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Buprestidae Collected as Prey by the Solitary, Ground-Nesting Philanthine Wasp *Cerceris fumipennis* (Hymenoptera: Crabronidae) in North Carolina

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ABSTRACT The solitary, ground-nesting crabronid wasp *Cerceris fumipennis* Say excels at detecting buprestid diversity in a given geographic area, and after the introduction of the invasive pest emerald ash borer (*Agrilus planipennis* Fairmaire) to the United States in 2002, has been developed as an effective tool for the biosurveillance of pest Buprestidae in eastern North America. Here we report records of Buprestidae collected from foraging *C. fumipennis* in 13 North Carolina counties over the course of three seasons (2009–2011). Nests of the wasp were located, and beetle prey collected from foraging females in three geographic regions, with a concentration on the western, mountainous area of the state. In total, 909 beetles were collected, comprising 52 buprestid species that included eight native pests and 17 species of *Agrilus*. Our results emphasize the utility of *C. fumipennis* in documenting buprestid biodiversity and in detecting forest pests. Eight new state records and five new prey records for the wasp are here recorded.

KEY WORDS *Agrilus*, foraging, biosurveillance, emerald ash borer, Hymenoptera

The ground-nesting, solitary wasp *Cerceris fumipennis* Say preys almost exclusively on adult wood-boring beetles of the family Buprestidae. This foraging behavior is the basis for its current development as a biosurveillance tool for the efficient detection of pest buprestid beetles, including emerald ash borer *Agrilus planipennis* Fairmaire, in Canada and several locations in the eastern United States (Marshall et al. 2005, Careless 2009, Careless et al. 2009, Careless and Marshall 2010). Recently, an emerald ash borer captured by *C. fumipennis* was the first record of that invasive pest in the state of Connecticut (Stafford and Rutledge 2012). The wasp also excels at documenting biodiversity of Buprestidae in a given region. For example, in a short study in an Ontario park, *C. fumipennis* collected 12 buprestid species in five genera, three of which were new species records for Canada (Marshall et al. 2005).

The goal of the current study was to begin documenting the diversity of Buprestidae detected by *C. fumipennis* in North Carolina (NC) before the establishment of emerald ash borer in the state. Here we report the results of prey collections from *C. fumipennis* in 13 NC counties over the course of three field seasons, from 2009 to 2011.

Materials and Methods

C. fumipennis prefers to nest in hard-packed, sandy soil in sunny areas that have some degree of human activity (Evans 1971, Careless 2009, Careless et al. 2009); these features are characteristic of baseball and softball diamonds. Ball diamonds were located using Google Earth 5 and surveyed for nests of the wasp using techniques discussed in Nalepa et al. (2012). Those fields that supported ≥ 15 *C. fumipennis* nests were revisited to collect beetle prey from foraging females. Permission to work on specific fields was obtained from relevant schools or directors of Parks and Recreation.

Four techniques developed by Marshall et al. (2005) and Careless (2009) were used to collect beetle prey from *C. fumipennis*. First, foraging females returning to the nest with prey were captured with a sweep net, her prey collected, and the wasp set free. Second, a wasp encumbered by prey can be somewhat sluggish when flying to the nest, and will drop her cargo if tapped gently with the fingers. Third, “Careless Collars” (Careless et al. 2009, Figs. 11–12) were placed over the nest entrance. These collars are 2.5×7.5 cm thin plastic strips, with a hole punched near the margin of each end using a standard office hole punch. A golf tee is driven through one hole to anchor the collar to the ground, and the other hole is positioned over the nest entrance. The hole is large enough to allow a female to exit her nest, but prevents or delays her reentry while carrying prey; beetles are removed from the wasps as they struggle to reenter nests after foraging trips. Fourth, at our initial arrival at a nesting site we opportunistically collected discarded prey.

