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OCCURRENCE OF *CAMPONOTUS PENNSYLVANICUS*
(HYMENOPTERA: FORMICIDAE) IN TREES PREVIOUSLY
INFESTED WITH *ENAPHALODES RUFULUS* (COLEOPTERA:
CERAMBYCIDAE) IN THE OZARK MOUNTAINS OF ARKANSAS

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ABSTRACT

Black carpenter ants, *Camponotus pennsylvanicus* (DeGeer), are nearly ubiquitous in North American forests. These ants are documented as predators of red oak borer, *Enaphalodes rufulus* (Haldeman), a native longhorn beetle that experienced an unprecedented population increase synonymous with an oak decline event in the oak hickory forests of the Ozark Mountains of Arkansas from the late 1990s until 2005. We examined previous red oak borer emergence holes, tree crown conditions, and site aspects in 13 pre-established vegetation monitoring plots and correlated these forest and tree attributes with the presence or absence of black carpenter ants. At each site, all red oaks >10 cm diameter at breast height were baited for black carpenter ants with a mixture of tuna and honey. Black carpenter ants were more frequently found on trees with low levels of previous red oak borer infestation versus those trees with previously high infestations. These data suggest a potential role for black carpenter ants in the dynamics of red oak borer populations. Distribution of black carpenter ants in red oaks prior to and during the outbreak is unknown. Future investigations should be directed at efforts to understand whether black carpenter ants simply prefer different tree and site attributes than red oak borer or if, via predation, these ants are acting as agents of red oak borer control.

Key Words: predation, carpenter ants, oak-hickory forest, red oak borer

RESUMEN

La hormiga carpintera negra, *Camponotus pennsylvanicus* (DeGeer), es casi ubicua en los bosques de Norte America. Estas hormigas están documentadas como depredadores del barrenador del roble rojo, *Enaphalodes rufulus* (Haldeman), un escarabajo de antenas largas (Cerambycidae) nativo que experimento un aumento sin precedentes en su población en relación al decremento del roble en los bosques de roble y nogal americano (*Carya*) de las Montañas Ozark de Arkansas desde el final de la década de los 1990s hasta el 2005. Examinamos hoyos de emergencia del barrenador del roble rojo hechos anteriormente, las condiciones de la corona del árbol, y aspectos del sitio en 13 parcelas de vegetación establecidas anteriormente para su muestreo y correlacionamos este bosque y atributos de los árboles con la presencia o ausencia de la hormiga carpintera negra. En cada sitio, todos los robles de diámetro de >10 cm al nivel de pecho fueron cebados para las hormiga carpintera negra con una mezcla de atún y miel. Se encontró la hormiga carpintera negra más frecuentemente en árboles con niveles bajos de infestaciones de barrenador del roble rojo previas versus en árboles con altas niveles de infestaciones previas. Estos datos indican un papel potencial de la hormiga carpintera negra en la dinámica de la población del barrenador del roble rojo. La distribución de la hormiga carpintera negra en el roble rojo antes de y durante del brote (de la población de *Enaphalodes rufulus*) es desconocida. Investigaciones en el futuro deben enfocarse en esfuerzos para entender si la hormiga carpintera negra sencillamente prefiere atributos diferentes de los árboles y de los sitios que el barrenador de roble rojo o si, por medio de la depredación, estas hormigas están actuando como agentes de control del barrenador de roble rojo.

Red oak borer, *Enaphalodes rufulus* (Haldeman) (Coleoptera: Cerambycidae), is a native wood-boring beetle that has been implicated as a significant agent of tree mortality in a large-scale red oak decline event (>300,000 hectares) that occurred throughout the Ozark and Ouachita Mountains of Arkansas and Missouri (Stephen et al. 2001; Heitzman 2003; Fierke et al. 2005a). This red oak borer outbreak occurred from 1999-

2005 and was unprecedented in scale (Riggins 2008). During the outbreak, over 5000 larval attacks were found on a single tree and an average of 77 living larvae were found in felled trees (Fierke et al. 2005b). Previous studies of red oak borer in the northeastern United States document the insect at low densities and do not report tree mortality associated with infestations (e.g., Hay 1974).

