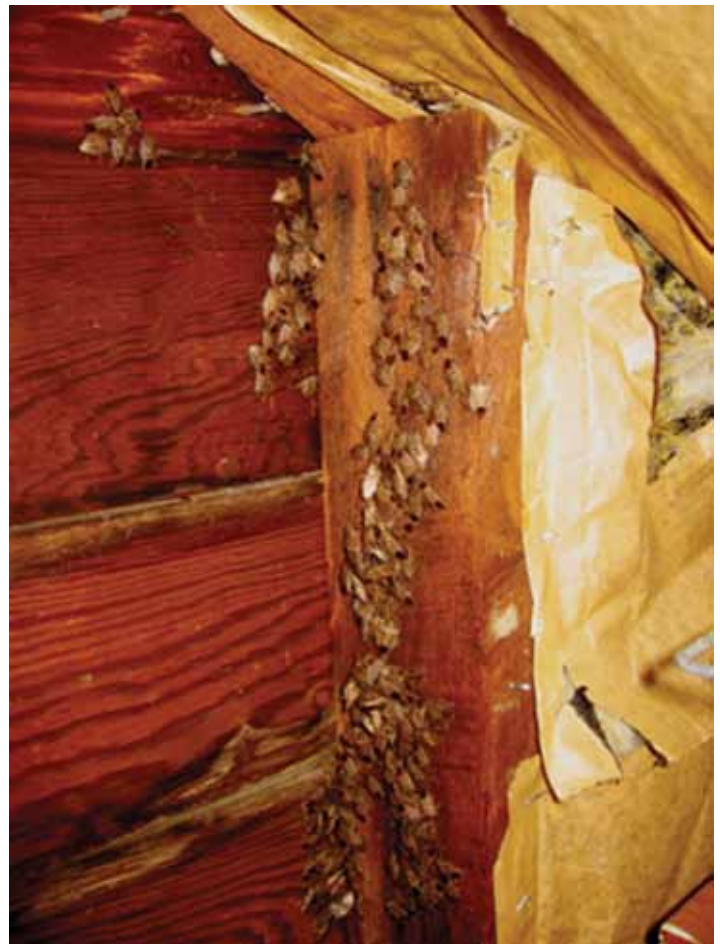
floors with their frass, and activity due to their attraction to light and moisture especially as temperatures warm (Inkley 2012). Their nuisance impact is well-documented by an enormous volume of requests for information on the biology and management of this pest at web sites and telephone hot lines maintained by state government agencies and institutions. Since 2004, a Rutgers University web-reporting site has received 10,000 BMSB reports and Pennsylvania State University's BMSB online fact sheet has been viewed more than 600,000 times since 2008 (Jacobs, *personal communication*). In 2010 and 2011, University of Maryland's BMSB web page received more than 80,000 visits, while email and phone contacts addressed approximately 900 inquiries (Traunfeld, *personal communication*) and a self-help YouTube for consumers generated about 1,300 hits per month since posting in 2011. Distinct autumnal peaks of reports/visits clearly defined the annual activity pattern of BMSB as they begin to enter homes in mid-September. Additional web activity occurs in January-April.

Long-term solutions

The Response. Most major media networks including ABC, CBS, NBC, Fox, CNN, BBC, and NPR and major print outlets including The Wall Street Journal, Washington Post, New York Times, Los Angeles Times, Chicago Tribune, and Philadelphia Inquirer have run stories on the agricultural and



(A)



(B)

Figure 9. BMSB adults aggregating (A) beneath a mattress and (B) in the attic of a home in rural MD in 2010-2011. Over 26,000 overwintering adults were removed from the interior of this home in 2011 (Inkley 2012).

nuisance pest problems caused by BMSB raising national attention. Researchers have formed a "Brown Marmorated Stink Bug IPM Working Group" through the Northeastern IPM Center (Leskey & Hamilton, 2010a,b, 2011a) which has established itself as the primary platform for facilitating and coordinating research efforts, priority development, and offering outreach across the USA. Content generated by



Figure 10. StopBMSB.org, the web site for the USDA-NIFA SCRI coordinated agricultural project.



