Phenology of Brown Marmorated Stink Bugs and Distribution near California Pear Orchards

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ABSTRACT

In the midtown Sacramento BMSB infestation area, 24 traps were placed and checked weekly to help evaluate BMSB phenology. Half of the traps were standing 4-ft. pyramid traps and half were 8-in. tall experimental double cone traps (Trece) secured to tree of heaven branches. The first traps were placed Feb. 9, and because Feb. 2016 was unusually warm, the first adults were found in traps only two days later and every week thereafter – far earlier than in past years. The first eggs were found on April 12, earlier than previous years and the earliest in the country. The first nymphs were trapped on May 9, 10 days earlier than 2015 and 25 days earlier than 2014. A typical peak of nymphs was seen in traps in June, but a late July heat wave decimated the population for a month and the typical large late summer peak was far lower than in 2014-15. In all 3 years, two generations were found, which agrees with the BMSB model. Traps caught significantly more nymphs than adults, and more females than males. Pyramid traps caught significantly more nymphs than experimental double cone traps. In March, 20 pyramid traps were placed south of Sacramento to Walnut Grove and traps were also placed in agricultural/urban interface areas in Lake and Mendocino counties. From mid-June through mid-July, 3 male adults and 2 nymphs were found in a plum tree near a vineyard by Clarksburg, and in late Sept. and Oct. 2016, three male adult BMSBs were found in a trap in Freeport. No BMSB were found in Lake or Mendocino.

INTRODUCTION

The brown marmorated stink bug (Halyomorpha halys) (BMSB) originated in East Asia and was first identified in the US in Pennsylvania in 2001; it has now spread to 43 states (www.stopbmsb.org). A large population was found in midtown Sacramento in Sept. 2013, and subsequent surveys show that dozens of individuals have been found in other areas of Sacramento County, with at least eight areas of reproducing populations (http://ccag-eh.ucanr.edu/Brown_Marmorated_Stink_Bug/BMSB_Finds/).

In 2010, BMSB caused $37 million in damage to fruit crops. BMSB has a host range of over 170 species, including most fruit crops and many vegetables with fruiting structures. Both adult and nymphal stages can damage fruits. Physical damage to fruits includes pitting and deformation, with pithiness under the stings. This makes the fruit unmarketable as a fresh or canned product. BMSB usually produce one generation per

year in cool climates and two per year in warmer climates (Lee et al., 2013; Nielsen and Hamilton, 2009).

Several trap designs have been developed, including free-standing and traps and those that are placed in trees. The AgBio, Inc. (Dead-Inn™) trap consists of an inverted clear plastic container with an entry cone opening that is attached with a bungee cord to tall corrugated plastic stands that are connected to form a pyramid shape. The "Grower" trap type stands 4 ft. tall. Research has shown that free-standing traps on larger pyramid stands catch more BMSB than those on smaller stands, and placement on the ground is more effective than in a tree canopy (Leskey et al., 2012). However, placement in on the ground may interfere with orchard operations.

USDA-ARS researchers have also found the greatest trap capture using two scents together – a BMSB aggregation pheromone scent and one containing the synergist methyl decatrienoate (MDT). These scents can be separate lures or combined into a single lure. In addition, increasing amounts of MDT have been shown to catch greater numbers of BMSB (Leskey et al., 2012). An insecticide-laced strip, such as Vaportape II (Hercon), is usually included to kill trapped bugs and prevent escape.

Traps have been shown to catch both adults and nymphs, but will attract them from less than about 100 ft. Field studies showed that 3rd and 5th instars walked 5-20 meters across a grass field to traps (Leskey, 2013). In addition to the BMSB caught inside traps, large numbers can often be found lingering outside of traps in summer.

There are a number of native natural enemies of BMSB, both predators and parasitoids, but they have had limited impact on BMSB populations in other states. Parasitoids of BMSB (most notably *Trissolcus japonicus*) have been imported and are now under quarantine in California and are undergoing testing at UC Riverside. In 2014, wild *T. japonicus* were found in a sentinel egg mass placed in a forest in Maryland. In 2015 and 2016, many more were found in other areas in the mid-Atlantic, and they were found in an egg mass in Vancouver, WA.

OBJECTIVES

Sacramento County:

1. Determine seasonal phenology of BMSB
2. Compare new Trece lures and double cone trap strategies
3. Monitor traps in pear orchards and in heavily traveled areas near orchards.
4. Study effects of natural enemies on BMSB eggs and determine seasonal progression of plant host use

Lake & Mendocino Counties:

1. Monitor susceptible host species near pear orchards and in urban areas.
2. Monitor traps in pear orchards and in heavily traveled areas near orchards.

PROCEDURES

Sacramento County

1. Determine seasonal phenology of BMSB and compare trap types

BMSB populations were monitored weekly from early Feb. through late Oct. 2016. A total of 24 traps were placed in landscape strips of residences and businesses in and near the central core area of the initial 2013 midtown Sacramento infestation. Of these, 12 were 4-ft.-tall, pyramid traps (AgBio, Inc.) and 12 were experimental Trece double cone traps placed in the canopies of tree of heaven trees (plastic, 8 in. tall) (Fig. 1). All traps were spaced at least 50 ft. apart. For each trap type, four traps in each of three sets were rotated weekly. Each trap was baited with a Trece BMSB lure (Figs. 1 and 2) and a Hercon Vaportape II insecticide strip (Fig. 1), all of which were replaced monthly. Adults and nymphs trapped were counted and the sex of adults in each trap was determined.

