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SHORT COMMUNICATION

Comparison of Buprestidae collected by *Cerceris fumipennis* (Hymenoptera: Crabronidae) with those collected by purple prism traps

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Abstract

1 Detection of low-level infestations of pest Buprestidae such as emerald ash borer is crucial for their effective management, but the efficiency of trapping techniques varies. In the present study, we compare two nondestructive methods for monitoring metallic wood-boring beetles.

2 Buprestidae captured by the wasp *Cerceris fumipennis* Say (Hymenoptera: Crabronidae) were compared with those captured by USDA-APHIS-PPQ standard issue purple prism traps (PPTs) at three sites in North Carolina, U.S.A. At each site, four PPTs were hung on trees at the edge of a known *C. fumipennis* nest aggregation, and changed at 5.5–7.0-week intervals. Buprestids were collected from hunting wasps once a week during their 5–6-week activity period.

3 A total of 28 buprestids (seven species) were caught by traps, whereas 267 buprestids (35 species) were collected from *C. fumipennis*. Of buprestids captured by PPTs, 22 were caught during the pre-flight period of *C. fumipennis*, six during their flight period and none during the post-flight period. One species of *Agrilus* Curtis was captured by PPTs, while six *Agrilus* species were captured by wasps. Of the 38 identified buprestid species taken at these sites, only four were recovered at a given location by both methods.

4 Although a standardized comparison of the two techniques is not feasible, *C. fumipennis* captured a greater number and diversity of Buprestidae than did PPTs. A combination of both techniques may provide the most complete temporal coverage of buprestid activity in a given area, provided that a nesting aggregation of *C. fumipennis* is available.

Keywords Biosurveillance, emerald ash borer, forest health, pest detection, solitary wasp.

Introduction

Early detection and delimitation of low level infestations of buprestid pests such as emerald ash borer [*Agrilus planipennis* Fairmaire (EAB)] is crucial for their efficient management, but the effectiveness of current techniques varies (Marshall *et al.*, 2010; Mercader *et al.*, 2013). Among the nondestructive methods currently employed are purple prism traps (PPTs) baited with plant volatiles, and the use of the solitary, ground-nesting buprestid hunting wasp *Cerceris fumipennis* Say (Hymenoptera: Crabronidae). The PPTs are three-sided, plastic, prism-shaped traps (each side $36 \times 60\,cm^2$) of purple corrugated plastic (Francese *et al.*, 2010). The outer surfaces of the trap are

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Table 1 Placement of four purple prism traps at the edge of woods surrounding a softball diamond harboring *Cerceris fumipennis* nests at three sites

Site	Tree species (common name), trap height (m) and distance (m) from pitcher's mound			
	Trap 1	Trap 2	Trap 3	Trap 4
1	*Liquidambar styraciflua* (sweet gum), height 6.1; distance 54.7	*Liquidambar styraciflua* (sweet gum), height 6.1; distance 116.7	*Melia azedarach* (chinaberry), height 4.6; distance 121.3	*Acer rubrum* (red maple), height 4.6; distance 169.6
2	*Betula nigra* (river birch), height 5.5; distance 103.2	*Pinus taeda* (loblolly pine), height 4.6; distance 104.3	*Pinus taeda* (loblolly pine), height 6.1; distance 91.1	*Quercus nigra* (water oak), height 4.6; distance 135.6
3	*Platanus occidentalis* (American sycamore), height 4.6; distance 87.0	*Melia azedarach* (chinaberry), height 4.0; distance 154.1	*Liriodendron tulipifera* (tulip poplar), height 6.7; distance 288.9	*Liquidambar styraciflua* (sweet gum), height 6.1; distance 227.9

coated with insect glue, lures [manuka oil and (Z)-3-hexenol] are hung in the central space and the assemblage is then suspended in a tree canopy. These traps are being used for the detection of EAB in a massive ongoing cooperative monitoring effort between the USDA and state agencies (USDA, 2014). Although there has been more than a decade of research devoted to trap designs for EAB, it is not known how well these techniques apply to other buprestid species considered threats, such as the oak pests *Agrilus sulcicollis* Lacordaire and *Agrilus biguttatus* Fabricius (Domingue *et al*., 2013). The colour of the PPTs and the plant extract lures were developed primarily to capture EAB, although the traps, as well as variations on their design, are considered general monitoring tools because they attract a variety of buprestids, particularly in the genus *Agrilus* (Oliver *et al*., 2002; Lelito *et al*., 2008; Skvarla & Holland, 2011; Domingue *et al*., 2013; Petrice *et al*., 2013). The lures used in these traps are general attractants (Crook *et al*., 2012), not pheromones, and are expected to draw a variety of buprestids.