Figure 11. Adult *Trissolcus* female attacking eggs of BMSB.

the Working Group and available on the Northeastern IPM website has resulted in > 16,000 visits since 2010. Successful grant initiatives that have cited priorities defined by the Working Group include the USDA-NIFA Critical Issues and Northeastern and Southern Regional IPM grants. In addition, a national coordinated agricultural project funded by USDA-NIFA Specialty Crop Research Initiative is studying the biology, ecology, and management of BMSB in specialty crops. This project includes over 50 researchers from 10 states and includes a national outreach program that specifically targets growers. The Northeastern IPM Center leads this national outreach effort. A website, StopBMSB.org, (Figure 10) serves as a hub for delivering BMSB management information and providing knowledge emanating from the project’s research program, links to key BMSB resources, and provides “the best of” current information with an eye toward adding value for growers. The United Soybean Board has funded a multi-state research project to develop information on impact by and management of BMSB in soybeans.

Conclusions. Without immediate intervention, BMSB could put many farmers out of business, and dismantle IPM and organic programs. The goal of the SCRI and other funded projects is to generate information and technology building a framework for management of BMSB in areas where it is established and preventing future problems in new regions and crops. Immediate efforts have focused on developing management programs with chemical tactics (Leskey *et al.* 2012b), and then integrating these chemicals into comprehensive management programs. Researchers are focusing on identification of the BMSB pheromone to improve monitoring tools to detect activity and need for intervention. Efforts to develop behaviorally based management strategies such as attract-and-kill and biological control programs to reduce insecticide inputs are underway.

Asian natural enemies of BMSB are thought to be an important mortality factor and high levels of egg parasitism are reported in China (Yang *et al.* 2009). In Asia, several species of parasitoid wasps in the genus *Trissolcus* and tachinid flies parasitize BMSB eggs and adults, respectively. Surveys to determine the occurrence and impact of resident natural enemies on BMSB in mid-Atlantic states revealed that in non-crop landscape habitats, parasitoids attack BMSB eggs and adults at very low levels that are typically less than 5% (Hoelmer, *unpubl. data*) much lower than in Asia. However, parasitoid activity may be significantly higher in agroecosystems. BMSB egg parasitism was found at rates of 23, 26, and 55% in eggplant, pepper and field corn plots, respectively (Hooks *et al, unpubl. data*). These varying results suggest that the local composition of host plant species and landscape structure influence natural enemy activity. Several indigenous *Trissolcus* spp., *Telenomus podisi*, generalist chalcidoid wasps, tachinid flies, and various invertebrate and vertebrate predators have been observed attacking BMSB. Predation of BMSB egg masses by spiders and big eyed bugs (*Geocoris* spp.) reached ~47% in MD soybean plots.

An entomopathogenic fungus, *Ophiocordyceps nutans*, was reported infecting BMSB in Japan (Sasaki *et al.* 2012) and several other fungus species have shown efficacy against BMSB in the laboratory (Gouli *et al.* 2011). Exploration in China, Japan, and South Korea resulted in the importation of Asian *Trissolcus* species for host range studies to determine their specificity to BMSB and suitability for field release in the USA (Figure 11). Ultimately, classical biological control utilizing Asian natural enemies and conservation biological control to enhance the activity of introduced and indigenous natural enemies may provide the most promising long-term solutions for landscape-level reduction of BMSB populations.