2. Compare new Trece lures and double cone trap strategies.

Two experimental BMSB lures by Trece were compared to the standard Trece lure. Four Trece experimental traps (see above) for each of the lure types were placed in Chinese pistache trees at least 50 ft. apart and rotated weekly from July 25 through Oct. 24. Each trap had an insecticide strip to prevent exiting.

An additional trial was conducted during the same time period, using three experimental Trece traps and three replicates, each trap containing a Trece lure: 1) an improved version of the trap discussed above (Fig. 3) with no insecticide strip, 2) the same trap with an insecticide strip, and 3) the trap with stickem on the inside and no insecticide strip. In each replicate, the three traps were rotated weekly.

3. Determine the spread from the initial infestation area

In March, 20 pyramid traps with Rescue lures and an insecticide strip (both replaced monthly) in each were placed from Freeport Blvd. near Meadowview Rd. south to the Walnut Grove area. Traps were placed at several types of locations, chosen because of their higher risk from people travelling from midtown/downtown Sacramento. These included farms that host visitors, pear orchards near which a resident commutes to Sacramento, packing sheds and trucking companies, and in the Freeport area.

Traps were checked every two weeks through October. Foliage of nearby susceptible hosts was checked for BMSB with visual searches and beat sheet samples. This monitoring was in addition to following the spread within Sacramento and nearby communities based on reports of BMSB sightings and verification that the stink bugs were actually BMSB; the findings in Sacramento have grown each year (Fig. 4).

4. Study effects of natural enemies on BMSB eggs and determine seasonal progression of plant host use (Kent Daane, unfunded)

Sentinel egg masses were to be used to determine if increased numbers of egg masses affect parasitism or predation compared to a single egg mass. Also, feeding vs. reproduction were to be used in caging studies to determine if specific plant host species sustain BMSB for a full generation or for only part of a generation. However, challenges arose in breeding colonies that resulted in only a small number of viable egg masses, so this objective could not be accomplished.

Lake and Mendocino Counties

BMSB were surveyed monthly from mid-March through mid-October by conducting beat tray samples early in the season and visual surveys after fruits or pods developed. Host trees were sampled in urban areas in proximity to pear orchards, in riparian corridors, and near pear orchards. Five locations in each county were selected and at each location the pear orchard and adjacent vegetation were surveyed.

Monitoring with pyramid traps continued in 2016. The selected trap locations are pear orchards pear orchards next to urban areas or close to high traffic transportation corridors. Three locations each per county were monitored with three traps at each location, spaced at least 100 ft. apart from March to October.

RESULTS

Sacramento County

1. Determine seasonal phenology of BMSB and compare trap types

Well over 5,000 BMSB were trapped in the 24 traps. Overall, more than twice as many nymphs were found than adults, pyramid traps caught significantly more BMSB than double cone traps, and significantly more females were caught than males (Fig. 5). Total seasonal adult trap counts in pyramid vs. double cone traps were virtually identical, whereas pyramid traps caught significantly more nymphs (Fig. 6).

Line graphs for seasonal BMSB trap counts for 2014 through 2016 are shown in Figs. 7-9, respectively. The 2014 graph uses data from four of the 10 traps that caught a substantial number of BMSB, the 2015 graph includes eight of the 20 traps that caught more than 100 BMSB through the season, and the 2016 graph uses data from half of the 24 traps – the six that caught the most BMSB of each of the two trap types. A summary of the BMSB phenology is shown below:

	2014	**2015**	**2016**
Traps placed	12-Mar.	24-Feb.	9-Feb.
First adults (found at first check)	17-Mar.	2-Mar.	11-Feb.
First eggs	5-May	17-Apr.	12-Apr.

First nymphs 3-Jun. 19-May 9-May

In 2016, unusually warm temperatures occurred in Feb., including 10 days in the upper 60s F and eight days at or above 70°F (Fig. 10); this warmth brought out overwintering adults very early. The first eggs and nymphs were found earlier in 2015 than in 2014, and also earlier in 2016 than in 2015; the 2016 dates are by far the earliest in the country. As in previous years, nymph peaks were found in June and early September. A heat wave occurred in late July 2016, with seven days at or above 100°F, including two 104°F days (Fig. 10). Likely due to this heat wave, trap counts crashed from late July through late Aug. and the Sept. trap counts were less than in the two previous years (Fig. 9).

2. Compare new Trece lures and double cone trap strategies.

Traps in this study were placed in Chinese pistache trees because tree of heaven trees were being used for the main study discussed above. Trap counts were likely very low, probably for two reasons: 1) the BMSB population crashed after the late July heat wave, and 2) because BMSB likely don't feed on Chinese pistache fruits until they soften in late summer.