The second nondestructive method for detecting pest Buprestidae is the novel technique of exploiting the natural hunting behaviour of the solitary wasp *C. fumipennis*. The system was first developed in Canada (Marshall *et al*., 2005; Careless *et al*., 2014) and has subsequently proven to be an effective biosurveillance tool for monitoring both native and invasive species of Buprestidae across eastern North America (Swink *et al*., 2013, 2014; Careless *et al*., 2014). The first reports of *Agrilus subrobustus* Saunders in North Carolina (Swink *et al.*, 2015) and EAB in Connecticut (Rutledge *et al*., 2013) are the result of prey beetles brought back to *C. fumipennis* nesting aggregations.

These two methods allow for an interesting comparison because they rely on very different mechanisms for the collection of Buprestidae. The PPTs rely on the behaviour of the beetles (i.e. their visual attraction to the trap and their olfactory response to plant volatiles). The *C. fumipennis* biosurveillance system, on the other hand, relies on the hunting behaviour of the wasp and the vigilance of field personnel in monitoring their nests. The present study aims to compare PPTs and *C. fumipennis* with respect to detecting buprestid diversity at a given site. Because *C. fumipennis* has a relatively short active period, we were particularly interested in identifying the buprestid species that may be attracted to PPTs outside the time frame of wasp activity. The specific goals were (i) to compare the number and diversity of Buprestidae captured using each method and (ii) to determine which buprestid species could be collected on traps prior to *C. fumipennis* activity, during the wasp flight period, and after *C. fumipennis* activity ceases.

Materials and methods

The present study was conducted on softball diamonds (Nalepa *et al*., 2012) at three locations in North Carolina; nesting aggregations of *C. fumipennis* were present at each location in previous years. Sites 1 and 2 were in the inner coastal plain (Wayne Co.). Site 1 was a private school in Goldsboro (35.397°N, 78.013°W); 68–154 *C. fumipennis* nests were present on the field during the study. Site 2 was a community college in Goldsboro (35.401°N, 78.943°W); 25–80 nests were active. Site 3 was in the mountains, a middle school in Mt Airy (Surry Co.) (36.481°N, 80.652°W), with 50–109 active wasp nests. Variations in nest number within a site reflect seasonal changes in wasp activity, wasp interactions, patterns of precipitation and stochastic factors (e.g. use or maintenance of the softball field).

The traps used were standard PPTs issued by USDA Animal and Plant Health Inspection Service (USDA, 2014). At each of the three study sites, four PPTs baited with (Z)-3-hexenol and manuka oil lures were arrayed along the edge of a woodlot surrounding a softball field predicted to harbour a *C. fumipennis* nesting aggregation (traps were hung prior to wasp emergence). The traps were hung on open accessible branches of a variety of host tree species, at a height of 3.0–7.6 m and within 300 m of the pitcher's mound on the softball field (Table 1). Each PPT was placed between 38 and 325 m from an adjacent trap. Study sites were chosen based on the probability that they would harbour a *C. fumipennis* nesting aggregation and not on the composition of the surrounding forest.

The prism traps were hung in April, with the timing shifted in accordance with site location and associated climatic differences (Table 2). The first set of traps and lures was changed when wasps at the site became active; the second set was changed when wasp foraging activity had ceased; and the third set was taken down 5 weeks later, resulting in three collections from four traps at each of the three sites ($n = 36$ traps). This schedule allowed for a comparison of the two techniques during the wasp flight period, as well as the determination of buprestids caught by PPTs prior to and after the *C. fumipennis* activity period.