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References

- American/Western Fruit Grower. (2011). Brown Marmorated Stink Bug Causes \$37 Million in Losses to Mid-Atlantic Apple Growers. April 14, 2011. <http://www.growingproduce.com/article/21057/brown-marmorated-stink-bug-causes-37-million-in-losses-to-mid-atlantic-apple-growers>. Accessed April 30, 2012.
- Bak W.C., Yeo W.H. & La Y.J. (1993). Little-leaf symptom development in the periwinkle infected with *Paulownia witches'-broom* mycoplasma-like organism by the yellow-brown stink-bug, *Halyomorpha halys* Stål (= *H. mista* Uhler). *Korean J. Plant Pathol.* **9**: 236–238.
- Chung B.K., Kang S.W. & Kwon J.H. (1995). Damages, occurrences and control of hemipterous insects in non-astringent persimmon orchards. *RDA. J. Agr. Sci.* **37**: 376–382.
- Fogain R. & Graff S. (2011). First records of the invasive pest, *Halyomorpha halys* (Hemiptera: Pentatomidae) in Ontario and Quebec. *J. Entomol. Soc. Ont.* **142**: 45–48.
- Fujjie A. (1985). Seasonal life cycle of *Halyomorpha mista*. *Bull. Chiba Agric. Exp. Stn.* **26**: 87–93.
- Funayama K. (2002). Comparison of the susceptibility to injury of apple cultivars by stink bugs. *Jpn. J. Appl. Entomol. Zool.* **46**: 37–40.
- Funayama K. (2004). Importance of apple fruits as food for the brown-marmorated stink bug, *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae). *Appl. Entomol. Zool.* **39**: 617–623.
- Gouli V., Gouli S., Skinner M., Hamilton G., Kim J.S. & Parker B.L. (2011). Virulence of select entomopathogenic fungi to the brown marmorated stink bug, *Halyomorpha halys* (Stål), (Heteroptera: Pentatomidae). *Pest Manag. Sci.* DOI10.1002/ps.2310.
- Hamilton G.C. (2009). Brown marmorated stink bug. *Am. Entomol.* **55**: 19–20.
- Hamilton G.C., Shearer P.W. & Nielsen A.L. (2008). The brown marmorated stink bug – a non-native stink bug in New Jersey. *Rutgers Coop. Ext. Fact Sheet.* FS002.
- Hoebeke E.R. & Carter M.E. (2003). *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae): A polyphagous plant pest from Asia newly detected in North America. *Proc. Entomol. Soc. Wash.* **105**: 225–237.
- Hoffmann W.E. (1931). A pentatomid pest of growing bean in south China. *Peking Nat. Hist. Bull.* **5**: 25–26.
- Inkley D.B. (2012). Characteristics of home invasion by the brown marmorated stink bug (Hemiptera: Pentatomidae). *J. Entomol. Sci.* **47**: 125–130.
- Kuhar T.P., Kamminga K.K., Whalen J., Dively G.P., Brust G., Hooks C., Hamilton G. & Herbert D.A. (2012). The pest potential of brown marmorated stink bug on vegetable crops. *Plant Health Prog.* (in press).
- Leskey T. & Hamilton G.C. (2010a). Brown Marmorated Stink Bug Working Group Meeting. <http://projects.ipmcenters.org/Northeastern/FundedProjects/ReportFiles/Pship2010/Pship2010-Leskey-ProgressReport-237195.pdf>. Accessed April 30, 2012.
- Leskey T. & Hamilton G.C. (2010b). Brown Marmorated Stink Bug Working Group Meeting. http://projects.ipmcenters.org/Northeastern/FundedProjects/ReportFiles/Pship2010/Pship2010-Leskey-ProgressReport-237195-Meeting-2010_11_17.pdf. Accessed April 30, 2012.
- Leskey T. & Hamilton G.C. (2011). Brown Marmorated Stink Bug Working Group Meeting. <http://projects.ipmcenters.org/Northeastern/FundedProjects/ReportFiles/Pship2010/Pship2010-Leskey-FinalReport-Meeting-June-2011-237195.pdf>. Accessed April 30, 2012.