Cannibalism, woodpeckers, carpenterworms (Lepidoptera: Cossidae) (Hay 1972; Donley and Acciavatti 1980; Galford 1985; Ware and Stephen 2006) and ants were cited as agents of red oak borer egg and larval mortality, and ants may be responsible for 13-29% of red oak borer predation at endemic levels (Galford 1985). Evidence from multiple studies confirms that carpenter ants are predators of a variety of forest pests (Parmelee 1941; Allen et al. 1970; Smirnov 1959; Youngs and Campbell 1984; Feicht and Acciavatti 1985; Galford 1985). Muilenberg et al. (2008) reported that 2 species of ants, black carpenter ants, *Camponotus pennsylvanicus* DeGeer (Hymenoptera: Formicidae), and *Aphaenogaster tennesseensis* Mayr removed 70% of artificially planted red oak borer eggs from tree surfaces in 1 h. Red oak borer DNA was detected in the guts of field-collected black carpenter ants, further confirming their role as predators of red oak borer (Muilenberg et al. 2008). Red oak borers laid an average of 119 eggs per female, with a mean egg viability of 99% (Donley 1978), suggesting that without significant egg predation, rates of tree colonization may be very high.

The relationship between black carpenter ant and red oak borer distribution may provide insight into factors influencing the recent red oak borer population explosion and decline in the Ozark Mountains. The objective of this study was to correlate the presence of black carpenter ants on previously infested red oaks to previous numbers of red oak borer emergence holes, site aspects and tree conditions.

MATERIALS AND METHODS

Three geographic locations, Fly Gap, White Rock, and Oark (UTM Zone 15-N NAD83: Fly Gap: 431660, 3954978; White Rock: 412668, 3949429; Oark: 450792, 3952369), within the Ozark National Forest were chosen for this study. These 3 locations are in areas previously identified as experiencing high red oak mortality and have been monitored for red oak borer since 2001 (Fierke et al. 2007). Stands at these locations were 70-100 years old and on shallow rocky limestone and sandstone soils (USDA Forest Service 1993; Starkey et al. 2000). Plots at each location, when originally established, had an average of 493 trees per ha (Fierke et al. 2007).

Each of these locations had a single pre-established 30 × 100 meter fixed-area rectangular vegetation plot on each of north, south, east, and west benches and ridges in which all northern red oaks had been annually monitored since 2001 for red oak borer attack holes, emergence holes, tree crown conditions, and red oak mortality (Fierke et al. 2005b). Although 15 plots were available for use, only 13 of the plots were used. The ridge plot at White Rock had been highly impacted by tree

removal and the west bench plot at Fly Gap had been treated with prescribed fire, so they were deemed unsuitable and excluded.

In each plot, all red oaks larger than 10 cm diameter at breast height (1.3 m above the ground, hereafter DBH) were identified and marked. Trees were baited with 5 mL of 1:1 mixture of clover honey and tuna in oil (Cannon 1998). Baits were placed in 10-mL paper cups and a single bait cup was affixed to each tree at breast height with aluminum nails. The bait was left undisturbed in the plot for 1 h, because previous studies report that 70% of red oak borer eggs are removed from the tree within the first hour of observation (Muilenberg et al. 2008). Ants within the bait cup or conspicuously visible on the bole of the tree were collected and returned to the laboratory for identification. All trees were evaluated on a presence/absence basis, because the number of ants present on a tree gives little indication of the number of colonies or individuals per unit area (Kilpelainen et al. 2005). All trees were sampled once during 06:00-11:00 h from 20 May 2007-9 Jun 2007 because carpenter ants typically do not forage in extreme afternoon heat (Nuss et al. 2005). In a related study in the Ozark Mountains, 95% of trees sampled a second time by the methodology described above reported the same presence (or absence) of ants. Therefore, a single sample per tree was taken as it allowed for a greater number of independent samples, which is of more statistical value than repeated measures on fewer samples (Verble & Stephen 2009).