Buprestid prey were collected from hunting *C. fumipennis* on the softball fields once a week during the wasp active period using methods described previously (Careless, 2009; Swink

Table 2 Timing of the study in three North Carolina sites during 2012

Site	Traps Hung	Traps Changed (Collection 1)	Traps Changed (Collection 2)	Traps Removed (Collection 3)
#1	9Apr12	17May12	25Jun12	8Jul12
#2	9Apr12	17May12	25Jun12	8Jul12
#3	11Apr12	31May12	9Jul12	21Aug12
Cerceris fumipennis	Pre-flight period	Flight period	Post-flight period	

Table 3 Number of Buprestidae collected using the two techniques at each of three sites

	Buprestidae from *Cerceris*		Buprestidae on PPTs	
Site	Number of beetles	Number of species [(a)]	Number of beetles	Number of species [(b)]
1	71	20 (17)	20	4 (1)
2	45	13 (11)	7	5 (3)
3	151	24 (24)	1	1 (1)
Total	267		28	

[a]Number of buprestid species collected by *C. fumipennis* but not purple prism traps (PPTs) at given site.
[b]Number of buprestid species collected by PPTs but not *C. fumipennis* at given site.

et al., 2013; Careless *et al*., 2014). Nest sites were monitored by one individual from 09.00 to 14.00 h on 6 days in Sites 1 and 2 (= 30 h of surveillance per site) and 5 days in Site 3 (= 25 h of surveillance). The exact day of biosurveillance within the week was weather dependent. The collected buprestids were frozen until pinned and labelled. Purple prism traps taken from a site were covered in waxed paper and refrigerated until attached Buprestidae were removed. Buprestid species were identified by two of the study investigators (WGS and JPB). Plant hosts of the collected Buprestidae are from Nelson *et al*. (2008), Paiero *et al*. (2012) and Harpootlian and Bellamy (2014). The present study was conducted prior to the documented arrival of *A. planipennis* in North Carolina; consequently, neither surveillance system tested was expected to capture EAB.

Results

Buprestidae on PPTs

A pooled total of 28 buprestids in seven species was caught by PPTs during the present study: *Acmaeodera tubulus* (F.) ($n=6$), *Agrilus bilineatus* (Weber) ($n=1$), *Anthaxia quercata* (F.) ($n=2$), *Chrysobothris chlorocephala* Gory ($n=1$), *Chrysobothris chrysoela* (Illiger) ($n=5$), *Chrysobothris quadriimpressa* Gory & Laporte ($n=9$) and *Chrysobothris shawnee* Wellso & Manley ($n=4$).

The largest number of a single species captured on PPTs was nine *C. quadriimpressa*; eight were collected from a trap on sweet gum, a known plant host of this buprestid. An additional specimen of *C. quadriimpressa* was taken from a PPT on a tree not known as a host: river birch. The remaining six buprestid species were collected from traps on trees not listed as their plant host. Overall, there was little overlap between the plant host on which the PPT was hung and the listed plant host of the captured buprestid. Although these results may be related to the completeness of published host lists, they also may indicate that buprestid species in transit between hosts are attracted to PPTs.

Of the 28 buprestids caught by PPTs, 22 specimens were caught during the pre-flight period of *C. fumipennis* and six during the flight period; none were caught during the post-flight period of the wasp. At the species level, four buprestid species were caught during the pre-flight period only (*Ac. tubulus*, *Ag. bilineatus*, *An. quercata* and *C. chrysoela*), and two were caught during the wasp flight period only (*C. chlorocephala* and *C. shawnee*). One species was caught during both pre-flight and flight periods (*C. quadriimpressa*). It is notable that 79% of the beetles caught by traps were taken during the wasp pre-flight period.

Buprestidae captured by *Cerceris fumipennis* and comparison with PPTs

A total of 267 buprestids was collected from *C. fumipennis* at the three study sites. As in collections from previous years (Swink *et al*., 2013), the genus most often collected was *Buprestis* L. (44.4%). This was followed by *Chrysobothris* Eschscholtz (27.2%), *Actenodes* Dejean (11.9%) and *Dicerca* Eschscholtz (7.8%). The genus *Agrilus* Curtis comprised 3.7% of the collection; the remaining 5.0% was a mixture of *Acmaeodera* Eschscholtz, *Brachys* Dejean, *Eupristocercus* Deyrolle, *Phaenops* Dejean and *Poecilonota* Eschscholtz.

