

Spatial Emergence Pattern of Bronze Birch Borer, (Coleoptera: Buprestidae) from European White Birch^{1,2}

Rodney C. Akers³ and David G. Nielsen

Department of Entomology, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH 44691

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ABSTRACT Spatial emergence patterns of the bronze birch borer, *Agilus anxius* Gory, and associated parasite and woodpecker predation in European white birch, *Betula pendula* Roth, were examined. Beetle and total hole density (beetle + parasite + woodpecker) were significantly lower from stem bolts 6 m above ground, 0.1 to 5.0 cm in circumference, and with 0.1 to 1.5 mm bark thickness than bolts 1 to 3 m above ground, 5.1 to 60.0 cm circumference, and with 1.51 to 3.0 mm bark thickness. Significantly more emergence occurred from the southwestern quadrant of trees than from other quadrants. Beetle emergence and total hole densities were also significantly less from branches than from tree trunks.

KEY WORDS *Agilus anxius*, bronze birch borer, Buprestidae, emergence, Coleoptera, *Betula pendula*, birch.

Factors influencing spatial distribution of adult emergence holes made by subcortical feeders in woody plants have been examined extensively in some beetle families, including the Scolytidae (Berryman 1968, Ferrell 1978, Hodges and Pichard 1971, Schenk *et al.* 1977, Sheperd 1965), but not in the Buprestidae. Investigations of host-emergence relationships in the buprestid genus *Agilus* have emphasized host specificity and quality (Anderson 1944, Balch and Prebble 1940, Ball and Simmons 1980, Barter 1957, Carlson and Knight 1969, Chapman 1915, Hespeneheide 1969, 1976).

Bronze birch borer (BBB), *Agilus anxius* Gory, has been associated with birch dieback since first cited as a pest of *Betula* spp. in the nineteenth century (Chittenden 1898, Slingerland 1906). Attacked trees are thought to be previously stressed, because larvae reportedly survive poorly in vigorous trees (Barter 1957, Hawboldt and Skolko 1948, Spaulding and MacAloney 1931). Trees successfully colonized by larvae are usually killed.

The purpose of this study was to examine the influence of height, circumference, bark thickness, and cardinal compass direction on distribution and abundance of BBB emergence holes and presence of associated parasite and woodpecker holes. This information is important to understand factors affecting successful adult

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³ Current address: BASF Corporation, 1401 Brookhaven Drive, Wilson, NC 37893.

emergence, to learn how hosts are colonized, and to increase efficiency in choosing infested *Betula* trees for obtaining beetles for experimentation.

Materials and Methods

Nineteen recently killed European white birch, *Betula pendula* Roth, with unbroken tops were selected from a commercial nursery near Shreve, Ohio, and a research nursery at the Ohio Agricultural Research and Development Center, Wooster. A wax pencil was used to delimit compass directions before trees were cut. Trees were then felled after insect emergence to facilitate data collection. Tree trunks were cut into 1 m bolts beginning at ground level. Bolt ends were measured to the nearest mm and averaged to determine circumference. Bark thickness was derived as the average of 2 measurements per compass direction per bolt. All *A. anxius*, *Phasgonophora sulcata* Westwood (Hymenoptera: Chalcididae), a larval parasitoid of *A. anxius*, and woodpecker predation holes were then counted to measure influence of aforementioned variables on emergence hole density on tree trunk *vs.* limbs and branches. Emergence was regressed on a combination of host parameters and by one-way analysis of variance of each parameter as a discrete variable. Data were transformed to $\text{Log}_{10}(X + 1)$ because means correlated positively with the variance. Means were separated with Duncan's (1955) new multiple range test ($P = 0.05$).

Results and Discussion

Beetle and total holes vs. height, circumference, and bark thickness. An average of 184 ± 82 (SD) beetle holes and 290 ± 162 (SD) total holes (beetle, parasitoid, and woodpecker) were recorded from trunks of trees 3.4 to 8 m tall. *Agrilus anxius* emergence and total holes per m^2 bark area were regressed on the variables height, circumference, and bark thickness of bolt. These relationships can best be described by the following equations:

$$\text{Log}_{10} \text{ BBB/m}^2 \text{ bark area} = 0.48 - 2.61 C + 1.69 \text{ log}_{10} \text{ BT}$$

$$r^2 = 0.50, P \leq 0.005$$

$$\text{Log}_{10} \text{ total holes/m}^2 \text{ bark area} = 0.63 - 3.01 C + 1.80 \text{ log}_{10} \text{ BT}$$

$$r^2 = 0.52, P \leq 0.005$$

where BBB/m^2 bark area is the density of beetles per unit area, total holes/m^2 bark area is the density of all holes per unit area, C is average circumference (cm) and BT is average bark thickness (mm) of bolt. Height did not add significantly to the equation. Although only approximately 50% of the variation in number of emergence holes and total holes can be explained by circumference and bark thickness, the relationship was significant ($P \leq 0.05$) and warranted independent analyses of the continuous variables height, circumference, and bark thickness as discrete variables.

