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Cover Page Footnote

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Pentatomidae (Hemiptera: Heteroptera: Pentatomidae) Captured on Purple Prism Traps Deployed for Detection of Emerald Ash Borer (*Agrilus planipennis*) (Copeoptera: Buprestidae) in Minnesota

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Abstract

The observation of bycatch from insect trapping programs, though often considered bothersome, may hold value for ecological and taxonomic studies. In Minnesota, a large trapping survey consisting of pheromone-baited purple prism traps, has been conducted for early detection of *Agrilus planipennis* Fairmaire, the emerald ash borer (Coleoptera: Buprestidae). Stink bugs (Heteroptera: Pentatomidae), which are pests of increasing importance in the North Central U.S., were observed to be captured by these traps. The objective of this study was to use trap bycatch from the *A. planipennis* traps for further documentation of the abundance and diversity of Pentatomidae in Minnesota. In 2011 and 2012, 4,401 and 5,651 purple prism traps, respectively, were deployed and checked in Minnesota. Across both years, a total of 17 species of Pentatomidae were identified from 2 subfamilies, Asopinae and Pentatominae. The most abundant and prevalent species collected were *Banasa calva* (Say), *B. dimidiata* (Say), *Chinavia hilaris* (Say), *Euschistus tristigmus luridus* Dallas, *Menecles insertus* (Say), and *Podisus maculiventris* (Say). The pentatomid community observed on purple prism traps deployed in arboreal habitats differed from pentatomid communities reported in Minnesota crops (i.e., soybean, wheat and corn). Results of this study show that many pentatomid species are captured on purple prism traps and therefore bycatch of these traps could provide valuable information on the pentatomid community. However, purple prism traps should be used in addition to traditional surveillance or scouting methods for pentatomids.

Keywords: *Agrilus planipennis*, bycatch, invasive species, purple prism traps, stink bugs

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An important component of integrated pest management of invasive species is early detection (Venette and Koch 2009). The goal of early detection programs is to detect invading populations early in the invasion process to increase the likelihood of successful eradication or containment of these incipient infestations (Venette and Koch 2009). Early detection surveys are often conducted on state, regional or national scales, and may employ the use of baited traps. The bycatch of such trapping programs, though often considered bothersome, may hold value for ecological and taxonomic studies (Buchholz et al. 2011, Spears and Ramirez 2015). For example, Coyle et al. (2012) recently documented the composition and phenology of native Siricidae of Minnesota based on the bycatch of an early detection trapping program targeting a new invader of North America, *Sirex noctilio* Fabricius (Hymenoptera: Siricidae), the sirex woodwasp.

A large, trapping-based early detection program was conducted for *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), the emerald ash borer, in Minnesota (United States Department of Agriculture 2012). Skvarla and Holland (2011) documented that a diversity of insect families are captured by the traps deployed for *A. planipennis* and suggest that examination of the trap bycatch could yield a wealth of information on the distribution and density of non-target species. The list of non-target taxa captured by *A. planipennis* traps includes several hemipteran families, but does not include Pentatomidae (Skvarla and Holland 2011). However, various native Pentatomidae were observed on purple prism traps deployed for *A. planipennis* in Minnesota in 2010 (R.L.K. personal observation), which suggested the potential utility of these traps for documentation of the pentatomid fauna.

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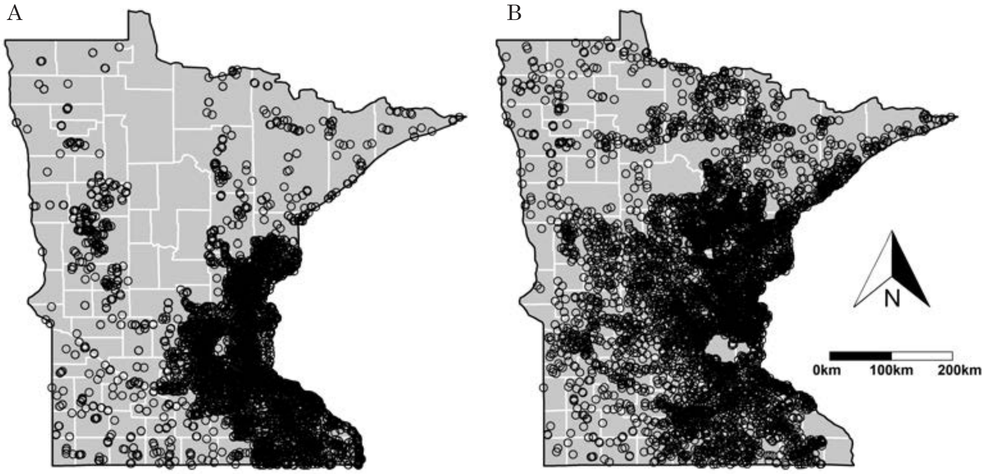