On average, the two experimental Trece lures caught virtually the same number of BMSB compared to the standard Trece lure (Fig. 11). In the trap comparison, those with insecticide strips or adhesive inner walls caught substantially more BMSB than traps with neither the strip nor adhesive. It is likely that BMSB could simply walk back out through the holes without a way to keep them inside. However, differences among traps were not significant due to low trap counts and high variability. Several traps malfunctioned as a result of sun exposure breaking down the plastic or wind causing branch movement and breakage.

3. Determine the spread from the initial infestation area

In 2016, a new infestation was discovered in a trap placed in a flowering plum tree near a vineyard near Clarksburg (Fig. 12). A total of 3 male adults and 2 nymphs were found in the trap between mid-June and mid-July. None were found in additional traps deployed at the site, and searches of plum and vineyard foliage turned up no additional BMSB. The plum tree was not sprayed. Plum is not on the www.stopBMSB.org host list. Monitoring at the site will continue in earnest at the site in 2017.

Also, in late Sept. and early Oct. 2016, a total of 3 male BMSB were found in a trap at the Bartley Cavanaugh Golf Course in Freeport (Fig. 12).One male BMSB was found at in a trap at the site in Oct. 2015.

BMSB populations often take up to 5 years to become a serious problem after the first introduction (Tracy Leskey, personal communication). A population is starting to build in Freeport and over the years the population will slowly increase and begin to spread.

Lake and Mendocino Counties

No BMSBs were detected in either the pyramid traps or during the host plant surveys in Lake or Mendocino Counties.

DISCUSSION

Although the midtown Sacramento trap counts had begun to decline just before the July heat wave began, it is likely that extended heat set back the population from late July through late Aug., as well as the reduced numbers in early September. In order to determine the lethal high temperature extremes of BMSB and efficacy of commercial heat treatments for control of the bug in export shipping cargo, Aigner and Kuhar (2016) exposed adults in petri dishes to varying high temperatures in a petri dish containing a water wick. Fifteen minutes of exposure to 122°F killed all bugs, as did 1 hour exposure to 113°F. Adults exposed to 95, 100, 104, 108, and 113°F for 4 hours killed 5, 12, 38, 91, and 100% of the adults, respectively. Mortality at 108°F and 113°F was significantly higher than it was at the lower temperatures, and mortality at 104°F was higher than it was at either 100 or 95°F. In Sacramento, the temperature on July 24 and 26 was 104°F for approx. 1 hour and 103°F for approx. 2 hours. Therefore, it is possible that perhaps 10-25% of adults were killed on each of those days, plus more on the other five 100°F+ days during the hot period. More importantly, nymphs and eggs are likely far more heat sensitive, and the heat wave hit when the second generation eggs were being laid.

The greater trap catches with pyramid traps agrees with previous research showing that large pyramid traps are most effective (Leskey et al., 2013). In 2015, pyramid traps caught 14% more BMSB than 1-gal. double cone traps placed in random trees. In 2016, pyramid traps caught an average of 34% more than the double cone traps (which were smaller than those used on 2015), even though the latter traps were placed in tree of heaven, which are highly attractive to BMSB. A key factor in this discrepancy is that pyramid traps were significantly more effective in trapping nymphs than double cone traps. BMSB nymphs have been shown to walk fairly long distances. Most nymph stages have been shown to walk on flat ground about 100 ft. in 1 hr. to baited traps, but third instar nymphs walked 130 ft.

Three years of monitoring have confirmed that two BMSB generations per year occur in Sacramento. It also shows that adults will become active in winter when days are warm, as temperatures in the upper 60s to mid-70s occurred on 18 days in Feb. 2016. A similar but less extreme phenomenon occurred in 2015. Warmer than normal temperatures also led to the early discovery of the first egg mass on April 12. However, the timings of the two generational peaks of 2016 were similar to those of 2014 and 2015.

The proportion of nymphs to adults in three years has been 3:1 in 2014, 4:1 in 2015, and 2.5:1 in 2016. Also, slightly more males were caught than females in 2014 and

2015, but in 2016, significantly more females were trapped.

The finding in 2015 of one male BMSB in a trap in Freeport and three in 2016 may indicate that the BMSB population there is slowly establishing on the northern edge of Delta farmland. Also, the finding of three males and two nymphs in a trap in the flowering plum tree near Clarksburg indicates a potential population already established. However, four additional traps caught none, and no BMSB were found in the trap after the late July heat wave. The finding of three males in the trap in June and two nymphs in July indicates that a population may be establishing, but finding none after mid-July could indicate that the BMSB did not survive. Not finding BMSB in other agricultural areas and anywhere in the North Coast does not necessarily mean that no BMSB are present in those areas. Lure scents are known to attract BMSB from only short distances – less than 100 ft. away (Leskey et al., 2013). Also, it takes 4-5 years for BMSB populations to build up to major pest levels after the first introduction (T. Leskey, personal communication). It is possible that the pest could be present and populations beginning to increase somewhere in agricultural areas but not yet detected.

LITERATURE CITED

Aigner, J.D. and T.P. Kuhar. 2016. Lethal high temperature extremes of the brown marmorated stink bug (Hemiptera: Pentatomidae) and efficacy of commercial heat treatments for control in export shipping cargo. J. Agric. Urban Entomol. 32: 1–6.

