N O T E

Overwintering Refuge Sites for *Megacopta cribraria* (Hemiptera: Plataspidae)[1]

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Megacopta cribraria F. (Hemiptera: Plataspidae) was first reported in the United States near Atlanta, Georgia, in fall 2009 (Suiter et al. 2010, J. Integr. Pest Manag. 1: 1–4) and has since spread throughout the southeastern United States (http://www.kudzubug.org/distribution_map.cfm). In Asia and the United States, it is commonly associated with its preferred host plant, kudzu, *Pueraria montana* Lour (Merr.) var. *lobata* (Willd.) (Fabales: Fabaceae) (Medal et al. 2013, Fla. Entomol. 96: 631–633). Nonetheless, *M. cribraria* has emerged as a significant pest of soybean, *Glycine max* (L.) Merrill and may damage a few other legumes in the United States (Eger et al. 2010, Insecta Mundi 0121: 1–11; Hu and Carroll 2012, htpp://agfax.com/2012/05/18/Alabama-soybean-kudzubugs-making-their-move/). In Georgia and South Carolina, yield losses in untreated soybean fields averaged 18% and ranged up to 59.6% (Greene et al. 2012, United Soybean Board, Chesterfield, MO; Seiter et al. 2012, J. Econ. Entomol. 106: 1676–1683).

Apart from being odoriferous, crushed nymphs have reportedly caused skin rashes, thereby raising health concerns for workers in soybean fields (Ruberson et al. 2013, Appl Entomol Zool. 48: 3–13). *Megacopta cribraria* is also viewed as a nuisance pest in fall through spring when adults aggregate on or around homes to overwinter, apparently close to kudzu patches (Eger et al. 2010, Insecta Mundi 0121: 1–11; Ruberson et al. 2013).

Little is known about the biology and ecology of *M. cribraria* in North America. Prominently, we do not understand their behavior and population dynamics when host plants are not available, as in the winter. Knowledge of the overwintering behavior and biology of this species could inform surveillance and management. This study was undertaken to identify overwintering refuge areas preferred by *M.*

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cribraria under natural conditions. Site selection and sampling were based on anecdotes of *M. cribraria* behavior and on patterns of overwintering by pentatomids.

Three sites with south-facing woodland borders adjacent to soybean fields previously identified as harboring *M. cribraria* populations during the preceding crop growing season were selected near Clayton (Johnston Co.), North Carolina. Geographic locations of the three sites were N 35.686093°, W −78.316169° (site 1), N 35.699303°, W −78.336124° (site 2), and N 35.700906°, W −78.337412° (site 3). Adjacent woodlands were mixed forests consisting primarily of mature loblolly pine (*Pinus taeda* L.) and sweet gum (*Liquidambar styraciflua* L.) trees. Pine and sweet gum were selected for sampling due to their prevalence and because bark of older trees in both species becomes deeply furrowed, offering potential refuge sites for overwintering bugs. Tree pairs were assigned for sampling, such that each pair consisted of 1 pine and 1 sweet gum tree that were never more than 3 m apart.

Leaf-litter samples were collected in plastic bags from a 0.09-m^2 area directly beneath north- and south-facing sides of caged trees, and between trees in each pair, at sites 2 and 3 (4–22 February 2013) when temperatures were never above 5°C and then refrigerated until tallied in the laboratory.

Megacopta cribraria overwintering in bark were sampled by wrapping landscaping fabric cages (0.9 m in height) (360-count Promat Professional, Lowe's Inc., Cary, North Carolina) edged with 2.5 cm of memory foam around tree bole bases at 1.5 m in height in January 2013. Cages were secured with clothespins, binder clips, and expanding foam (Great Stuff™ Pond and Stone Foam, Dow Chemical Company, Midland, Michigan). A funnel-bottle collection system was secured facing north to the top of each cage (Fig. 1). Ten tree pairs were caged at sites 2 and 3, and seven tree pairs plus four sweet gums were caged at site 1. *Megacopta cribraria* were collected from attached bottle traps (4–29 March 2013) and stored in 70% ethanol until tallied in the laboratory. Voucher specimens from all collections were submitted to the North Carolina State University Insect Museum. Diameter at breast height of each tree and its distance from the forest edge were measured.