Figure 1: Locations of 4,401 and 5,651 purple prism traps in Minnesota that were checked for Pentatomidae in 2011 (A) and 2012 (B), respectively.

The family Pentatomidae is the fourth largest family within the order Hemiptera and contains around 4,700 species worldwide (McPherson and McPherson 2000). Fifty-two pentatomid species (49 native and 3 exotic) have been recorded in Minnesota, spanning the subfamilies Asopinae, Pentatominae and Podopinae (Koch et al. 2014, Koch et al. 2018) and accounting for approximately 23% of the 222 species known to occur in North America (Froeschner 1988, McPherson and McPherson 2000). Pentatomids are increasing in pest importance in the North Central U.S., because of the apparent increasing abundance of native species (Hunt et al. 2011, 2014; Michel et al. 2013) and introduction of exotic species (Swanson and Keller 2013, Koch 2014, Koch et al. 2018). However, due to their historical lack of economic importance in the region, stink bugs are relatively poorly documented in Minnesota. *Halyomorpha halys* (Stål), the brown marmorated stink bug, was first detected in North America in Pennsylvania in 1996 (Hoebeke and Carter 2003). This pest has since spread throughout much of the United States (Leskey et al. 2012) and was first detected in Minnesota in 2010 (Koch 2014). *Halyomorpha halys* has potential to cause significant adverse impacts as a pest of a diversity of crops and as a nuisance household invader (Hoebeke and Carter 2003, Leskey et al. 2012, Bergmann et al. 2016, Koch et al. 2017). *Fraxinus americana* L., white ash, is a host for *H. halys*, especially from early July to mid-October (Nielsen and Hamilton 2009) and is one of the *Fraxinus* species in which *A. planipennis* traps are deployed. Other North American Pentatomidae documented in association with *Fraxinus* species include *Banasa rolstoni* Thomas & Yonke, *B. subcarnea* Van Duzee, *Brochymena quadripustulata* (Fabricius) and *Euschistus tristigmus* (Say) (Sites et al. 2012). In this paper we explore the use of *A. planipennis* traps as an additional tool for documentation of the abundance and diversity of Pentatomidae in Minnesota.

Materials and Methods

In 2011 and 2012, Pentatomidae were collected from traps deployed in a statewide survey for *A. planipennis*. Trapping was conducted using purple prism traps (35.5 × 60.9 cm on each rectangular face) as described by Francese et al. (2008), which were deployed, maintained, and checked according to the national protocol (United States Department of Agriculture 2012). Traps were supplied by the USDA, Animal and Plant Health Inspection Service, Plant Protection and Quarantine for the purpose of emerald ash borer survey. Each trap was baited with a Z-3-Hexen-1-ol lure and a manuka oil lure (Crook et al. 2008) (Synergy Semiochemicals Corp., Burnaby, Canada). Traps were hung in the lower canopy of ash (*Fraxinus* spp.) trees, throughout the state of Minnesota (Fig. 1). Allocation of traps was based on national priorities for detection and delimitation of *A. planipennis* infestations (United States Department of Agriculture 2012). In 2011, 4,401 traps were placed in the field beginning 11 April. After approximately 60 days the traps were checked and the lures were replaced. Traps were checked again