Lee, D-H., B.D. Short, S.V. Joseph J.C. Bergh, and T.C. Leskey. 2013. Review of the biology, ecology, and management of Halyomorpha halys in China, Japan, and the Republic of Korea. Environ. Entomol. 42(4):627-641.

Leskey, T.C. 2013. Presentation at Cumberland-Shenandoah Fruit Workers Conf., Dec. 2013.

Leskey, T.C., S.E. Wright, B.D. Short, et. al. 2012. Development of behaviorally based monitoring tools for the brown marmorated stink bug in commercial tree fruit orchards. J. Entomol. Sci. 47(1):76-85.

Nielsen, A. 2008. Developmental rate estimation and life table analysis for *Halyomorpha halys*. Environ. Entomol. 37(2):348-355.

Figure 1. AgBio pyramid trap (left) and 8-inch tall double cone trap in tree (right), with red insecticide strip and Trece lure. Twelve of each trap type were used in the main study.

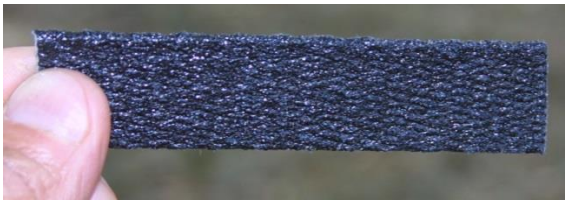

Figure 2. Trece BMSB lure.

Figure 3. Improved version of the experimental Trece double cone trap, with a plastic ring fitted to top and bottom to secure the cone screen on top and bottom instead of a rubber band and staples. This trap has adhesive on the inside to keep BMSB in the trap.

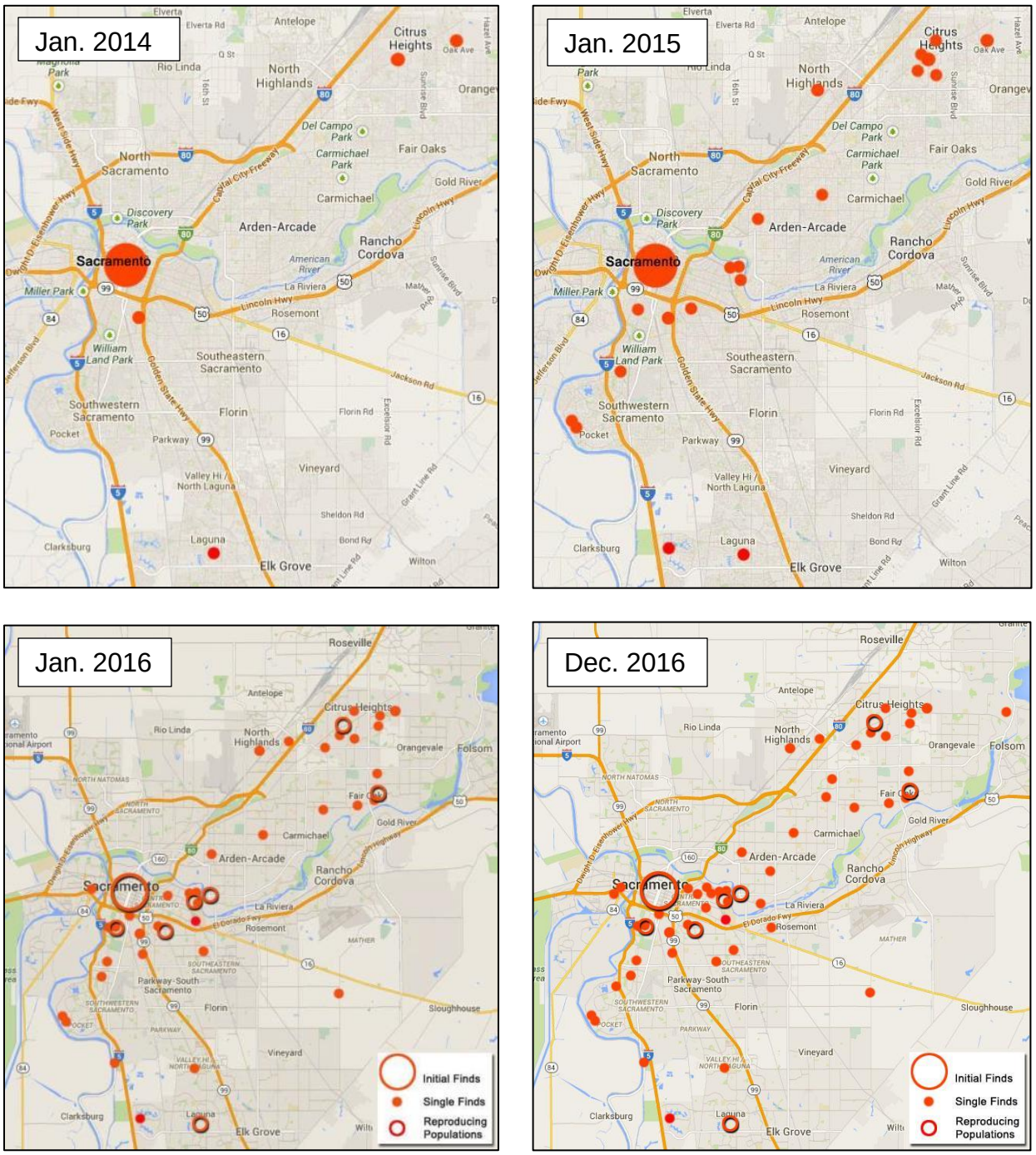

Figure 4. Locations where BMSB have been found in the Sacramento region, Jan. 1, 2014 (left), Jan. 1, 2015 (middle), Jan. 1, 2016 and Dec. 1, 2016. Small dots indicate single finds and circles indicate reproducing populations. Approx. 15 new finds were discovered between Jan. 1 and Dec. 1, 2016.

