Effects of larval host diameter on body size, adult density, and parasitism of cerambycid beetles

Peter F. Reagel, Michael T. Smith, Lawrence M. Hanks

Abstract—In this study, we assessed the relationship between the size of bolts cut from pin oak trees, *Quercus palustris* Münchhausen (Fagaceae), and eastern white pines, *Pinus strobus* Linnaeus (Pinaceae), and the number and body size of cerambycid beetles (Coleoptera: Cerambycidae) that develop within them. From oak bolts emerged adult *Graphisurus fasciatus* (De Geer) (98% of beetles) and *Xylotrechus colonus* (Fabricius), while pine bolts produced *Monochamus carolinensis* (Olivier) (95%) and *Astylopsis sexguttata* (Say). The number of *G. fasciatus* was positively correlated with the diameter of the oak bolts, while the greatest number of *M. carolinensis* emerged from pine bolts of intermediate diameter. Body size of both species was positively correlated with bolt diameter. Rates of parasitism were very low, only 0.9% for oaks, and averaging 5.3 ± 8.6% across pine bolts. Oak bolts yielded the braconid wasps (Hymenoptera: Braconidae) *Wroughtonia ferruginea* (Brues) and a species in the genus *Atanycolus* Förster (similar to *Atanycolus charus* (Riley)), and an ichneumonid (Hymenoptera: Ichneumonidae) in the genus *Demopheles* Förster. Pine bolts produced a braconid in the genus *Digonogastra* Viereck, and the tachinid fly (Diptera: Tachinidae) *Billaea monohammi* (Townsend).

Larvae of most species of cerambycid beetles feed subcortically in woody plants, and many species are important pests in managed and natural forests worldwide (Solomon 1995). For some cerambycid species, performance by the larvae is strongly influenced by the physical dimensions of larval hosts (Hanks *et al.* 2005), as well as parasitism rate (Hanks *et al.* 2001). Here, we summarise research that assessed the relationship between the size of bolts cut from trees and the number and size of cerambycid beetles that emerge, and parasitism rates.

The study was conducted in a ~ 0.08 ha tree plantation (United States of America: Illinois: Champaign Co.; 40°05′06.43″N, 88°12′49.88″W) with pin oaks, *Quercus palustris* Münchhausen...
Table 1. Total number (% female) and mean density (per m² bark surface of bolt, ±1SD) of adult cerambycid beetles that emerged from bolts of pin oak and eastern white pine. Sex ratios of all species were not significantly different from 1:1 (G-test for goodness of fit, $P > 0.05$)

<table>
<thead>
<tr>
<th>Subfamily</th>
<th>Species</th>
<th>Oaks</th>
<th>Pines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerambycinae</td>
<td>Xylotrechus colonus</td>
<td>13 (60%) 0.5 ± 2.2 beetles/m²</td>
<td>0</td>
</tr>
<tr>
<td>Lamiinae</td>
<td>Astylopsis sexguttata</td>
<td>0</td>
<td>21 (53%) 0.4 ± 1.4 beetles/m²</td>
</tr>
<tr>
<td></td>
<td>Graphisurus fasciatus</td>
<td>647 (47.3%) 17.7 ± 21 beetles/m²</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Monochamus carolinensis</td>
<td>0</td>
<td>385 (52%) 17.9 ± 19.5 beetles/m²</td>
</tr>
</tbody>
</table>

(Fagaceae), and eastern white pines, *Pinus strobus* Linnaeus (Pinaceae) (oaks ~ 40 years old, pines ~ 50 years old; average diameter of trunk [±1 SD] at 1 m: 27 ± 7 and 23 ± 2 cm, respectively). During 6–19 July 2005, we felled six oaks and cut them into 81 bolts (63 from trunk, 18 from branches, mean diameter 0.17 ± 0.08 m, length 0.79 ± 0.16 m). Bolt diameter was strongly autocorrelated with bark thickness (adjusted $r^2 = 0.56$, $P < 0.0001$). We felled three pines and cut them into 72 bolts (42 from the trunk, 30 from branches, diameter 0.12 ± 0.07 m, length 0.8 ± 0.17 m). We confirmed that few adult insects emerged from the bolts during 2005 by enclosing a subset (two oak, three pine bolts) in aluminium screen (2mm mesh) in early fall. Neither adult beetles nor parasitoids emerged from those bolts until the following spring. In April 2006, we enclosed the remaining bolts in screen, individually wrapping large bolts from trunk and larger branches (>0.1 m in diameter), but wrapping smaller bolts (<0.08 m) together in groups of 3–7 ($n = 3$ and six groups of the smaller bolts for oaks and pines, respectively). Wrapped bolts were checked for insects weekly through September 2006.