One-way analysis of variance ($P \leq 0.05$) for each variable, height, circumference, and bark thickness, indicated a significant difference in emergence density for beetles and total holes. Emergence hole density was lower from bolts 6 m above ground, 0.1 to 5.0 cm in circumference, and 0.1 to 1.5 mm bark thickness than from

bolts 1 to 3 m above ground, 5.1 to 60 cm in circumference, and with bark 1.51 to 3.0 mm thick (Tables 1-3). These variables are correlated, because circumference and bark thickness decrease as tree height increases.

Although emergence and total holes were greatest in the lower trunk, emergence hole and total hole density per unit area were evenly distributed except for the upper tree crown. There was little emergence from bolts less than 5 cm in circumference. This may be due to crown tissues becoming necrotic before larvae complete development. Small larvae are probably not "Pitched-out" of susceptible trees because they feed in a zig-zag pattern that tends to minimize exposure to high vascular pressures (Barter 1957). Ball and Simmons (1980) and Loerch (1983) recorded more beetle emergence from the lowest section of the trunk, but when emergence was adjusted for unit surface area, emergence hole density did not vary significantly between sections of tree trunks. We found, however, that the penultimate and ultimate bolts had significantly less emergence, both actual and per unit area, than the rest of the tree trunk.

Because 29.4% of the total holes on *B. pendula* trunks resulted from woodpecker predation (25.4%) and parasite emergence (4%), we examined the sum of these holes separately from total holes. One-way analysis of variance ($P \leq 0.05$) for variables height and circumference indicated that significantly fewer holes were found in the 1-m bolt nearest the ground than in bolts 2 to 3 m above ground (Tables 1 and 2). There was no significant difference in number of holes in bolts taken at 1-m and 4- to 6-m, but parasite emergence and woodpecker predation was extremely variable from tree to tree. Bark thickness did not influence parasite activity or woodpecker predation (Table 3), but fewer holes were found in the thickest bark. Significantly more holes occurred on the south side of the tree than the north side (Table 4). As expected, there was a high correlation ($r = 0.87$) between total holes (i.e., *Agrius* density) and the extent of woodpecker predation and parasite emergence. If 86% of the combined woodpecker predation and parasite emergence holes is due to woodpecker predation, the low occurrence of these holes on the bolt nearest the ground indicates that other factors besides larval distribution influence woodpecker predation.

Emergence vs. cardinal compass direction. Analysis of variance indicated a significant difference in emergence holes and total holes associated with different compass directions (Table 4). To adjust for different tree heights, we calculated % of *A. anxius* and total emergence from each tree before analysis. Significantly more emergence occurred from the SW quadrant than from other quadrants. Significantly more beetles emerged from the SE quadrant than from the NE or NW quadrants. These results are not surprising, because *A. anxius* adults are photopositive and respond to environmental cues above a temperature threshold of 20°C (Barter 1959, Larsen 1901). The south side of a tree is the warmest and the SW quadrant usually receives the most sunlight. Ovipositing beetles may respond to these stimuli, temperature and sunlight, by spending more time on the SW side of trees. Larvae may dwell in the sunny, warmer positions of the tree when completing development (Loerch 1983).

Bole vs. branch emergence. There were significantly fewer bronze birch borer emergence and total holes in branches, 61 ± 69 and 116 ± 143 ($\bar{X} \pm SD$), respectively, than in tree trunks, 184 ± 82 and 280 ± 13 ($\bar{X} \pm SD$), respectively, according to Student's *t*-test ($P \leq 0.01$). When emergence holes were converted to numbers/m² of bark area, results were similar. There were significantly fewer

Table 1. Comparison of *Agrilus anxius*, parasite, woodpecker predation, and total holes in *Betula pendula* vs. height near Wooster, Ohio.*

Height (m)	No. of observations	\bar{X} <i>A. anxius</i> emergence holes/ m ² bark surface \pm SD†	\bar{X} Parasite emergence and woodpecker predation m ² bark surface \pm SD‡	\bar{X} Total holes/ m ² bark surface \pm SD§
1	19	248 \pm 180	28 \pm 33	276 \pm 193
2	19	251 \pm 158	106 \pm 80	356 \pm 178
3	19	225 \pm 182	180 \pm 154	406 \pm 293
4	19	159 \pm 153	123 \pm 143	282 \pm 265
5	8	198 \pm 245	234 \pm 313	432 \pm 497
6	4	54 \pm 90	153 \pm 185	207 \pm 268

* Data were transformed to log₁₀ (X + 1) before analysis of variance.