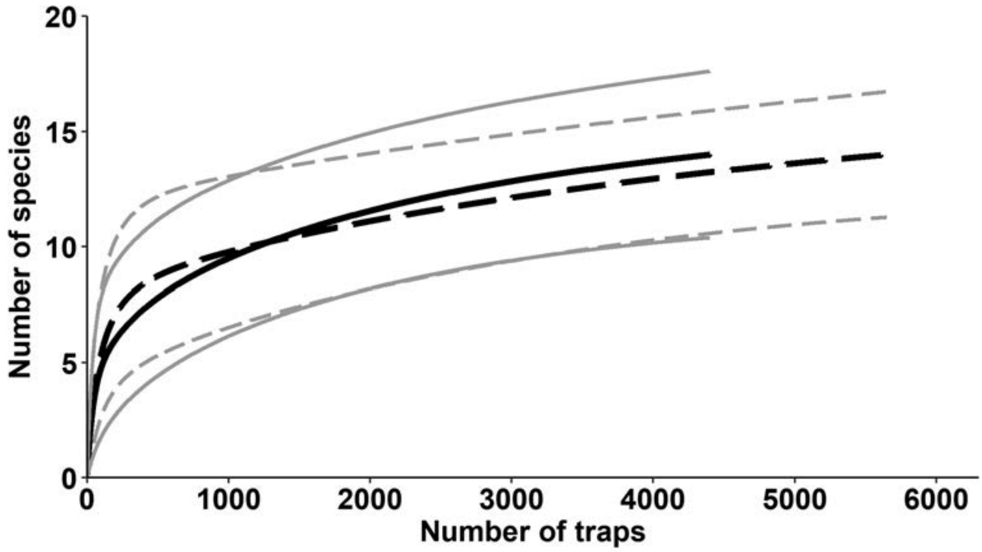

Figure 2: Sample-based rarefaction curves (black lines) and 95% confidence intervals (gray lines) indicating the number of pentatomid species collected on purple prism traps over the trapping season in 2011 (solid lines) and 2012 (dashed lines).

and removed from the field by 24 October. In 2012, 5,651 traps were placed in the field beginning 2 April. As in 2011, the traps were checked and the lures were replaced after approximately 60 days, and the traps were checked again and removed from the field by 8 September. On each date that a trap was checked, Pentatomidae observed on the traps were carefully removed with a forceps, placed in small plastic zipper-locking bags (4 × 5 cm) and were transferred within 24 hours to a freezer for storage until later identification in the laboratory. Pentatomidae were identified using McPherson and McPherson (2000), Rider (2012) and Paiero et al. (2013).

For each year, species abundance was summarized on a per-trap basis over the two collection dates. From this, the relative abundance of each species was calculated as a percentage of the total individuals collected, and prevalence (i.e., frequency of detection) was calculated as the percentage of traps from which each species was collected. Nonparametric Friedman's Test and *post hoc* multiple comparisons were used to compare relative abundance among species within each year (Hothorn et al. 2006, 2008) and logistic regression with Tukey-Kramer-adjusted pairwise comparisons of least square means were used to compare prevalence among species within each year (Hothorn et al. 2008, Lenth 2016). The aforementioned analyses were performed with R version 3.4.4 (R Core Team 2018) and RStudio Desktop version 1.1.383 (RStudio Team 2016). In addition, sample-based rarefaction curves with 95% confidence intervals were computed for each year with EstimateS using the Colwell method (Colwell et al. 2012).

Results and Discussion

Observation of bycatch from traps, although uncommon, can provide valuable information (e.g., relative abundance and diversity) on non-target insects (Buchholz et al. 2011, Spears and Ramirez 2015). Captures from invasive species surveys, such as the national *A. planipennis* survey with purple prism traps, are of particular value because these efforts are deployed across large geographic areas with standardized protocols and can provide a wealth of data on non-target organisms (Spears and Ramirez 2015). A previous study of non-target insect families collected on purple prism traps identified 25 families from 5 insect orders; however, no pentatomid species were reported (Skvarla and Holland 2011).

In contrast, the present study showed that pentatomid species can be captured on purple prism traps and therefore bycatch from these traps could provide valuable information on the pentatomid fauna. The greater sampling intensity in the present study compared to Skvarla and Holland (2011) may have contributed to differences in pentatomid capture. From the purple prism