Tree classes were developed during the red oak borer outbreak to rapidly assess large numbers of trees for decline and damage. Tree classes reflect the recent history of red oak borer colonization on individual trees and utilize the number of red oak borer emergence holes in the basal 2 m of a tree and the percent dieback in the tree crown to group trees into 3 classes: I, II and III. Class I trees have the fewest red oak borer emergence holes and healthiest crown, and Class III trees have the most red oak borer emergence holes and the least healthy crown, while Class II is an intermediate to Classes I and III; this method is explained in detail in Fierke et al. 2005b. Records of these tree classes were compared with current presence of black carpenter ants for all trees within study plots.

Numbers of red oak borer emergence holes visible in 2005 (the last year of the outbreak) were categorized as "high" (>5 visible red oak borer emergence holes on the basal 2 m of the tree) or "low" (0-5 visible red oak borer emergence holes on the basal 2 m of the tree). These categories were compared to current presence of black carpenter ants for all trees within the study plots.

Data were summarized as percentages of trees of a given attribute (e.g., aspect) with black carpenter ants present and normalized with arc-sine

transformation. The presence of ants was analyzed in relation to aspect, DBH, geographic location, tree class, and red oak borer emergence hole classes. All relationships were tested with a one-way ANOVA and Tukey pairwise comparison tests. Data were analyzed with JMP 7.0 (SAS Institute 2007). Voucher specimens of ants were deposited in the Insect Museum at the University of Arkansas, Fayetteville, Arkansas, USA.

RESULTS

A total of 328 red oaks were surveyed for ants in this study. Stand characteristics are reported in Table 1. An overall mean of 77.1% of red oaks had ants present (SE = 2%). Aspect was not significantly correlated to black carpenter ant presence ($P = 0.43$). Geographic location within the Ozark National Forest did not significantly influence black carpenter ant presence ($P = 0.21$).

Tree class was significantly correlated to black carpenter ant presence ($P = 0.003$) (Fig. 1). Ant presence on Class I and Class II trees was not significantly different; however, ants were present significantly less frequently on Class III trees than on either Class I or Class II trees.

Black carpenter ants were present on a significantly higher percent of trees with low numbers (0-5) of red oak borer emergence holes than trees with high numbers (>5) red oak borer emergence holes ($P < 0.001$) (Fig. 2). Ants were present on 29% of trees with high numbers of red oak borer emergence holes, whereas ants were present on 81% of trees with low numbers of red oak borer emergence holes.

Black carpenter ant presence was significantly affected by tree DBH ($P < 0.001$). Ants are more likely to be present on large diameter trees than on small ones. This was an anticipated result and is detailed in Verble and Stephen (2009). However, tree DBH does not influence the number of red oak borer emergence holes ($P = 0.21$). If only the "medium" DBH trees (mean DBH = 34.5 cm, "medium" = 32-41 cm, $n = 119$) are analyzed, which comprise approximately one third of all trees surveyed, the effect of DBH on black carpenter ant presence is removed ($P = 0.19$) and black carpenter ants are still present on a significantly higher percent of trees with low numbers of red oak borer emergence holes ($P = 0.004$), confirming that this trend does not result from ant preference for tree sizes.

DISCUSSION

The discovery that red oak borer is less likely to be found in trees where black carpenter ants are present supports our research hypothesis. Black carpenter ants are more abundant in apparently healthy Class I and even Class II trees than apparently unhealthy Class III trees. There are several reasons why this trend may exist. Class I trees, having a more full crown, may provide more nutrients, moisture or a cooler foraging environment to the ants. However, the presence of black carpenter ants, no matter the reason for this association, may result in greater red oak borer egg predation.

Ito & Higashi (1991) found that oaks on which *Formica* ants tended aphids had higher fecundity

TABLE 1. STAND CHARACTERISTICS FOR ALL PLOTS SURVEYED (INCLUDING ASPECT), INCLUDING NUMBER OF RED OAKS, MEAN AND STANDARD ERROR OF DIAMETER AT BREAST HEIGHT (DBH) (CM) AND DBH RANGE. SUMMARY STATISTICS, IN ITALICS, ARE PRESENTED FOR EACH GEOGRAPHIC LOCATION AND ALL PLOTS.