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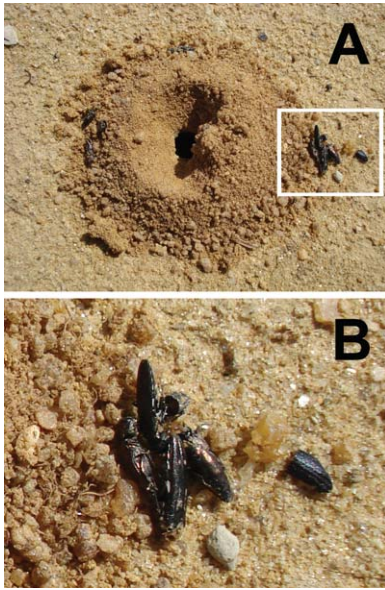


Fig. 1. (A) Nest of *Cerceris fumipennis* with 10 discarded buprestids in and around the tumulus; the box highlights five of these. (B) Detail of beetles. (Online figure in color.)

These discards are common (e.g., Grossbeck 1912), and are thought to occur when females are fatigued, when males attempt to mate with a female returning from a foraging trip (S.M.P., unpublished data), or when a nest is usurped by a conspecific (Evans 2000, Rosenheim 1987). In the latter case, beetles collected and stored by the original owner are intentionally or accidentally removed from the nest as the new female becomes established (Field 1992; A. Hook, personal communication). Nest usurpation is widespread in *C. fumipennis* (Careless 2009). We were able to collect up to 10 discarded beetles at a single nest (Fig. 1).

NC is typically divided into three geographical regions: Mountains, Piedmont, and Coastal Plain. Bee-

tles were collected 2009–2011 from *C. fumipennis* during their active season in 13 counties representing each of these regions (Fig. 2). In 2009 we began collecting locally from nesting sites in Wake Co., and in 2010 began expanding the survey east and west. In 2011 we concentrated our efforts in the western, mountainous part of the state (10 counties) because of the recent discovery of emerald ash borer in several Tennessee counties adjacent to the western border of NC (updated maps available at <http://www.emeraldashborer.info/map.cfm>).

Prey beetles were frozen until pinned and labeled, then identified by W. G. Swink and S. M. Paiero. David Stephan (NC State University) identified or confirmed several species for us, and specimens in the genera *Chrysobothris* and *Agilus* were sent to Joshua P. Basham (Tennessee State University) for identification or confirmation. Beetles have been deposited in the NC State University Insect Museum (Raleigh, NC), the University of Guelph Insect Collection (Guelph, Ontario, Canada), and in the collection of the NC Department of Agriculture Beneficial Insects Laboratory (Cary, NC).

Results and Discussion

In total, 909 beetles representing 11 genera and 52 species of Buprestidae were collected from *C. fumipennis* in NC between 2009 and 2011: 222 beetles from the Piedmont region of the state, 237 from the Coastal Plain, and 450 from the Mountains. Thirteen species of buprestid beetle were taken as prey in 2009, 24 species in 2010, and 45 species in 2011; these numbers reflect both increased survey and collecting efforts and a wider geographic range of collection sites each year. Variation in the number of *C. fumipennis* nests, tree diversity in the vicinity of nests, foraging behavior of the wasps, human activity at the nesting site (i.e., ball games), and the number and timing of our collection visits were all factors that influenced the number and variety of collected prey, and also hindered the use of

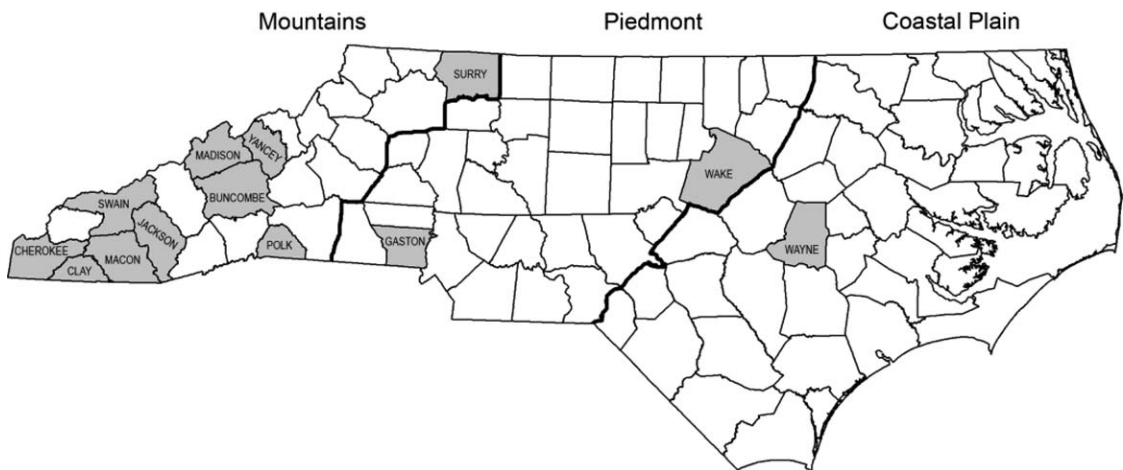


Fig. 2. Map of North Carolina divided into major geographic regions; buprestid beetles were collected from foraging *Cerceris fumipennis* females in the 13 highlighted counties 2009–2011.