All data were subjected to analysis of variance (PROC GLM) followed by Fisher's protected least significant difference (LSD) for mean separation (SAS Institute 2013, SAS Institute, Cary, North Carolina). Leaf-litter data were $\log_{10}(x+1)$ transformed to achieve approximate normality, and transformed data were used for analysis. Reported data were reverse transformed. A curve was fit to the number of bugs in leaf-litter samples versus the distance from forest edge and the prediction equation computed $\log_{10}(Y+1)$.

Location of leaf-litter (north-facing, south-facing, between trees) was a significant factor affecting overwintering *M. cribraria* numbers ($F = 6.56$; df = 25, 74; $P < 0.0001$). Mean bug number in south-facing sweet gum leaf-litter was 11× higher than in north-facing gum-litter and 14× higher than north-facing pine-litter and litter between trees (Table 1). Tree distance from forest edges significantly influenced numbers of overwintering *M. cribraria* ($F = 24.30$; df = 1, 74; $P < 0.0001$) with a quadratic distance effect ($F = 10.87$; df = 1, 74; $P = 0.0015$), so that very few were found beyond 5 m (Fig. 2).

However, no significant effect of tree species ($F = 1.65$; df = 1, 19; $P = 0.2141$) or site ($F = 0.41$; df = 1, 19; $P = 0.5281$) was seen on number of *M. cribraria* overwintering in bark. There was also no significant effect of tree species on the number of bugs in either north-facing ($F = 0.41$; df = 3, 55; $P = 0.6856$) or south-

Fig. 1. Mesh cage with funnel-bottle collection system to collect overwintering *Megacopta cribraria* from bark at three woodland border sites adjacent to soybean fields in Clayton, NC (January–March 2013).

facing ($F = 0.89$; df = 3, 55; $P = 0.3736$) leaf-litter. Similarly, tree diameter, which ranged from 0.21 to 0.53 m (0.38 $\pm$ 0.09 [mean $\pm$ SD]), had no significant effect on number of *M. cribraria* found in leaf-litter ($F = 0.23$; df = 1, 55; $P = 0.6327$). We found 80$\times$ more *M. cribraria* overwintering in pine leaf-litter versus pine bark, and $>$400$\times$ higher numbers were recorded from sweet gum leaf-litter versus gum bark.

In this study, *M. cribraria* strongly preferred overwintering in leaf-litter at the south-facing bases of trees within 5 m of the edge of woodlands bordering soybean fields. Horizontal cover provided by sweet gum leaves likely helped protect the bugs from weather exposure. Examples of overwintering habitats in South Carolina of agriculturally significant pentatomids (Jones and Sullivan 1981, Environ. Entomol.

Table 1. Overwintering *Megacopta cribraria* in leaf-litter samples collected near Clayton, NC.

Location	No.	No. of *M. cribraria*/0.09-m^2 Leaf-Litter Sample*
Sweet gum, south-facing side	20	41.1 ± 13.82 a
Pine, south-facing side	20	21.85 ± 9.06 a
Sweet gum, north-facing side	20	3.75 ± 1.56 b
Pine, north-facing side	20	2.9 ± 1.42 b
Leaf litter between trees	20	3.0 ± 0.93 b

* Means ± SE followed by the same letter are not significantly different (LSD, $P \leq 0.05$; SAS Institute 2013).