Plot Location and Aspect	No. red oaks	Average DBH	Std Error DBH	DBH Range
<i>Fly Gap</i>	123	31.3	0.78	12.0-57.5
Fly Gap East	27	34.8	1.54	21.0-57.5
Fly Gap North	5	26.4	2.68	17.0-33.0
Fly Gap Ridge	51	29.8	1.22	12.0-51.0
Fly Gap South	40	31.3	1.37	16.5-47.0
<i>Oark</i>	124	36.5	1.00	11.0-73.5
Oark East	22	44.6	2.66	11.0-73.5
Oark North	28	34.3	1.89	14.5-54.0
Oark Ridge	36	32.8	1.34	11.0-51.0
Oark South	18	32.2	2.65	11.0-52.0
Oark West	20	41.0	2.28	17.0-57.0
<i>White Rock</i>	81	36.0	1.14	12.5-63.0
White Rock East	21	38.6	2.30	20.5-60.5
White Rock North	10	40.3	3.21	21.0-54.5
White Rock South	17	31.1	2.15	12.5-45.0
White Rock West	33	35.4	1.74	21.0-63.0

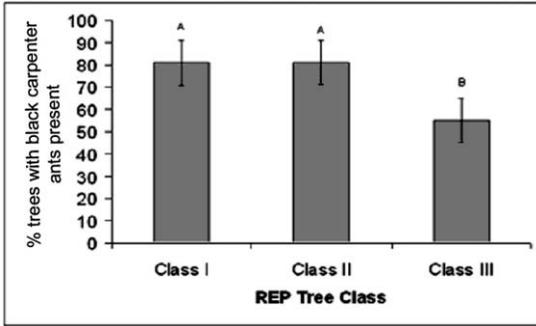


Fig. 1. Relationship between REP tree class and black carpenter ant presence. Mean percentages for classes followed by the same letter are not significantly different ($F = 8.25, P = 0.0003$). Data shown are not statistically transformed.

than those on which ants were not present; they suggest that an indirect mutualism exists between ants and oaks via aphids. While black carpenter ants do not tend specific “herds” of aphids, they may depend on oaks for another vital resource—a nest site. While the relationship between oaks and carpenter ants remains largely unexamined, black carpenter ants are often reported to be found in the apparently “healthiest and largest” trees in the forest (pers. obs.).

Though there is a body of literature suggesting that black carpenter ants are important predators of forest insect pests (Parmelee 1941; Allen et al. 1970; Smirnoff 1959; Youngs & Campbell 1984; Feicht & Acciavatti 1985; Galford 1985), we know of no direct tests of this hypothesis. This study was conducted after area-wide red oak borer populations had declined, and we have no knowledge of carpenter ant abundance and distribution previous to or during the red oak borer outbreak. As

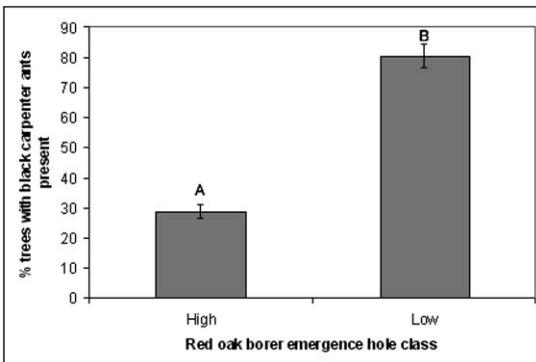


Fig. 2. Relationship between black carpenter ant presence and within-tree red oak borer populations. Means classes with the same letter are not significantly different ($F = 32.82, P < 0.001$). Data shown are not statistically transformed.

our data are correlative in nature, since direct assessments were impossible after the outbreak, it is impossible to draw firm conclusions about the role of black carpenter ants in population dynamics of red oak borer. Future studies should be aimed at understanding the general ecology of temperate ant species, their roles in pest insect predation and regulation and the factors which govern both ant and pest insect colonization of trees.

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