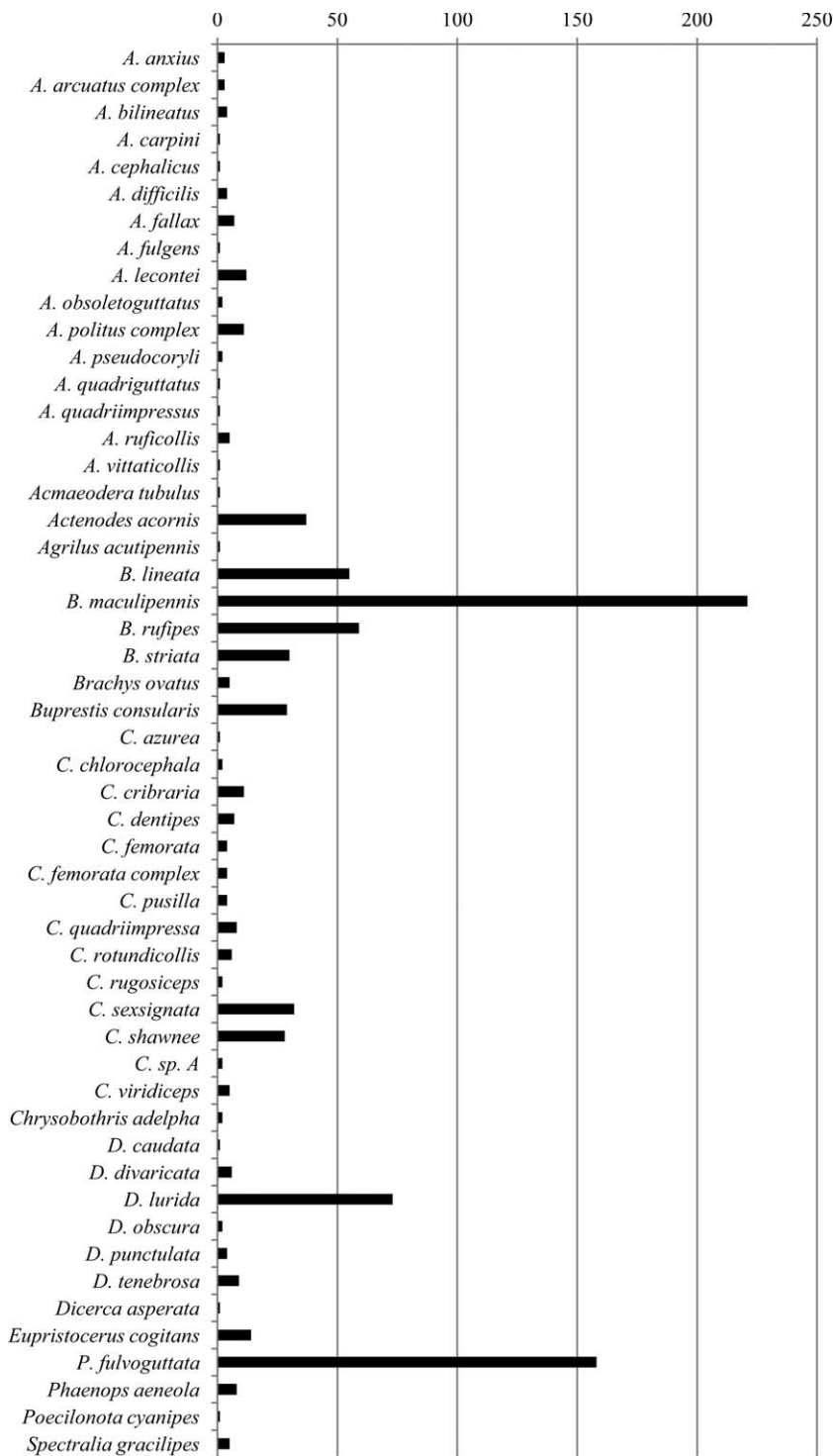


Fig. 3. The number of buprestid beetle species collected by *Cerceris fumipennis* 2009–2011.