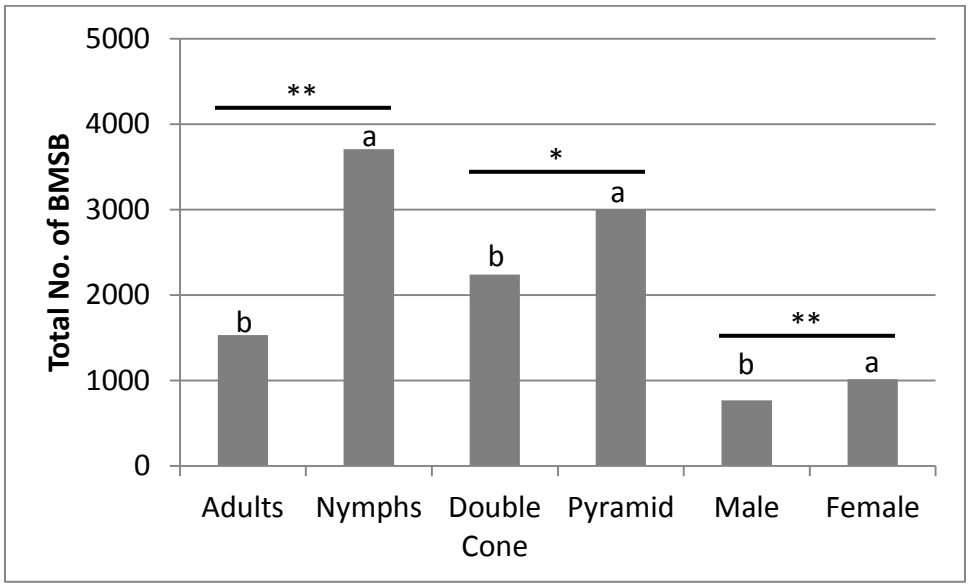

Figure 5. Total number of BMSB adults vs. nymphs caught in 24 traps (9-May to 10-Oct.), total number of BMSB caught in 12 double cone vs. 12 pyramid traps (9-May to 10-Oct.), and total number of adult male vs. females caught in 24 traps (18-Apr to 31-Oct.). (** and ** = significantly different at P≤0.05 and P≤0.01, respectively, Duncan's MRT.*)

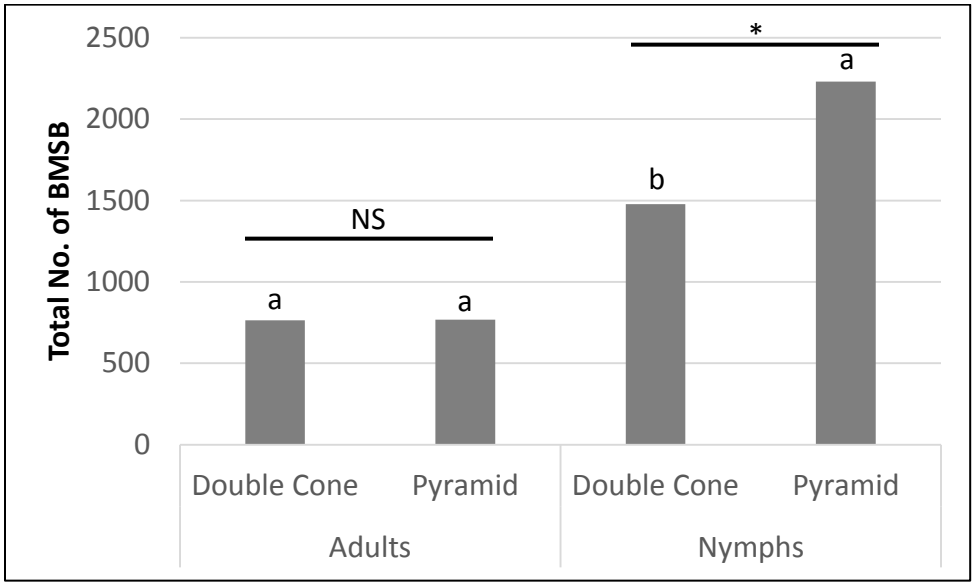

Figure 6. Total number of BMSB adults vs. nymphs caught in 12 double cone vs. 12 pyramid traps, 9-May to 10-Oct. (* = *significantly different at P≤0.01; NS = not significant, Duncan's MRT.*)