- Leskey T.C., Wright S.E., Short B.D. & Khirman A. (2012a). Development of behaviorally based monitoring tools for the brown marmorated stink bug, *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae) in commercial tree fruit orchards. *J. Ent. Sci.* **47**: 76–85.
- Leskey T.C., Short B.D., Butler B.B. & Wright S.E. (2012b). Impact of the invasive brown marmorated stink bug, *Halyomorpha halys* (Stål) in mid-Atlantic tree fruit orchards in the United States: case studies of commercial management. *Psyche*. (in press).
- Maxey L.M. (2011). Pest management of Japanese beetle (Coleoptera: Scarabaeidae) and a study of stink bug (Hemiptera: Pentatomidae) injury on primocane-bearing caneberries in Southwest Virginia. M.S. thesis, Virginia Tech, Blacksburg.
- Nielsen A.L. & Hamilton G.C. (2009a). Life-history of the invasive species *Halyomorpha halys* (Hemiptera: Pentatomidae) in the Northeastern United States. *Ann. Entomol. Soc. Am.* **102**: 608–616.
- Nielsen A.L. & Hamilton G.C. (2009b). Seasonal occurrence and impact of *Halyomorpha halys* (Hemiptera: Pentatomidae) in tree fruit. *Econ. Entomol.* **102**: 1133–1140.
- Nielsen A.L., Hamilton G.C. & Matadha M. (2008). Development rate estimation and life table analysis for *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae). *Environ. Entomol.* **37**: 348–355.
- Nielsen A.L., Hamilton G.C. & Shearer P.W. (2011). Seasonal phenology and monitoring of the non-native *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) in soybean. *Environ. Entomol.* **40**: 231–238.
- Pfeiffer D.G., Leskey T.C. & Burrack H.J. Threatening the harvest: The threat from three invasive insects in late season vineyards. In “Arthropod management in vineyards” (Eds. N.J. Bostanian, R. Isaacs & C. Vincent), Springer, Dordrecht, The Netherlands. (in press).
- Sasaki F., Miyamoto T., Yamamoto A., Tamai Y. & Yajima T. (2012). Relationship between intraspecific variations and host insects of *Ophiocordyceps nutans* collected in Japan. *Mycoscience* **53**: 85–91.
- USDA APHIS PPQ. (2010). Qualitative analysis of the pest risk potential of the brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål), in the United States.
- Watanabe M., Arakawa R., Shinagawa Y. & Okazawa T. (1994). Anti-invading methods against the brown marmorated stink bug, *Halyomorpha mista*, in houses. *The Japan Soc. Med. Entomol. Zool.* **45**: 311–317.
- Wermelinger B., Wyniger D. & Forster B. (2008). First records of an invasive bug in Europe: *Halyomorpha halys* Stål (Heteroptera: Pentatomidae), a new pest on woody ornamentals and fruit trees? *Mit. Sch. Ges.* **81**: 1–8.
- Yang Z.Q., Yao Y.X., Qui L. & Li Z. (2009). A new species of *Trissolcus* (Hymenoptera: Scelionidae) parasitizing eggs of *Halyomorpha halys* (Heteroptera: Pentatomidae) in China with comments on its biology. *Ann. Entomol. Soc. Am.* **102**: 39–47.
- Yu G. & Zhang J. (2009). The brown-marmorated stink bug, *Halyomorpha halys* (Heteroptera: Pentatomidae) in P. R. China. In “International workshop on biological control of invasive species of forests” (Eds. Y. Wu & X.-y. Wang), 20–25 September 2007, Beijing, China.