We reared from the bolts 1066 cerambycid beetles of four species (Table 1). Of the 81 oak bolts, 70 (86%) produced beetles, of which 98% were *Graphisurus fasciatus* (De Geer) and the remainder *Xylotrechus colonus* (Fabricius) (Table 1). Males and females did not differ in emergence period ($t$-test of mean ordinal dates of emergence, $t = 0.13$; df = 442; $P > 0.1$). It is notable that 11 of the 13 adult *X. colonus* emerged from three oak bolts that produced no *G. fasciatus*, suggesting that larvae of the two species compete aggressively. Cerambycid larvae can be opportunistic predators of other wood-boring insects (e.g., Dodds *et al.* 2001).

Density of adult *G. fasciatus* (number of beetles per unit bark area) was positively, though weakly, correlated with bolt diameter (Fig. 1A; regression analysis, adjusted $r^2 = 0.24$; $F_{1,67} = 21.8$; $P < 0.0001$), suggesting that adult females preferred to oviposit into larger bolts, and/or that survivorship of larvae was greater in such bolts. Other studies of cerambycids also have reported greater rates of oviposition and enhanced survivorship in larger bolts (e.g., Hanks *et al.* 2005). Larger bolts may accommodate greater numbers of larvae because they offer thicker phloem and cambial tissue for the larvae to feed (Hanks *et al.* 2005). Body size of *G. fasciatus* (length of right elytron) was positively, but weakly correlated with the diameter of their natal bolts (best fit regression equation: $Y = 0.002X + 0.0077$; adjusted $r^2 = 0.012$; $F_{1,506} = 7.13$; $P = 0.0078$).

Of the 72 pine bolts, 44 (61%) yielded adult *Monochamus carolinensis* (Olivier) (95% of beetles), and *Astylopsis sexguttata* (Say) (Table 1). Of the latter species, 86% emerged from three different groups of smaller branches, however, densities were not significantly different between bolts cut from branches or from the trunk (means ± SE: 1.88 ± 1.1 and 0.22 ± 0.18 beetles/m² of bark surface for branches and larger bolts, respectively; Kruskal–Wallis $Q_{1,60} = 2.5$, $P = 0.11$).

Densities of *M. carolinensis* were greatest in logs of intermediate size, although the correlation was weak (Fig. 1B; regression analysis,
adjusted $r^2 = 0.21; F_{3,51} = 5.49; P < 0.0025$). A similar parabolic relationship has been reported for a different Monochamus Dejean species (Zhang et al. 1993). Fewer beetles may have emerged from the largest logs because their thick bark hindered oviposition, as has been reported for $M. \text{carolinensis}$ in an earlier publication (Walsh and Linit 1985). Consistent with $G. \text{fasciatus}$, body size of $M. \text{carolinensis}$ was positively, but weakly correlated with diameter of pine bolts (best fit regression equation: $Y = 0.007X + 0.014$; adjusted $r^2 = 0.09; F_{1,190} = 20.8; P < 0.0001$).

Very few adult parasitoids emerged from oak bolts, with an overall parasitism rate (i.e. number of parasitoids/total number of insects) of 0.88%. This finding was surprising, given the high densities of beetle larvae in many bolts, and the fact that they had been exposed to the parasitoid community for several months. From oak bolts we reared the braconids (Hymenoptera: Braconidae) $Atanycolus$ Förster species (a species similar to $Atanycolus \text{charus}$ (Riley) (two females) and $Wroughtonia \text{ferruginea}$ (Brues) (one of each sex), and an ichneumonid
(Hymenoptera: Ichneumonidae) in the genus *Demopheles* Förster (two females). Voucher specimens were deposited in the Insect Collection of the Illinois Natural History Survey, Champaign, Illinois, United States of America. Parasitism rate for beetles that emerged from pine bolts averaged $5.3 \pm 8.6\%$, including a braconid in the genus *Digonogastra* Viereck (one female), and the tachinid fly (Diptera: Tachinidae) *Billaea monohammi* (Townsend) (28 adults, approximately equal numbers of females and males). *Billaea* Robineau-Desvoidy species are known to parasitise larvae of a different *Monochamus* species (Allison *et al.* 2000).

Wood-boring insects can be shielded from parasitoids by the woody tissues of their hosts (*e.g.*, Hanks *et al.* 2001). In our study, however, the parasitism rate of *M. carolinensis* was not correlated with the diameter of pine bolts (regression $P > 0.05$). Very low rates of parasitism also have been reported for other species of cerambycid beetles (*e.g.*, Bashford 1994).

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**References**


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