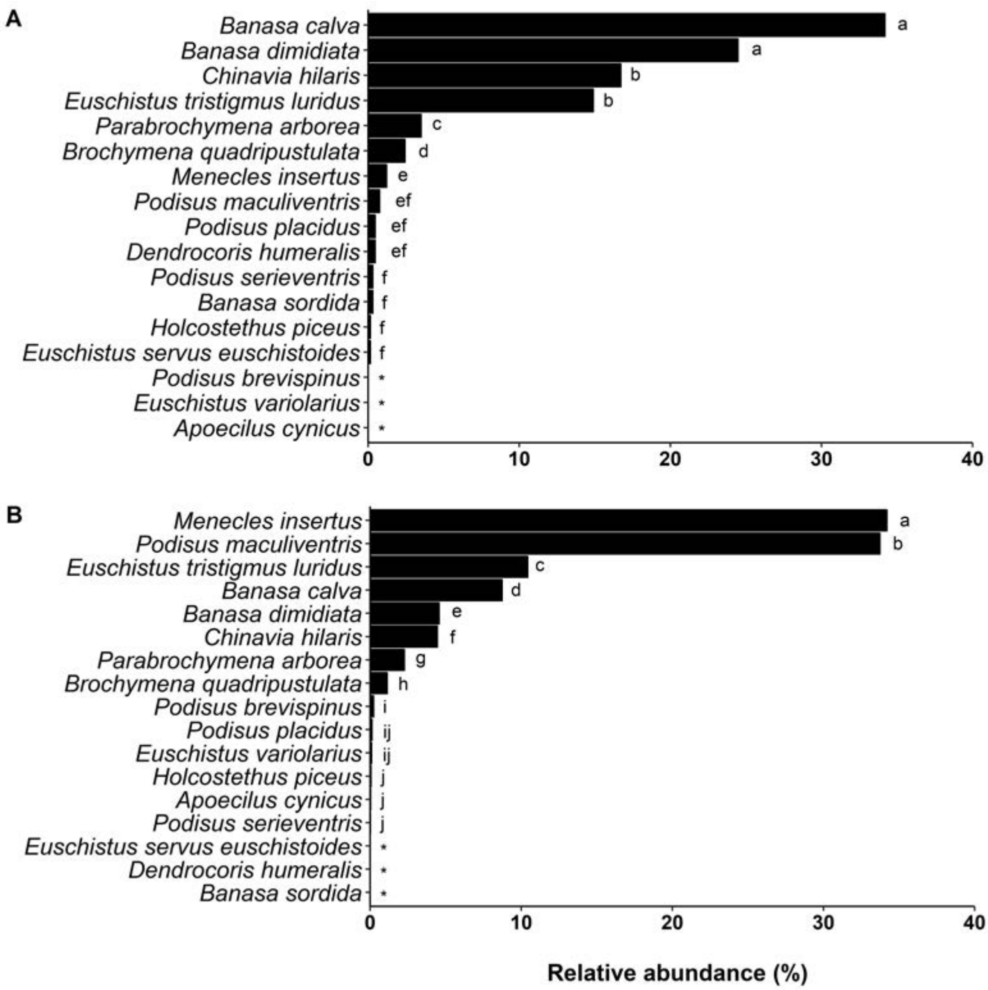

Figure 3: Relative abundance of adult Pentatomidae collected on purple prism traps in 2011 (A) and 2012 (B) in Minnesota. In 2011 and 2012, 658 individuals were collected from 4,401 traps and 5,714 individuals were collected from 5,651 traps, respectively. Species followed by the same letter do not differ ($\alpha < 0.05$), *post hoc* analysis on Friedman's test. Asterisks (*) indicate that a species was not detected.

traps deployed over the duration of the two year study, a total of 6,377 adult pentatomid specimens were collected, comprising 17 species from 2 subfamilies. The subfamily Asopinae, which contains predatory species, was represented by a total of 5 species from two genera: *Apoecilus cynicus* (Say), *Podisus brevispinus* Phillips, *P. maculiventris* (Say), *P. placidus* Uhler, and *P. serieventris* Uhler. The subfamily Pentatominae, which contains herbivorous species, was represented by a total of 12 species from 8 genera: *B. calva* (Say), *B. dimidiata* (Say), *B. sordida* (Uhler), *B. quadripustulata*, *Chinavia hilaris* (Say), *Dendrocoris humeralis* (Uhler), *Euschistus servus euschistoides* (Vollenhoven), *E. tristigmus luridus* Dallas, *E. variolarius* (Palisot de Beauvois), *Holcostethus piceus* (Dallas), *Menecles insertus* (Say), and *Parabrochymena arborea* (Say). The species of Pentatomidae collected in this study have all previously been reported to occur in Minnesota (Koch et al. 2014). The invasive *H. halys* was not detected in either year, despite purple prism traps being deployed in southeastern Minnesota, where low-level populations of *H. halys* were known to occur (Koch 2014, Koch et al. 2014). Sample-based rarefaction curves approached asymptotes for both years, which indicates that a sufficient number of