standard diversity indices. The genus most frequently collected was *Buprestis* and the species most frequently collected was *Buprestis maculipennis* Gory (Fig. 3). *Buprestis lineata* F., *B. maculipennis*, and *B.*

striata F. were the most widespread species, with each taken from 12 different locations spread across the three sampled geographic regions (Table 1). The second most frequently collected buprestid was *Phaenops*

Table 1. Buprestidae collected by *Cerceris fumipennis* in North Carolina by geographic region

Species	C	P	M	Species (cont.)	C	P	M
<i>Acmaeodera tubulus</i>	✓			<i>C. azurea</i>			✓
<i>Actenodes acornis</i>	✓	✓	✓	<i>C. chlorocephala</i>	✓	✓	✓
<i>Agrilus acutipennis</i>		✓		<i>C. cribraria</i>	✓	✓	✓
<i>A. anxius</i>			✓	<i>C. dentipes</i>			✓
<i>A. bilineatus</i>			✓	<i>C. femorata</i>		✓	✓
<i>A. carpini</i>		✓		<i>C. femorata complex</i>	✓	✓	✓
<i>A. cephalicus</i>		✓		<i>C. sp. A</i>		✓	✓
<i>A. arcuatus complex</i>		✓	✓	<i>C. pusilla</i>	✓	✓	✓
<i>A. difficilis</i>		✓	✓	<i>C. quadriimpressa</i>	✓	✓	✓
<i>A. fallax</i>	✓		✓	<i>C. rotundicollis</i>	✓	✓	✓
<i>A. fulgens</i>		✓	✓	<i>C. rugosiceps</i>			✓
<i>A. lecontei</i>	✓	✓		<i>C. sexsignata</i>	✓	✓	✓
<i>A. obsoletoguttatus</i>	✓			<i>C. shawnee</i>	✓	✓	✓
<i>A. politus complex</i>	✓		✓	<i>C. viridiceps</i>		✓	✓
<i>A. pseudocoryli</i>			✓	<i>Dicerca asperata</i>	✓		
<i>A. quadriguttatus</i>	✓			<i>D. caudata</i>			✓
<i>A. quadriimpressus</i>		✓		<i>D. divaricata</i>			✓
<i>A. ruficollis</i>	✓			<i>D. lurida</i>	✓	✓	✓
<i>A. vittaticollis</i>			✓	<i>D. obscura</i>			✓
<i>Brachys ovatus</i>	✓	✓	✓	<i>D. punctulata</i>			✓
<i>Buprestis consularis</i>	✓	✓	✓	<i>D. tenebrosa</i>			✓
<i>B. lineata</i>	✓	✓	✓	<i>Eupristocerus cogitans</i>		✓	✓
<i>B. maculipennis</i>	✓	✓	✓	<i>Phaenops aeneola</i>	✓	✓	✓
<i>B. rufipes</i>	✓	✓	✓	<i>P. fulvoguttata</i>			✓
<i>B. striata</i>	✓	✓	✓	<i>Poecilnota cyanipes</i>			✓
<i>Chrysobothris adelpha</i>			✓	<i>Spectralia gracillipes</i>			✓

C = Coastal Plains; P = Piedmont; M = Mountains; see Fig. 2.