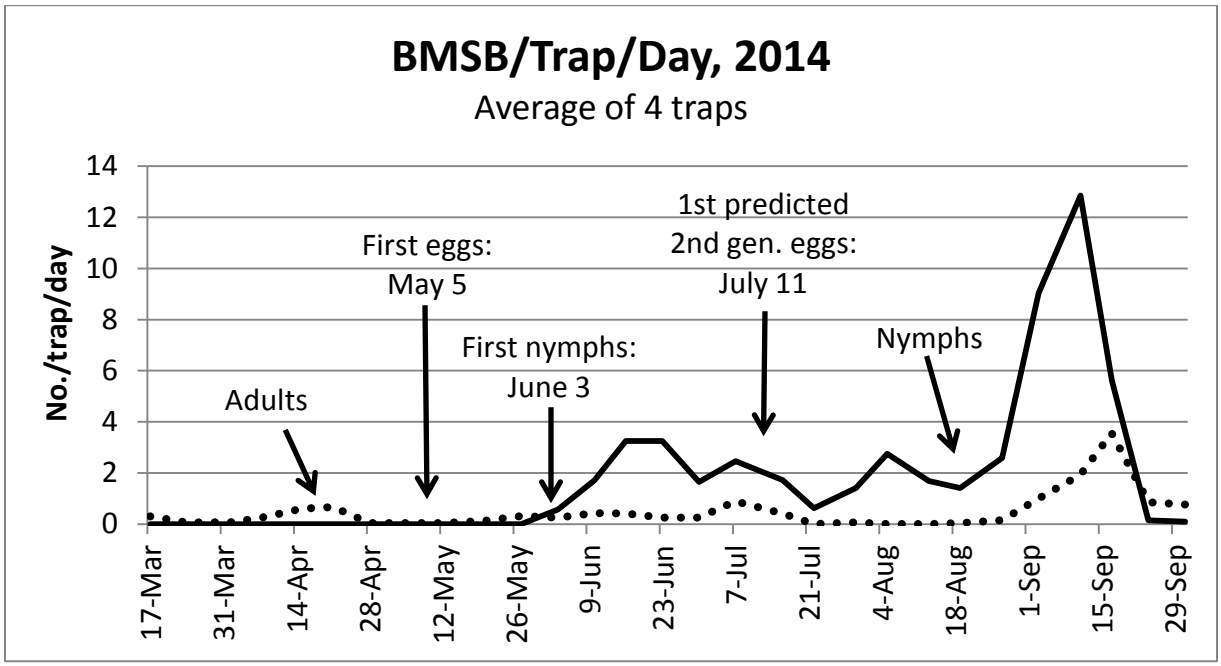

Figure 7. Average number of adults and nymphs per trap per day found in the 4 Midtown traps that caught substantial numbers in 2014.

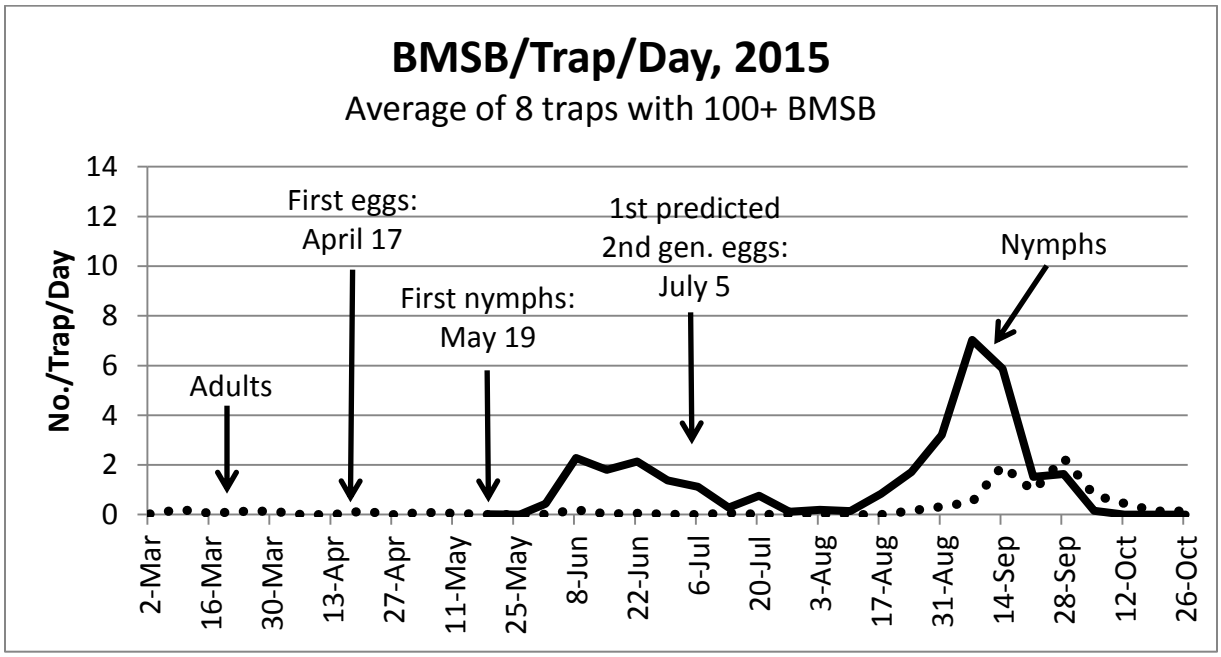

Figure 8. Average number of adults and nymphs per trap per day found in the 8 Midtown traps that caught >100 in 2015.