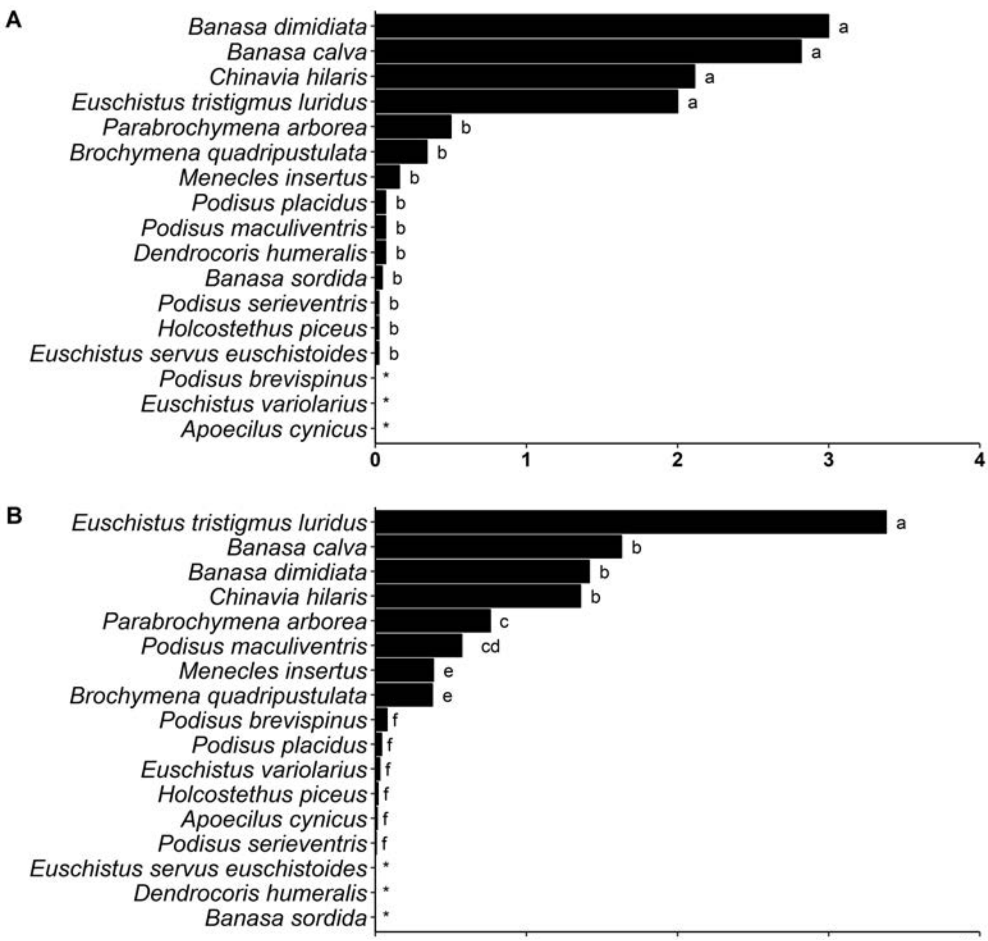

Figure 4. Prevalence (i.e., frequency of detection) of adult Pentatomidae collected on purple prism traps in 2011 (A) and 2012 (B) in Minnesota. Species followed with the same letter do not differ (α = 0.05) based on logistic regression with Tukey-Kramer-adjusted pairwise comparisons. Asterisks (*) indicate that a species was not detected. X-axes of graphs A and B are on different scales.

purple prism traps were checked to obtain a reasonable estimate of species richness (Fig. 2). Furthermore, the overlapping 95% confidence intervals of the rarefaction curves indicate that a similar number of species was collected between years (Fig. 2).