fulvoguttata (Harris), followed by *Dicerca lurida* (F.) (Fig. 3). Of the species collected, 17 were collected only in the Mountains, 4 were collected only in the Piedmont, and 6 were collected only in the Coastal Plain (Table 1). Species richness was highest at one site in Wayne Co. where 23 different buprestids were collected (Table 2); this likely reflects both plant diversity of the adjacent forest and the frequency of our collecting trips to this site. The least diverse sites were those where just one prey species was collected. In these sites, however, ≤ 5 total beetles were collected, typically as discards (Fig. 1). Twelve species were represented by a single specimen (*Acmaeodera tubulus* (F.), *Agrilus acutipennis* Mannerheim, *A. carpini* Knull, *A. cephalicus* LeConte, *A. fulgens* LeConte, *A. quadriguttatus* Gory, *A. quadriimpressus* Ziegler, *A. vittaticollis* (Randall), *Chrysobothris azurea* LeConte, *Dicerca asperata* (Laporte & Gory), *D. caudata* LeConte, and *Poecilnota cyanipes* (Say)). Five species of Buprestidae collected by *C. fumipennis* are new prey records for the wasp (*Acmaeodera tubulus*, *Agrilus acutipennis*, *A. difficilis* Gory, *A. lecontei* Saunders, and *A. quadriimpressus*) (Careless 2009; S.M.P., unpublished data). Six *Neochlamisus* sp. Karren (*Chrysomelidae*), a known alternative prey of *C. fumipennis* (Scullen and Wold 1969, Young 1976, Rutledge et al. 2011), were collected in one site in Polk Co. in mid-July of 2011.

New State Records. Of the 52 species of Buprestidae collected in NC from *C. fumipennis*, eight were apparently new records for the state, based on Nelson et al. (2008): *Agrilus anxius* Gory, *A. fulgens*, *A. lecontei*, *A. pseudocoryli* Fisher, *A. quadriimpressus*, *Buprestis consularis* Gory, *Chrysobothris azurea*, and *Poecilnota cyanipes*. However, an examination of specimens in the NC State University Insect Museum indicates that three of these

Table 2. Number of Buprestidae specimens and species collected at sites across North Carolina from 2009 to 2011

County	Coordinates	Total beetles collected	No. beetle species
Buncombe	35.577° N, 82.600° W	83	14
Buncombe	35.564° N, 82.513° W	5	1
Cherokee	35.093° N, 84.026° W	53	16
Cherokee	35.104° N, 84.222° W	5	4
Cherokee	35.202° N, 83.833° W	10	3
Clay	35.045° N, 83.813° W	17	11
Gaston	35.281° N, 81.192° W	2	1
Gaston	35.344° N, 81.337° W	5	4
Gaston	35.286° N, 81.224° W	5	3
Jackson	35.295° N, 83.182° W	6	2
Macon	35.164° N, 83.432° W	1	1
Macon	35.157° N, 83.391° W	5	3
Macon	35.161° N, 83.359° W	1	1
Madison	35.796° N, 82.688° W	1	1
Polk	35.295° N, 82.172° W	51	15
Surry	36.481° N, 80.652° W	67	19
Swain	35.434° N, 83.441° W	66	7
Wake	35.796° N, 78.615° W	2	2
Wake	35.801° N, 78.689° W	2	1
Wake	35.799° N, 78.644° W	102	17
Wake	35.889° N, 78.698° W	86	12
Wake	35.907° N, 78.668° W	18	6
Wayne	35.402° N, 77.942° W	121	14
Wayne	35.399° N, 78.012° W	116	23
Yancey	35.910° N, 82.332° W	79	13

had been previously collected in NC but not reported: *A. anxius* from a dead birch twig in Wake Co. on 26 May 1973, *B. consularis* (identified as *B. nutalli* Kirby) collected 25 May 1919 in Raleigh, Wake Co., and *C. azurea* collected 2 May 1952 in Roper, WA Co. from a fire-scorched cherry tree. Additional specimens of *C. azurea* collected in NC have since been identified from the NC State University Insect Museum by Joshua Basham, reported as follows: *Chrysobothris azurea* LeConte 1857: Moore Co., Southern Pines, 6.v.1901 (1), F. Sherman Jr.; Moore Co., Aberdeen, 28.v.1928 (1), J.A. Harris; Wake Co., Raleigh, 1.v.193? (1); 19.v.1940 (1); Craven Co., New Bern, 11.v.1958 (1); Cary, 26.v.1935 (1). Most new state records detected by *C. fumipennis* were represented by just a few specimens (see Appendix). A notable exception, however, was *B. consularis*. *C. fumipennis* collected 29 specimens of this species from three NC counties, each representing a different geographic region of the state. These results highlight the ability of *C. fumipennis* to detect not only rare species, but also those that may be common and widespread but for some reason elude more conventional collection methods.