There was little overlap in the identity of buprestid species collected by the two surveillance techniques at a given site (Table 3). Overall, just one buprestid species captured on PPTs was not captured by *C. fumipennis*: two *An. quercata* taken from a trap hung on water oak at Site 2 during the pre-flight period. A compilation of all records of Buprestidae collected in North Carolina indicate that *An. quercata* is active during the *C. fumipennis* flight period (Klingeman *et al*., 2015); nonetheless, this species is not yet recorded as *C. fumipennis* prey in the state (Swink *et al*., 2013).

A total of 35 species were captured by *C. fumipennis* at the study sites (Table 4). Three specimens were identified as being in the *Chrysobothis femorata* complex, and three beetles in the genus *Actenodes* could not be identified to the species level because of antennal loss. In sum, *C. fumipennis* recovered almost one order of magnitude more beetles and five times as many species at the three study sites.

Just one *Agrilus* (*Ag. bilineatus*) was captured by the PPTs at these sites during the present study; *C. fumipennis*, on the other hand, brought back 10 specimens of *Agrilus*, representing six species (Table 4). No species of the large bodied buprestid genera *Buprestis* and *Dicerca* were captured on traps, although these made up 52.2% of the catch from *C. fumipennis*. Of the 35 buprestid species taken at the sites, just four were recovered at a given location by both methods (Table 4): *Ac. tubulus* at Site 1; *C. chrysoela* at Site 2; *C. quadriimpressa* at Sites 1 and 2; and *C. shawnee* at Site 1.

Table 4 Species of Buprestidae collected by *Cerceris fumipennis* and purple prism traps at three North Carolina sites during 2012

Species	Site	Number from *Cerceris*	Number on trap	Trap host	Trapping period
Acmaeodera tubulus (F.)	1	3	6	Sweet gum	Pre-flight
	2	1	–		
Actenodes acornis (Say)	1	4	–		
	2	3	–		
	3	12	–		
Actenodes simi Fisher	3	10	–		
Actenodes sp. Dejean[a]	3	3	–		
Agrilus anxius Gory	3	1	–		
Agrilus bilineatus (Weber)	2	–	1	Loblolly pine	Pre-flight
Agrilus lecontei Saunders	1	1	–		
Agrilus politus (Say)	3	1	–		
Agrilus quadriguttatus quadriguttatus Gory	1	1	–		
Agrilus quadriimpressus Ziegler	1	1	–		
Agrilus ruficollis (F.)	1	2	–		
	3	3	–		
Anthaxia quercata (F.)	2	–	2	Water oak	Pre-flight
Brachys ovatus (Weber)	1	1	–		
Buprestis consularis Gory	1	1	–		
	2	2	–		
Buprestis lineata F.	1	8	–		
	2	1	–		
	3	10	–		
Buprestis maculipennis Gory	1	15	–		
	2	16	–		
	3	37	–		
Buprestis rufipes Olivier	1	7	–		
	2	6	–		
Buprestis striata F.	3	16	–		
Chrysobothris adelpha Harold	3	4	–		
Chrysobothris azurea LeConte	3	1	–		
Chrysobothris chlorocephala Gory	3	–	1	Sweet gum	Flight
Chrysobothris chrysoela (Illiger)	1	–	4	Red maple	Pre-flight
	2	1	1	Water oak	Pre-flight
Chrysobothris cribraria Mannerheim	1	2	–		
	3	6	–		
Chrysobothris dentipes (Germar)	2	1	–		
	3	2	–		
Chrysobothris femorata (Olivier)	3	2	–		
Chrysobothris femorata complex[a]	1	1	–		
	3	2	–		
Chrysobothris pusilla Gory & Laporte	1	1	–		
Chrysobothris quadriimpressa Gory & Laporte	1	3	8	Sweet gum	Pre-flight
	2	4	1	River birch	Flight
	3	12	–		
Chrysobothris rotundicollis Gory & Laporte	3	6	–		
Chrysobothris rugosiceps Melsheimer	1	1	–		
	3	4	–		
Chrysobothris sexsignata Say	3	2	–		
Chrysobothris shawnee Wellso & Manley	1	9	1	Sweet gum	Flight
			1	Chinaberry	Flight
	2	–	2	River birch	Flight
	3	4	–		
Chrysobothris viridiceps Melsheimer	1	4	–		
	3	1	–		
Dicerca lurida (F.)	1	5	–		
	2	4	–		
	3	5	–		
Dicerca punctulata (Schönherr)	3	2	–		
Dicerca spreta (Gory)	2	1	–		
Dicerca tenebrosa knulli Nelson	2	1	–		
	3	3	–		
Eupristocerus cogitans (Weber)	3	1	–		
Phaenops aeneola (Melsheimer)	1	1	–		
	2	4	–		
Poecilonota thureura (Say)	3	1	–		