† F_(6, 82) = 4.72

‡ F_(5, 82) = 3.43

§ F_(5, 82) = 3.03

Table 2. Comparison of *Agrilus anxius*, parasite, woodpecker predation, and total holes in *Betula pendula* vs. circumference near Wooster, Ohio.*

Circumference (cm)	No. of observations	\bar{X} <i>A. anxius</i> emergence holes/ m ² bark surface \pm SD†	\bar{X} Parasite emergence and woodpecker predation m ² bark surface \pm SD‡	\bar{X} Total holes/ m ² bark surface \pm SD§
0.1 to 5.0	8	33 \pm 94	6 \pm 16	39 \pm 110
5.1 to 10.0	18	190 \pm 190	170 \pm 236	360 \pm 374
10.1 to 15.0	16	260 \pm 161	225 \pm 159	485 \pm 257
15.1 to 20.0	15	249 \pm 156	140 \pm 141	389 \pm 256
20.1 to 25.0	14	258 \pm 171	103 \pm 103	361 \pm 180
25.1 to 35.0	16	237 \pm 187	39 \pm 46	277 \pm 205
35.1 to 60.0	9	88 \pm 48	103 \pm 86	191 \pm 121

* Data were transformed to $\log_{10}(X + 1)$ before analysis of variance.

† $F(6, 89) = 22.7$

‡ $F(6, 89) = 8.3$

§ $F(6, 89) = 3.7$

Table 3. Comparison of *Agrilus anxius*, parasite, woodpecker predation, and total holes in *Betula pendula* vs. bark thickness near Wooster, Ohio.*

Bark thickness (mm)	No. of observations	\bar{X} <i>A. anxius</i> emergence holes/		\bar{X} Parasite emergence and woodpecker predation		\bar{X} Total holes/	
		m ² bark surface ± SD†	m ² bark surface ± SD‡	m ² bark surface ± SD‡	m ² bark surface ± SD§		
0.1 to 1.5	37	174 ± 186	151 ± 218	325 ± 359			
1.51 to 3.0	37	250 ± 168	124 ± 96	374 ± 202			
3.1 to 7.4	22	185 ± 146	73 ± 82	258 ± 169			

* Data were transformed to log₁₀ (X + 1) before analysis of variance.

† F(2, 93) = 7.4

‡ F(2, 93) = 2.7

§ F(2, 93) = 5.7

emergence holes and total holes in branches, 46 ± 37 and 83 ± 56 ($\bar{X} \pm SD/m^2$ bark area), than in tree trunks, 232 ± 122 and 330 ± 156 , according to Student's t-test ($P \leq 0.01$). Ball and Simmons (1980) sampled for *A. anxius* larvae by removing 10 cm strips of bark from *B. pendula* trees, and also found significantly lower larval density in branches than in tree trunks.

Table 4. Comparison of *Agilus anxius* and parasite emergence, woodpecker predation, and total holes in *Betula pendula* vs. compass direction near Wooster, Ohio.

Compass direction	\bar{X} % <i>A. anxius</i> \pm SD* emergence	\bar{X} % Parasite emergence and woodpecker predation \pm SE*	\bar{X} % Total holes \pm SD*
SW	38.2 \pm 10.1a	35.2 \pm 18.9a	37.5 \pm 9.8a
SE	27.4 \pm 6.7b	31.3 \pm 14.2a	28.1 \pm 6.4b
NE	15.1 \pm 5.8c	16.4 \pm 7.9b	15.5 \pm 5.8c
NW	19.3 \pm 5.4c	17.1 \pm 7.8b	18.9 \pm 5.2c

* Means within a column followed by the same letter are not significantly different at the $P = 0.05$ level (Duncan's (1955) new multiple range test).

Agilus anxius larvae utilize the inner bark of branches and tree trunks as food resources. Although less emergence occurs from branches and the upper portion of the trunk, these pioneer attacks may influence subsequent host quality for the beetle.

A typical progression of dieback occurs in birch starting with "flagging" in the upper canopy with little or no beetle emergence, to tree death and the production of many beetles from the lower bole (Akers and Nielsen, unpublished). Mass emergence from a tree during the year of its death would seem to be adaptive. Beetles do not colonize dead trees. Production of a large number of beetles during the end of host utilization may enhance the likelihood that some beetles will locate acceptable hosts for larvae and suitable mates. In a rural area an extensive flight may be required before a suitable larval host is located.

Information about buprestid-host relationships is limited. More studies are needed to understand oviposition preferences, larval success, population effects on host trees, and the efficiency of these borers in utilizing their food source. Host quality is probably the most important factor in determining success of borer larvae in woody plants. However, biotic and abiotic factors that contribute to borer susceptibility need to be identified.

Researchers interested in obtaining beetles for experimentation should collect from bole sections less than 3 m above the ground of recently killed birches. The temperature of infested bolts can be manipulated to influence adult emergence (Akers 1986).

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