Pest Buprestidae. The diversity of species identified as prey for *C. fumipennis* (Fig. 3) emphasizes the utility of the wasp as a detection tool for pest Buprestidae. Buprestids are frequently intercepted at ports (Haack 2006), and species in the genus *Agrilus* are of particular concern. Emerald ash borer is currently the primary focus of the *Cerceris* biosurveillance program, but the wasp may serve as an early detection system for other invasive species recently reported in North America, including *A. auroguttatus* Schaeffer (gold-spotted oak borer) (Coleman et al. 2012), and *A. sulcicollis* (Lacordaire) (European oak borer) (Jendek and Grebennikov 2009). *C. fumipennis* was successful in detecting 17 species of *Agrilus* during our

survey (Fig. 3), including five previously unreported in the state (see above). Each *Agrilus* species collected by *C. fumipennis* in NC during our survey was represented by just a few specimens (Fig. 3).

Of the buprestid species collected in NC from 2009 to 2011, eight are known native pests: *Agrilus acutipennis* (spotworm borer; Solomon 1995), *A. anxius* (bronze birch borer; Anderson 1944), *A. arcuatus* (Say) (a pest of hickory; Solomon 1995), *A. bilineatus* (Weber) (twolined chestnut borer; Dunn et al. 1986), *A. ruficollis* (F.) (rednecked cane borer; Solomon 1995), *Chrysobothris femorata* (Olivier) (flatheaded appletree borer; Solomon 1995), *Phaenops fulvoguttata* (hemlock borer; Balch 1935), and *Poecilnota cyanipus* (a pest of eastern poplar; Solomon 1995).

In 2011, 157 *P. fulvoguttata* (hemlock borer) were collected by *C. fumipennis* in the NC mountains (Nalepa and Swink 2011), making it the second most frequently collected species in our survey (Fig. 3). Although this pest was collected in ten different mountain sites in seven counties, just two sites were responsible for nearly 80% of the beetles. At one *C. fumipennis* nesting site in Swain County, 57 of 64 (89%) beetles collected as prey were hemlock borers, and they constituted 67 of 71 beetles (92%) from a site in Buncombe County. Hemlock borers are typically secondary pests that can develop to outbreak levels when trees are stressed by environmental factors or primary pests such as hemlock woolly adelgid (*Adelges tsugae* Annand) (Frank 2010). Because we know little about the foraging behavior of *C. fumipennis*, it is unknown whether high numbers of a given buprestid species brought back to the nest represents wasp foraging fidelity to a few badly infested plant hosts, or alternatively, signals a more widespread pest infestation.

In conclusion, *C. fumipennis* is proving to be an effective tool for documenting regional buprestid diversity, as evidenced by the wide range of prey species and new state records reported here. Continued survey for nests of *C. fumipennis* and documentation of the prey used by the wasp in NC will help establish a foundation for effectively using the wasp as a biosurveillance system for emerald ash borer and other buprestid pests threatening trees in the state. There are decided advantages to having this early detection system in place, in that it eliminates any lag time associated with developing traps and attractants for newly introduced species of pest Buprestidae, and can potentially detect infestations before the appearance of symptoms in host trees. Prey records of the wasp are continually being updated as the initiative for using *C. fumipennis* to detect emerald ash borer and other pest species accelerates. Continued studies of the life history, regional activity periods, and foraging behavior of *C. fumipennis* in relation to activity of target prey will help refine the use of this charismatic wasp as a biosurveillance system.

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Appendix

Details of New State Records of Buprestidae for North Carolina

Agrilus anxius Gory. Cherokee County: Konehete Park, 35.093° N, 84.026° W, 20 June 2011, coll: J. Anderson (two specimens); 27 June 2011, coll: C. A. Nalepa (one specimen).

Agrilus fulgens LeConte. Buncombe County: Vance Elementary School, 35.577° N, 82.600° W, 28 July 2010, coll: W. G. Swink (one specimen).

Agrilus lecontei Saunders. Wayne County, Faith Christian Academy, 35.399° N, 78.012° W, two Jun 2011, coll: W. G. Swink (six specimens); Wayne County, Faith Christian Academy, 35.399° N, 78.012° W, three Jun 2011, coll: C. A. Nalepa (four specimens); Wake County, Jaycee Park, 35.799° N, 78.644° W, 3 June 2011, coll: W. G. Swink (one specimen); Wayne County, Faith Christian Academy, 35.399° N, 78.012° W, six Jun 2011, coll: C. A. Nalepa (one specimen).