Tracy C. Leskey is a Research Entomologist with USDA-ARS, Appalachian Fruit Research Station, Kearneysville, WV. She holds advanced degrees from Penn State University and University of Massachusetts at Amherst. Her current research program targets development of effective monitoring tools and behaviorally based management strategies for the brown marmorated stink bug, plum curculio, dogwood borer, and apple maggot fly to reduce insecticide inputs and increase sustainability of orchard agroecosystems.

George Hamilton is an Extension Specialist in Pest Management and chair of the Department of Entomology at Rutgers University, New Brunswick, NJ. Baccalaureate, Master's and Ph.D. degrees were obtained at Eastern Connecticut State College, University of Missouri and Rutgers University. Conservation biological control and biology and management of the brown marmorated stink bug are studied in a wide range of agricultural crops and urban settings.

Anne L. Nielsen is an Extension Specialist in fruit entomology at Rutgers University in Bridgeton, NJ. Her research focus is on developing biologically based management programs through investigations in population ecology, the development of phenological models and influence of habitat characteristics on biological control efficacy. Much of this research to date has centered on the brown marmorated stink bug.

Dean Polk is a Tree Fruit IPM coordinator at Rutgers University in Cream Ridge, NJ. He received an M.S. degree in Entomology from the University of Idaho in 1979. He coordinates the state-wide fruit IPM programs for apples, peaches, blueberries and wine grapes. Some of his program interests have included mating disruption in tree fruit and blueberries, reduced risk methods in fruit crops, development of a database for tracking grower practices and pesticide use, IPM practices for the invasive pests: brown marmorated stink bug and spotted wing drosophila, and spatially referenced IPM for blueberry and other fruit pests.

Cesar Rodriguez-Saona is an Extension Specialist in Blueberry and Cranberry IPM, Department of Entomology, Rutgers University, P.E. Marucci Center, Chatsworth, NJ. He received his M.S. degree from Oregon State University and his Ph.D. from the University of California, Riverside. He conducts basic and applied research on the development and implementation of cost-effective reduced-risk insect pest management practices and delivers educational information to growers. Prior to joining Rutgers University, he worked for the USDA-ARS in Phoenix, AZ, University of Toronto in Ontario, Canada, and Michigan State University in East Lansing, MI.

Chris Bergh is a Professor of Entomology at Virginia Tech's Alson H. Smith, Jr. Agricultural Research and Extension Center, Winchester, VA, where he has a 75% research, 25% extension assignment. His research focuses on applied insect ecology and behavior in relation to the development and validation of new or improved pest monitoring and management tactics in commercial tree fruit orchards and vineyards. His extension programming emphasizes and promotes the adoption of tools and tactics intended to reduce or replace insecticide use.

Ames Herbert is a Professor of Entomology at Virginia Tech stationed at the Tidewater Agricultural Research and Extension Center, Suffolk, VA. His program addresses state-wide management of the insect pests of soybean, small grains, cotton and peanut. Current projects focus on early season thrips management, evaluation of transgenic cotton varieties for Lepidopteran pests, forecasting cereal leaf beetle egg and larval peaks in wheat and stink bug management in cotton and soybean. He is also the state IPM Coordinator.

Thomas Kuhar is an Associate Professor in the Department of Entomology at Virginia Tech in Blacksburg, VA. His applied research program encompasses all aspects of integrated pest management in vegetable crops with a recent focus on stink bug pests.

Doug Pfeiffer is a Professor of Entomology at Virginia Tech, specializing in IPM in vineyard, small fruit and tree fruit systems. Recent and current research includes mating disruption of grape root borer, risk assessment and monitoring of grape berry moth, control of Japanese beetle and stink bugs in primocane-bearing caneberries, spotted wing drosophila in small fruits, and biogeography of races of plum curculio and their *Wolbachia* symbionts. In addition to fruit IPM research and extension, he teaches graduate, undergraduate, and on-line course in IPM. Pfeiffer also directs the on-line master's program for the College of Agriculture and Life Sciences.

Galen P. Dively is an emeritus professor in the Department of Entomology at the University of Maryland. He received his B.S. in biology at Juniata College and M.S. and Ph.D. in entomology from Rutgers University. He worked as an Extension Specialist in Agricultural IPM for 34 years and served as the State IPM Coordinator for 16 years. Since his retirement in 2006, he continues to conduct research on ecological risk assessment of transgenic insecticidal crops, sublethal effects of pesticides on honey bee colony health, efficacy evaluation of organic insecticides, and studies addressing information gaps in the biology and management of emerging pest species.