In 2011, 658 specimens comprising 14 species across 9 genera were collected from purple prism traps (0.15 specimens per trap/year). The relative abundance differed significantly among species ($\chi^2 = 1324.2$, df = 16, $P < 0.001$) with *B. calva* (34.19%) and *B. dimidiata* (24.47%) having the highest relative abundance, followed by *C. hilaris* (16.72%), and *E. tristigmus luridus* (14.89%) (Fig. 3A). Prevalence (i.e., frequency of detection) also differed significantly among species in 2011 ($\chi^2 = 1053.2$, df = 16, $P < 0.001$). *Banasa dimidiata*, *B. calva*, *C. hilaris* and *E. tristigmus luridus* were the most prevalent species, found in 2.90, 2.80, 2.10 and 1.90% of the traps, respectively (Fig. 4A). In 2012, 5,719 specimens comprising 14 species across 8 genera were collected from purple prism traps (1.01 specimens per trap/year). The relative abundance differed significantly among species ($\chi^2 = 4014.0$, df = 16, $P < 0.001$) with *M. insertus* (34.20%) having the highest relative abundance, followed by *P. maculiventris* (33.73%), *E. tristigmus luridus* (10.42%), *B. calva* (8.73%), and *B. dimidiata* (4.56%) (Fig. 3B). Prevalence (i.e., frequency of detection) also differed significantly among species in 2012 ($\chi^2 = 3204.3$, df = 16, $P < 0.001$). *Euschistus tristigmus luridus* was the most prevalent species, found in 10.10% of the traps (Fig. 4B). Due to differences in trap allocation throughout the state (Fig. 1), comparison of abundance, relative abundance and prevalence between years was not performed.

The most commonly collected species mentioned above have biologies associated with the types of deciduous habitats in which the purple traps were deployed. *Banasa calva* is commonly found on herbaceous plants and deciduous trees and *B. dimidiata* on ornamental plants and small fruits (McPherson 1982). *Menecles insertus* is an arboreal species that feeds on a wide variety of deciduous trees, such as hickory, beech, hackberry and maple (McPherson 1982). Because of its apparent lack of economic importance, little is known about *M. insertus* biology and behavior. *Chinavia hilaris* can be found on a wide variety of wild hosts and cultivated plants including fruits, vegetables and grain crops. However, it has preference for feeding on woody plants (McPherson 1982, Kamminga et al. 2012). *Euschistus tristigmus luridus* feeds on a variety of deciduous trees and herbaceous and cultivated plants (McPherson 1982). *Podisus maculiventris* is the most common predatory stink bug in the U.S. (De Clercq 2000). These predators have a broad host range, reportedly attacking ninety insect species from over eight orders, including several economically important pests (De Clercq 2000).

The community of Pentatomidae observed on purple prism traps deployed in arboreal habitats in this study differed considerably from pentatomid communities reported in Minnesota crops, such as soybean (Koch et al. 2014, Koch and Pahs 2014), wheat (Koch et al. 2016) and corn (Koch and Pahs 2015). For example, the one-spotted stink bug, *E. variolarius*, and the brown stink bug, *E. servus euschistoides*, are the most abundant phytophagous pentatomid species reported in crops in Minnesota, with relative abundances of approximately 60% and 20%, respectively (Koch et al. 2014; Koch and Pahs 2014, 2015; Koch et al. 2016). However, *E. variolarius* and *E. servus euschistoides* relative abundances were only 0.08% and 0.02% on purple prism traps deployed in Minnesota (Fig. 3). The most abundant species of herbivorous pentatomidae (i.e., *B. calva* and *M. insertus*) captured on purple prism traps in arboreal habitats were uncommonly encountered in Minnesota crops (Koch and Pahs 2014, 2015; Koch et al. 2016; Koch et al. 2017). These differences in the pentatomid communities documented for the arboreal and crop habitats are likely driven by species-specific host preferences and behaviors that may influence likelihood of detection via the different survey methods.

Results presented in this study show that observation of bycatch from purple prism traps deployed for detection of *A. plannipenis* can provide additional information about the community of Pentatomidae in arboreal habitats. However, it remains unknown whether any of these pentatomids were attracted to the traps, or if their capture was result of random interception with the traps. Therefore, traditional surveillance or scouting for pentatomids of interest should continue to be implemented. The results presented here provide further evidence that bycatch from large coordinated pest surveys is an available and useful resource for entomologists.

Acknowledgments

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