Conservative Estimates of Hunting Distance in *Cerceris fumipennis* Say (Hymenoptera: Crabronidae)[1]

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Abstract Plant host specificity of prey buprestid beetles was used to estimate the minimum distance of hunting flights by the solitary fossorial wasp, *Cerceris fumipennis* Say. Plant hosts of the 5 beetle species investigated were each found at less than 200 m of the wasp nesting area. Although these results indicate neither average nor maximal hunting range, they suggest a working hypothesis that foraging in close proximity to the nesting site may be the norm.

Key Words Buprestidae, *Agrilus*, biosurveillance, emerald ash borer

Cerceris fumipennis Say is a solitary, ground-nesting wasp that typically nests in colonies in sunny, open areas of hard-packed, sandy soil with some degree of human disturbance, such as fire pits, dirt parking lots, trail edges, and baseball and softball diamonds. It hunts almost exclusively for adult beetles in the family Buprestidae; consequently, nesting sites are invariably found in the vicinity of wooded habitat suitable for supporting their prey. The wasps are central place hunters. They search vegetation for buprestids, then fly back to their nest carrying a single prey item at a time, several times a day, to provision their brood cells (reviewed by Careless 2009). The distance that *C. fumipennis* flies to collect prey beetles is of considerable interest because a nesting aggregation of this wasp provides a natural monitoring station for detecting introduced pest buprestids such as emerald ash borer (*Agrilus planipennis* Fairmaire), European oak borer (*Agrilus sulcicollis* Lacordaire), and goldspotted oak borer (*Agrilus auroguttatus* Schaeffer) (Marshall et al. 2005, Careless 2009, Careless et al. 2009). Understanding the scale at which they hunt, then, is crucial to effectively using the wasp as a biosurveillance tool. If a wasp brings an emerald ash borer back to her nest, how large a radius needs to be scouted to find the infested tree?

Direct measurement of individual low altitude flights has been successful in a number of insects, but is constrained in *C. fumipennis* by their hunting and nesting behavior and by the equipment currently available. Harmonic radar is a useful technique for tracking relatively large insects that forage in open areas (Riley and Osborne 2001, Chapman et al. 2011). The physical dimensions of the transponders that reradiate radar transmissions have been reduced to the point where they may be compatible for

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use on *C. fumipennis* (Psychoudakis et al. 2008, Zhu et al. 2011), but they require flight over open terrain. *Cerceris fumipennis* hunts for buprestids in vegetation, where the physical obstruction of trees and shrubs and the high water content of leaves would interfere with signal strength (Zhu et al. 2011). Radiotelemetry is a second possible option for directly measuring flight distance. The radio transmitters used for tracking insects are relatively large (≥200 mg), with antennal lengths of ≥3 cm (Wikelski et al. 2010, Hagen et al. 2011). Radiotelemetry is probably an intractable system for *C. fumipennis,* then, because transmitter weight is likely to interfere with handling and transportation of prey, and the length of the antenna would affect entry and maneuverability at the nest. The *C. fumipennis* nest entrance is generally correlated with wasp body size and ranges from about 0.4 - 1.0 cm (Grossbeck 1912, Careless 2009).

The few attempted indirect measures of *C. fumipennis* flight range have been largely limited to homing experiments. Fabre (1915) displaced *Cerceris* females by 3 km and some returned to their nests (discussed in O'Neill 2001), and Careless (2009, pp. 88 and 133) hypothesized a maximum foraging distance of 1.3 - 1.5 km based on a combination of flight speed, flight duration, and the release of marked wasps at a given distance from the nest. Willmer (1985a) calculated a foraging range of about 6 km for *C. arenaria* based on similar criteria; this author included estimations of prey handling time, but noted that search time may greatly contribute to variability. In general, homing experiments are indicative of the ability to relocate a nest, with uncertainty as to how well this extrapolation represents routine flight distances. Greenleaf et al. (2007) noted that, rather than measure foraging distance, homing experiments integrate across a number of relevant factors, including flight capacity, available navigation cues, weather, familiarity with the landscape, and memory.

In this study we used an indirect method analogous to a technique used to estimate foraging distances in bees: pollen brought back to the nest by a bee is identified, and a systematic search is conducted to determine the distance of that pollen source from the nest (e.g., Osborne et al. 2008, Smith et al. 2012). Our technique used prey analysis. Beetles brought back to the nest by wasps were identified, and their plant host range determined. If the host range of a given prey species was limited to one or a few plant hosts, then the distance between *C. fumipennis* nests and the nearest plant host of that buprestid was measured.