Cerruti RR Hooks is an Assistant Professor and Extension Specialist in the Department of Entomology, University of Maryland in College Park, MD. His research involves the use of ecological principles and biological control in the development of farming tactics that concurrently suppresses above and below soil pest complexes while improving soil quality and health.

Michael J. Raupp is a Professor of Entomology and Extension Specialist in the Department of Entomology at the University of Maryland, College Park, MD. He holds advanced degrees from Rutgers University and the University of Maryland. His research interests focus on the mechanisms of plant resistance and biological control of insect pests of ornamental plants. He works closely with the tree care, landscape, and nursery industries and homeowners to develop IPM programs.

Paula Shrewsbury is an entomologist at the University of Maryland in the Department of Entomology. She received her M.S. from the University of California, Riverside, and a Ph.D. from the University of Maryland in Entomology. She conducts applied research and extension education programs to implement Integrated Pest Management for pests of ornamentals and turf grass. Her current research focus is on methods to restore plant and insect community dynamics as they relate to ecosystem services such as biological control in managed environments, including the role of native and non-native plants, and indigenous and exotic natural enemies towards managing invasive species.

Greg Krawczyk is an extension tree fruit entomologist/research associate professor in the Department of Entomology at The Pennsylvania State University. His work is focused mainly on practical applications of principles of integrated pest management in pome and stone fruit systems.

Peter W. Shearer is a Professor of Entomology at Oregon State University and is stationed at the Mid-Columbia Agricultural Research & Extension Center, Hood River, OR. His research activities involve studies on the management of arthropod pests of pome and stone fruits by enhancing IPM strategies and tactics including chemical, cultural, and biological control. Current focus areas include sublethal effects of new pesticides on natural enemies, insecticide resistance management and using herbivore induced host plant volatiles to evaluate impacts of pesticides on beneficial insects.

Joanne Whalen is the Extension Integrated Pest Management Specialist (Agriculture) for Cooperative Extension at the University of Delaware. She has had thirty three years of experience carrying out applied research and extension programs in field, fruit and vegetable crops. Current research and extension programs focus on development and evaluation of new insect sampling

strategies; evaluation of seed treatments, transgenic crops and insecticides for insect management in field crops and vegetables; and evaluation of tillage for slug management in not-till field crops.

Carrie Koplinka-Loehr directs the Northeastern IPM Center at Cornell University, Ithaca, NY. The Center promotes and funds agricultural and urban integrated pest management projects in 12 northeastern states and in Washington, D.C. With 23 years of experience in fostering IPM, she focuses on managing staff and programs in ways that enhance environmental, economic, and human health benefits.

Elizabeth Myers is Communications Director for the Northeastern IPM Center at Cornell University. She has an M.S. in Environmental Policy and a background in scholarly publishing, science writing, and environmental consulting. Current work focuses on IPM outreach, web content planning and development, and impact reporting.

Doug Inkley is the National Wildlife Federation's Senior Scientist, with a Ph.D. in Zoology from the University of Wyoming. His work focuses on wildlife conservation policy, including climate change and invasive species. His published

research on BMSB reported on characteristics of a severe infestation (in his own home).

Kim Hoelmer is a USDA-ARS Research Entomologist and the current Director of the ARS European Biological Control Laboratory in Montferrier, France. His research concerns the biology and behavior of predators and parasitoids, and involves foreign exploration for new biocontrol agents of invasive insect pests and their evaluation, field release and establishment in the field.

Doo-Hyung Lee is a postdoctoral research entomologist at USDA-ARS, Appalachian Fruit Research Station, Kearneysville, WV. He has studied the behavioral aspects of economically important pests in agriculture and the application of the knowledge for enhancing pest management programs. Current research interest includes the overwintering biology of brown marmorated stink bug and the dispersal capacity and pattern of the bug at landscape level.

Starker E. Wright is a Support Entomologist with USDA-ARS, Appalachian Fruit Research Station, Kearneysville, WV. His research efforts support development of effective monitoring tools and behaviorally based management strategies for tree fruit pests to increase sustainability of orchard agroecosystems.

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