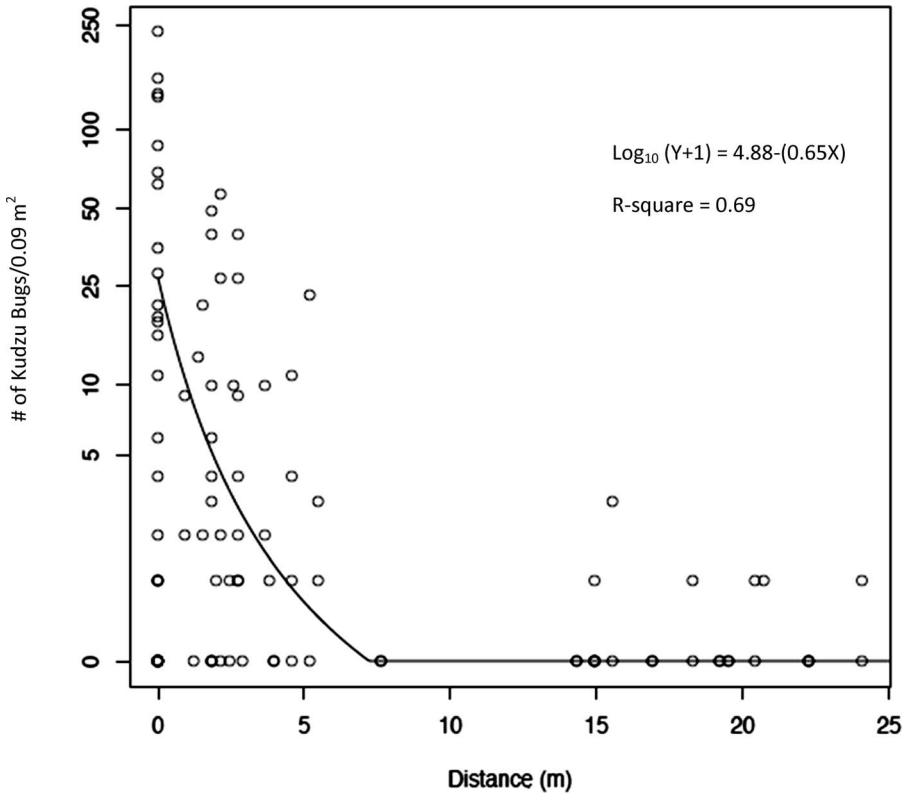

Fig. 2. Number of overwintering *Megacopta cribraria* from 0.09-m^2 leaf-litter samples at the base of pine and sweet gum trees ($n = 100$) in relation to tree distance (m) from the edge of south-facing woodland borders next to soybean fields at two sites near Clayton, NC.

10: 409–414), close relatives of the plataspids, include *Euschistus servus* (Say) that were found to be the most abundant species and preferred open habitats such as soybean stubble, whereas *Euschistus tristigmus* (Say), *Podisus maculiventris* (Say), and *Acrosternum hilaris* (Say) overwintered in deciduous woods and their borders. *Nezara viridula* (L.) was found to overwinter primarily in leaf-litter, behind bark of living and dead trees, in tree crotches, in accumulations of pine needles, and in buildings. *Euthyrhynchus floridanus* (L.) overwintered as eggs under tree bark. Deciduous woodlands yielded more overwintering hemipteran species than pine woodlands (Jones and Sullivan 1981).

Anecdotal observations have reported *M. cribraria* under tree bark and in plant debris near kudzu patches and soybean fields (Reisig and Bacheler 2012, http://ipm.ncsu.edu/cotton/insectcorner/PDF/Kudzu%20bug%20Summer%202012%20Handout.pdf; Reisig 2013, http://www.nccrops.com/2013/04/09/what-to-do-with-kudzu-bugs-on-the-move/). *Megacopta cribraria* has also been reported to aggregate on south-facing walls of houses in fall and spring. Around homes and other structures, *M. cribraria* aggregate in tree bark crevices and under bark, rocks, leaf-litter, and lightly colored surfaces, such as siding or fascia boards, when temperatures drop (Waldvogel and Alder 2012, http://www.ces.ncsu.edu/depts/ent/notes/Urban/kudzubug.htm), presumably because of the thermal properties of these surfaces. In this study, we found that *M. cribria* strongly preferred overwintering in leaf-litter compared to tree bark, even though some of the sampled trees were large pine trees of ≈0.5 m in diameter. Bugs were observed by S.L. and D.O. sunning themselves on south-facing tree bark on warm winter days but retreated to leaf-litter on cold days. Results of this study improve understanding of *M. cribraria* overwintering preferences and will improve sampling methodology for future population dynamics, monitoring, and management studies.

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