Materials and Methods

Buprestid prey of *C. fumipennis* were collected using established methods (Marshall et al. 2005, Careless 2009, Careless et al. 2009) discussed in more detail elsewhere (Swink et al. 2013). Prey beetles varied widely in their plant host range. At one extreme were species like *Actenodes acornis* (Say), collected from 7 genera of plant hosts (Nelson et al. 2008). We concentrated our efforts at the opposite, oligophagous end of the range: buprestid prey with a limited host range in North Carolina. We identified 5 candidate buprestid species, distributed among 3 geographically distant nesting colonies in the state (Table 1). Buprestid host information is from Nelson et al. (2008) and Morgan D. Jackson (University of Guelph); Buprestidae were identified by Steven M. Paiero (University of Guelph).

Nesting aggregation in the mountains (Site 1). This site was a ball diamond at an elementary school in Asheville, Buncombe Co. (35.577° N, 82.600° W). Between 60 and 100 *C. fumipennis* nests were present on the field on dates when the beetles were collected. Hemlock borer, *Phaenops (=Melanophila) fulvoguttata* (Harris) was

Table 1. *Cerceris fumipennis* study site, target prey, and buprestid plant host.

Site	County	Buprestid prey	Buprestid plant host
1	Buncombe	*Phaenops fulvoguttata*	*Pinus strobus* (eastern white pine) *Tsuga canadensis* (eastern hemlock)
2	Wake	*Agrilus cephalicus*	*Cornus florida* (dogwood)
	Wake	*Agrilus difficilis*	*Gleditsia triacanthos* (honeylocust)
3	Wayne	*Agrilus lecontei*	*Celtis* spp. (hackberry, sugarberry)
	Wayne	*Agrilus ruficollis*	*Rubus* spp. (blackberry)

the focal prey at this site. Hosts of this beetle in North Carolina are primarily *Pinus strobus* L. (eastern white pine) and *Tsuga canadensis* Carrière (eastern hemlock). The beetle comprised 49 of 53 (92.5%) buprestids collected at this site by *C. fumipennis* on 13 June 2011, 14 of 14 collected 21 June 2011, and 4 of 4 collected 28 June 2011.

Nesting aggregation in the piedmont (Site 2). This site was a ball diamond in a city park in Raleigh, Wake Co. (35.799° N, 78.664° W). Twelve to 16 nests of *C. fumipennis* were present on the field on dates the beetles were collected. Two buprestid species were studied at this site. The first, *Agrilus cephalicus* LeConte, utilizes *Cornus florida* L. (dogwood) as host. One *A. cephalicus* was collected as prey on 10 June 2010. The second beetle was *Agrilus difficilis* Gory, whose host is *Gleditsia triacanthos* L. (honeylocust). Two beetles of this species were collected as prey 7 - 10 June 2010.

Nesting aggregation in the inner coastal plain (Site 3). The third study site was a ball diamond at an elementary school in Goldsboro, Wayne Co. (35.398° N, 78.013° W). Fifty-seven nests were present on the field when beetle prey were collected. Two focal prey species were analyzed at this site. The first, *Agrilus ruficollis* (F.), utilizes *Rubus* spp. as host (wild and cultivated blackberry and raspberry). Five beetles were collected as prey on 2 June 2011. The second was *Agrilus lecontei* Saunders. This species infests trees in the genus *Celtis* (*C. laevigata* Willdenow, *C. occidentalis* L., *C. tenuifolia* Nuttall; hackberry, sugarberry). Eleven beetles were collected as prey between 2 and 6 June 2011.

In each case the area in the vicinity of the wasp nests was systematically searched for the closest host plant of the focal buprestid, using techniques that varied depending on the distribution of surrounding vegetation. Site 1 was located in an urban neighborhood dominated by planted ornamentals, Site 2 was in a city park surrounded by areas of both naturally-occurring woods and ornamental plantings, and Site 3 was in a rural area where strips of forest bordered both developed areas and agricultural fields. Because the nesting site in each was a ball diamond with *C. fumipennis* nests scattered around a sandy infield of roughly 28 m^2, the pitcher's mound was used as the reference point for measuring distance from the nesting area to the host of interest, and calculated using coordinates from a Magellan Meridian Gold GPS receiver.

Accessible dead or dying branches were collected from plant hosts of *A. cephalicus* (Site 2) and *A. lecontei* (Site 3) during December 2011, and placed into standard emergence traps (light-proof plywood boxes with glass vials attached to holes drilled

into one side). These were placed in a sheltered outdoor area and checked periodically during the spring of 2012 for emergence of buprestids; emerged insects were collected and identified.

Because prey retrieval was the focus of this study, flights are described as "hunting" rather than "foraging" distance. Adults forage on flowers to meet water, energy, and nutrient requirements (Evans 1966, Scullen and Wold 1969, Willmer 1985a).