[a]Not included in the total species count of 35.
Species recovered by both methods at a given site are highlighted.

Discussion

Although standardized comparisons of the two methods cannot be made, *C. fumipennis* wasps captured a greater number and variety of buprestids than did the traps at each site in the present study. At Site 3, 151 beetles were collected from wasps, but only one was recovered from the PPTs. The large number of *C. fumipennis* nests present at this site is evidence suggesting that numerous buprestids were locally available to sustain such a large wasp population, but the PPTs were unsuccessful in capturing them. *Cerceris fumipennis* is suggested to hunt primarily within a 200-m radius of their nest site (Nalepa *et al*., 2013), but the sphere of attraction by PPTs is unknown. Given that a sizable, active aggregation of *C. fumipennis* is available, the wasps can supply a more complete snapshot of buprestid diversity in any given area. Similar conclusions were reached by Looney *et al.* (2014), who compared Buprestidae captured by PPTs with those captured by *Cerceris californica* Cresson in Washington state.

Beetles taken by the wasps skewed toward the larger buprestid species, although *C. fumipennis* also collected more of the relatively small-bodied and economically important genus *Agrilus*. Purple prism traps are considered to be attractive to *Agrilus* (Skvarla & Holland, 2011), but that was not the case in the present study. A weak performance by PPTs was also documented by Teerling (2010), who reported no buprestids on 26 PPTs set in southern and central Maine in 2009, and by Mercader *et al*. (2013), who reported that PPTs can be unsuccessful at attracting EABs even when the beetles are present at moderately high levels. It should be noted that, at a given site, PPTs succeeded in capturing one to three buprestid species not taken by *C. fumipennis* (Table 3); however, *C. fumipennis* succeeded in capturing up to 24 species not represented on traps.

Despite the exceptional performance of *C. fumipennis* in the present study, there are constraints associated with the use of these wasps as a biosurveillance system. Nesting aggregations are easier to find in some regions than in others (Nalepa *et al*., 2012) and the hunt for beetle prey occurs within a limited time frame: the wasps are active for 5 or 6 weeks after their emergence (Careless *et al*., 2014). Season to season wasp nesting behaviour and within season flight behaviour can be unpredictable; this is problematic if substantial travel is required to conduct biosurveillance at a given site. The daily hunting success of *C. fumipennis* is sensitive to weather conditions and varies both with individual wasps and with nest ontogeny (Careless *et al*., 2014; C. A. Nalepa and W. G. Swink, unpublished data).

The buprestids on PPTs in the present study were captured primarily during the pre-flight period of the wasp; the flight period of *C. fumipennis* nonetheless overlaps with the activity period of most buprestids recorded in North Carolina (Klingeman *et al.*, 2015). PPTs hung early in the season combined with biosurveillance by the wasp may provide comprehensive temporal coverage of buprestid activity. Detection of pest buprestids at low densities is one of the biggest challenges for their successful management, and the employment of multiple techniques may provide the best solution (Marshall *et al*., 2010; McCullough *et al*., 2011).

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