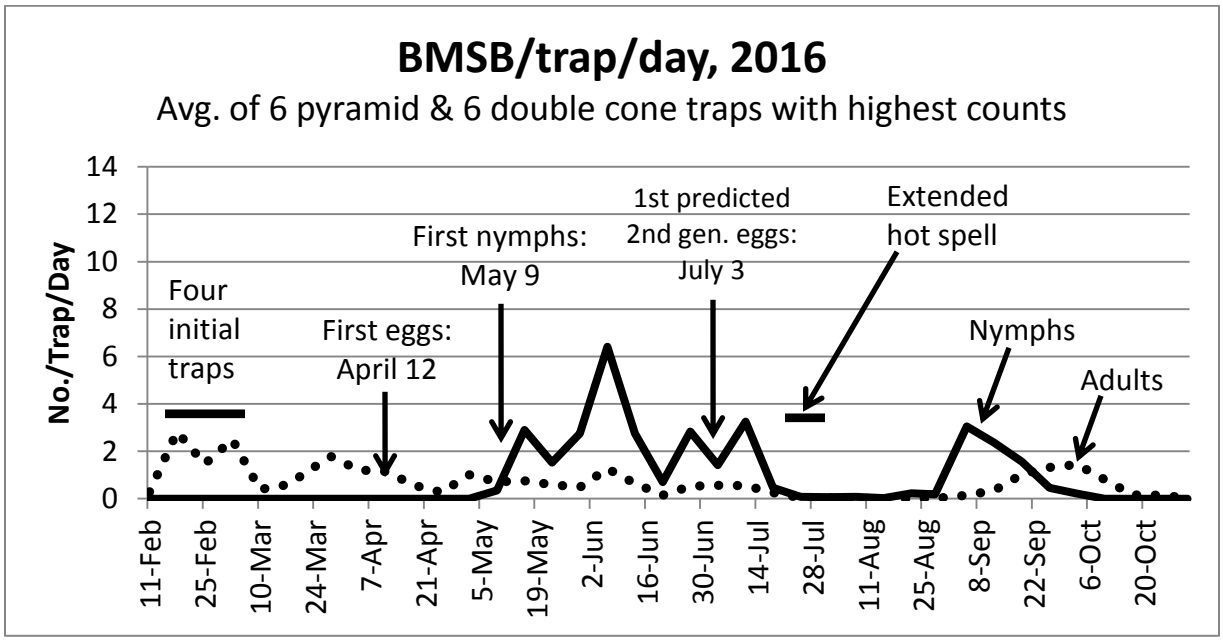

Figure 9. Average number of adults and nymphs per trap per day found in the 12 (6 pyramid and 6 double cone) traps that caught the most BMSB in Midtown in 2016.

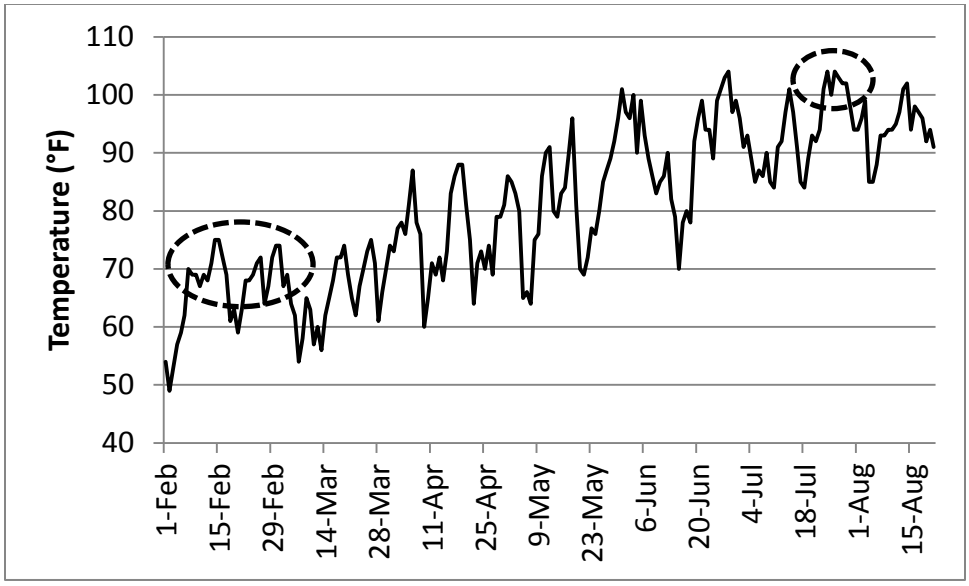

Figure 10. High temperatures at Sacramento Executive Airport, 2016. February was unusually warm, bringing out adults early, and an extended period of extreme heat occurred June 23-29, reducing the population to near zero for four weeks.