Results

At each site, plant hosts of the buprestid prey collected by *C. fumipennis* were located in the immediate vicinity of the wasp nesting area, at minimal distances ranging from 32 - 177 m (Table 2).

Site 1. Twenty-seven hosts of the hemlock borer *P. fulvoguttata* were found at less than 200 m of the wasp nesting site: 17 of eastern white pine, and 10 of eastern hemlock (Fig. 1). At least 8 of these (3 pine, 5 hemlock) were noted to have crown thinning or top dieback suggestive of insect infestation. An additional 3 pines and 7 hemlocks with thinning crowns were noted at distances 200 - 330 m from the nest site.

Site 2. *Cornus florida,* host of *A. cephalicus,* was abundant in the forest bordering the outfield of the ball diamond, and 8 dogwoods were identified 50 - 61 m from the nesting area. Most of the trees were in poor condition, with dead branches displaying 'D-shaped' emergence holes characteristic of *Agrilus.* Two *A. cephalicus* emerged (on 3 and 30 April 2012) from dead branches of a dogwood collected 50 m from the *C. fumipennis* nesting site. Two mature honey locust trees (host of *A. difficilis*) were located, one at 152 m and the other at 274 m from the nesting area.

Site 3. Blackberry bushes were common in the immediate area, both as individual plants dispersed throughout hedgerows, and in tangled thickets along the forest edge. Six of these were noted within 150 m of the nesting area, with the closest measured at 32 m. Plant 'swellings' characteristic of infestation by *A. ruficollis* (Pfeiffer 2011) were noted but when 6 of these were dissected, no buprestid larvae were found. The closest *Celtis* sp. tree (host of *A. lecontei*) at this site was located 177 m from the nest site, and 'D-shaped' emergence holes characteristic of *Agrilus* were noted on dead branches on the ground beneath it. An additional 7 *Celtis* spp. trees were found between 208 and 320 m of the nest area. Five *A. lecontei* were collected from emergence boxes: one from branches of *Celtis* sp. collected 212 m from the *C. fumipennis* nesting site, and 4 from branches collected 296 m from the nesting site.

Table 2. Minimum distance from a *Cerceris fumipennis* nesting area to a plant host of collected prey Buprestidae.

Buprestid prey	Distance from *C. fumipennis* nests to nearest plant host (m)
Phaenops fulvoguttata	32
Agrilus cephalicus	50
Agrilus difficilis	152
Agrilus lecontei	177
Agrilus ruficollis	32

Fig. 1. Aerial view of Site 1, with 100 m and 200 m distances centered on the *Cerceris fumipennis* nesting site indicated. Hosts of the buprestid species *Phaenops fulvoguttata* (hemlock borer) are marked with red dots, together with their number and identity (P = *Pinus strobus*, eastern white pine; H = *Tsuga canadensis*, eastern hemlock). Image source: North Carolina Center for Geographic Information and Analysis, 2010.

Discussion

Each of the 5 investigated beetle species potentially could be captured by *C. fumipennis* at no more than 200 m from the nesting aggregation, suggesting that these wasps hunt within a limited radius of their nests. Emergence of target prey from branches of plant hosts collected in close vicinity to the nesting areas in Sites 2 and 3 supports this hypothesis. Like other attempts at measuring hunting distance of *C. fumipennis* to date, however, the prey analysis technique has limitations. It assumes that *C. fumipennis* flew to the nearest host of the focal beetle, and that the beetles were captured on or near their listed plant hosts.

The hunting distance of a *C. fumipennis* female likely depends on individual characteristics of the wasp and her prey, habitat structure, weather (e.g., Willmer 1985b), and interactions among all of these. Wasp body size (Willmer 1985a,b), wing wear (Higginson et al. 2011, Nalepa 2012), age (Johnson 1976), and experience (Linsley

and McSwain 1956, Zeil 1993) are influential, as well as prey availability (Brockmann 1985, Rosenheim 1987), prey mobility, prey size relative to wasp size (Evans 1962, Coelho and Ladage 1999, Polidori et al. 2005), and prey habitat (Coelho et al. 2008). *Cerceris* hunting distance may also shift seasonally with the life history of their prey, as adults of different buprestid species may be active at different parts of the active wasp season. Given sufficient variation in the vegetation surrounding a nesting area, however, buprestids on different hosts and with varying activity periods may serve as a consistent resource in close proximity to nests.

Our results suggesting a hunting distance of ≤200 m are consistent with the observation that *C. fumipennis* nests only in open areas with a nearby tree line (Careless 2009) and with Willmer's (1985b) suggestion that, because the nesting season is brief and activity possible only in good weather, hunting efficiency is of utmost importance. Prey analysis at additional locations may determine if our results represent typical flights, and continued improvements in the equipment for directly measuring flight will eventually refine estimations of both typical and maximum hunting distance.

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