Agrilus pseudocoryli Fisher. Macon County, Macon County Soccer Club, 35.164° N, 83.432° W, 14 June 2011, coll: J. Anderson (one specimen); Clay County, Hayesville Veteran's Park, 35.045° N, 83.813° W, 28 June 2011, coll: C. A. Nalepa (one specimen).

Agrilus quadrimpressus Ziegler. Wake County, Jaycee Park, 35.799° N, 78.644° W, 10 June 2010, coll: W. G. Swink (one specimen).

Buprestis consularis Gory. Wake County, Baileywick Park, 35.907° N, 78.668° W, 19 June 2009, coll: C. A. Nalepa (one specimen); Wake County, Baileywick Park, 35.907° N, 78.668° W, 29 June 2009, coll: C. A. Nalepa (one specimen); Wake County, Lake Lynn Community Center, 35.889° N, 78.698° W, 29 June 2009, coll: C. A. Nalepa (two specimens); Wake County, Baileywick Park, 35.907° N, 78.668° W, 24 June 2009, coll: C. A. Nalepa (one specimen); Wake County, Lake Lynn Community Center, 35.889° N, 78.698° W, 25 June 2009, coll: C. A. Nalepa (one specimen); Wake County, Baileywick Park, 35.907° N, 78.668° W, 29 June 2009, coll: C. A. Nalepa (one specimen); Wake County, Lake Lynn Community Cen-

ter, 35.889° N, 78.698° W, 1 July 2009, coll: C. A. Nalepa (one specimen); Wake County, Jaycee Park, 35.799° N, 78.644° W, 7 June 2010, coll: W. G. Swink (one specimen); Wake County, Jaycee Park, 35.799° N, 78.644° W, 8 June 2010, coll: W. G. Swink (one specimen); Wayne County, Faith Christian Academy, 35.399° N, 78.012° W, 8 June 2010, coll: C. A. Nalepa (one specimen); Wayne County, Faith Christian Academy, 35.399° N, 78.012° W, 11 June 2010, coll: C. A. Nalepa (one specimen); Wayne County, Wayne Community College, 35.402° N, 77.942° W, 17 June 2010, coll: W. G. Swink (one specimen); Wayne County, Wayne Community College, 35.402° N, 77.942° W, 2 June 2011, coll: W. G. Swink (two specimens); Wake County, Jaycee Park, 35.799° N, 78.644° W, 3 June 2011, coll: W. G. Swink (one specimen); Wayne County, Wayne Community College, 35.402° N, 77.942° W, 3 June 2011, coll: W. G. Swink (one specimen); Wayne County, Faith Christian Academy, 35.399° N, 78.012° W, 6 June 2011, coll: C. A. Nalepa (one specimen); Wayne County, Wayne Community College, 35.402° N, 77.942° W, 6 June 2011, coll: W. G. Swink (three specimens); Wake County, Jaycee Park, 35.799° N, 78.644° W, 7 June 2011, coll: W. G. Swink (one specimen); Wake County, Jaycee Park, 35.799° N, 78.644° W, 8 June 2011, coll: W. G. Swink (one specimen); Wake County, Lake Lynn Community Center, 35.889° N, 78.698° W, 8 June 2011, coll: J. Anderson (one specimen); Wayne County, Wayne Community College, 35.402° N, 77.942° W, 8 June 2011, coll: W. G. Swink (two specimens); Wake County, Lake Lynn Community Center, 35.889° N, 78.698° W, 13 June 2011, coll: J. Anderson (one specimen); Wayne County, Faith Christian Academy, 35.399° N, 78.012° W, 1 July 2011, coll: C. A. Nalepa (one specimen); Polk County, Polk County Middle School, 35.295° N, 82.172° W, 11 July 2011, coll: J. Anderson (one specimen).

Chrysobothris azurea LeConte. Surry County, Meadowview Middle School, 36.481° N, 80.652° W, 4 June 2011, coll: C. A. Nalepa (one specimen).

Poecilota cyanipes (Say). Surry County, Meadowview Middle School, 36.481° N, 80.652° W, 10 June 2011, coll: C. A. Nalepa (one specimen).