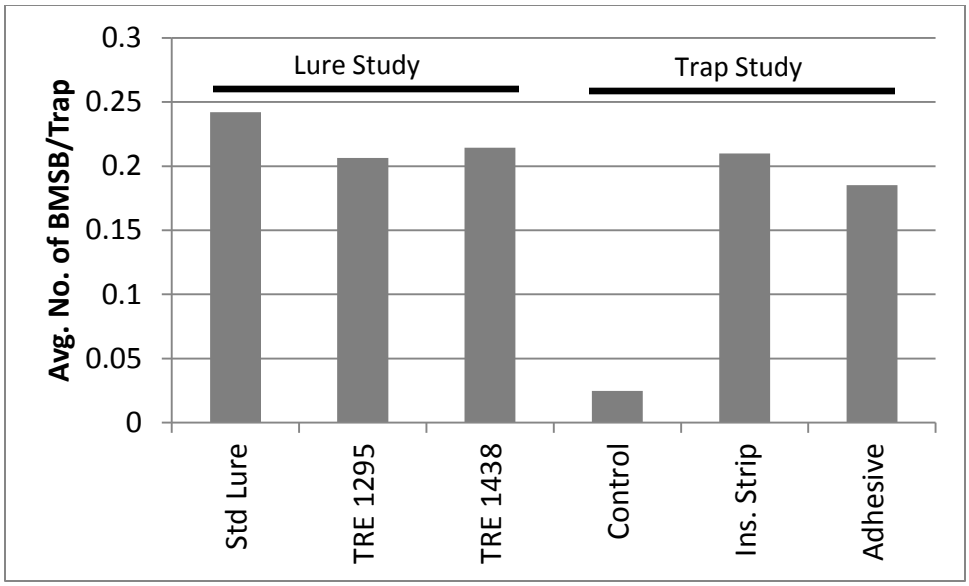

Figure 11. Average trap counts per week in the Trece lure and trap study. The three lure types caught very similar numbers of BMSB (left three bars).

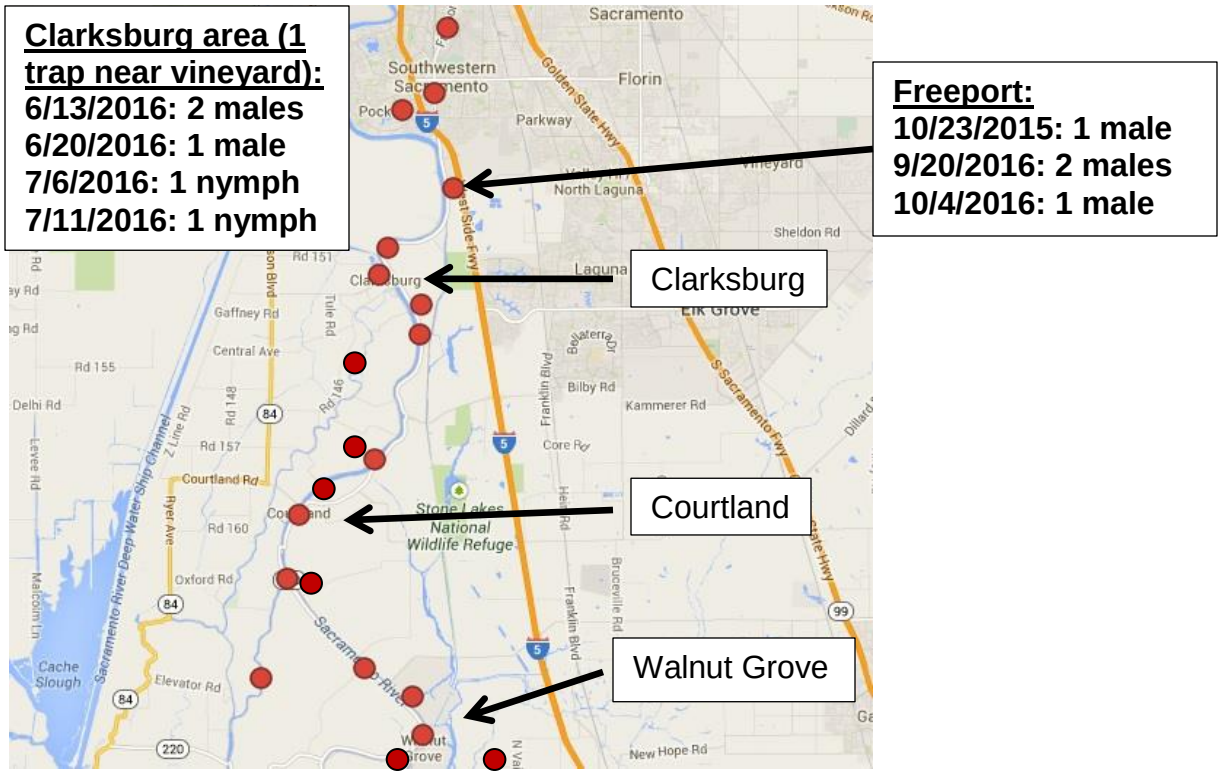

Figure 12. Locations of the BMSB traps placed from South Sacramento to Walnut Grove and number and locations of BMSB found, 2016.