Silvicultural methods of *Lymantria dispar* L. management: effects on *Agrilus bilineatus* (Weber) populations

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ABSTRACT The abundance of twolined chestnut borer, *Agrilus bilineatus* (Weber), adults were sampled using sticky panels over a 6-year period in a mixed hardwood forest in West Virginia. Sixteen stands (average size 10.5 ha) were used in the study; eight of these were silviculturally thinned in 1989, the remainder were uncut. During 1990 and 1991, populations of gypsy moth, *Lymantria dispar* L., reached outbreak levels. Densities of *A. bilineatus* adults peaked in 1992, the year following the second defoliation year (1992), and were always greater in thinned than unthinned stands, however overstory mortality was greater in unthinned stands. Correlations between twolined chestnut borer abundance and tree mortality were not strong, nor were the relationships between defoliation and twolined chestnut borer.

KEY WORDS *Agrilus bilineatus*; silviculture; mortality; *Quercus*; defoliation

FOR AT LEAST the past 100 years, the two-lined chestnut borer, *Agrilus bilineatus* (Weber), has been recognized as a significant source of mortality to oaks(*Quercus* spp.*)* and to American chestnut, *Castanea dentata* (Chittenden, 1909, Haack and Acciavatti 1992). *Agrilus bilineatus* is frequently associated with trees that have been stressed through defoliation. As a major cause of defoliation for hardwood trees in the Northeastern United States, *Lymantria dispar* L. (gypsy moth), provides an initial stress to its preferred hosts, i.e. *Quercus,* and has been followed by *A. bilineatus* and *Armillaria mellea* as secondary mortality agents (Wargo 1977).

Silvicultural approaches to managing gypsy moth impacts have been proposed several times over the last 100 years (Fisk 1913, Clement and Munro 1917, Behre 1939, Bess et al. 1947, Gottschalk 1993). The intent of this approach is to minimize damage if defoliation does occur or reduce the likelihood of defoliation. Few studies have examined the effect of silviculture on the secondary mortality agents of gypsy moth host trees. The objective of this study was to determine if silvicultural treatments affected *A. bilineatus* adult population densities. Because portions of the study area was defoliated by the gypsy moth, we were also able to examine the relationships among *A.bilineatus* abundance, defoliation, and tree mortality.

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Methods

The study took place on the West Virginia University Forest (WVUF), located in Monongalia and Preston Counties, West Virginia. This oak-mixed hardwood forest (ca. 3075 ha) is along the Chestnut Ridge anticline, in the Appalachian Plateau physiographic province (Fenneman 1938). Average elevation of the WVUF is 591 m, but ranges from 318 m to 796 m. Overstory vegetation ranges from stands with a diverse assemblage of mixed-hardwood species to those dominated by oak. Variation in composition of overstory tree species corresponds in part to elevation -- percentage of oak increases with elevation. The 16 forest stands studied ranged in size from 7.8 to 12.6 ha, with an average size of 10.5 ha. The stands were physically selected to be arranged as eight pairs; one of each pair was thinned.

Within each stand, square plots (0.4 ha) were located within a stratified grid; each plot was separated by at least 100 m . Stands had 10 to 19 plots, depending on their size. The boles of two oaks associated with each stand were wrapped with a cardboard band impregnated with resin and coated with Tanglefoot™. Bands were 22.9 cm wide and were place at 1.4 m above ground. The bands were placed on trees in mid-May, and the diameter, species and vigor condition of the tree were recorded at that time. Bands were removed in mid-August at which time all adult *A.bilineatus* were removed and counted. The number of *A.bilineatus* adults / m^2 were calculated to adjust for the diameter of the tree.

Bands were first deployed in 1989 and the study continued until 1994. No data were collected in 1990, however. During the winter of 1989-90, 8 of the 16 stands were thinned to reduce susceptibility or vulnerability to the gypsy moth. During 1990 and 1991, six stands (three thinned and three unthinned) were defoliated by gypsy moth. Each of the six stands incurred more than 50% defoliation of preferred species and more than 40% defoliation of all species for 2 years. Defoliation in the other stands, i.e. background defoliation level, was less than 15% of all species, including preferred. The data on *A. bilineatus* from 1989, then, represents base-line information prior to treatment or defoliation effects.

Results and Discussion

When grouped by treatment, it is apparent that 1989 levels of *A. bilineatus* were similar among all stand types (Table 1). However, following defoliation in 1990 and 1991, the abundance of *A. bilineatus* increased significantly in the defoliated stands. Relative to control stands, the thinned stands also showed an increase in *A. bilineatus* populations in 1991, presumably due to the thinning effect, i.e. thinning may have damaged or stressed some trees, thereby attracting the insect (Dunn et al. 1986). Despite an increase in *A. bilineatus* in thinned stands, mortality of overstory species was minimal for stands that were not defoliated.

Table 1. Average number of *Agrilus bilineatus* in each of four treatments in West Virginia University Forest. The first year of defoliation was 1990, and silvicultural thinnings took place during the winter of 1989 - 1990.

Treatment	1989 #/m^2	1991 #/m^2	1992 #/m^2	1993 #/m^2	1994 #/m^2
Thinned	8.68	30.36	50.87	19.14	2.82
Control	12.33	3.27	16.96	20.19	6.90
Defoliated	5.69	85.78	533.34	92.89	4.47
Defoliated and Thinned	11.91	111.23	899.31	65.64	7.65

Figure 1 describes the temporal pattern of defoliation, abundance of *A. bilineatus* and overstory mortality. These data represent the pair of stands that was most heavily defoliated, but the trend resembles that of the other defoliated stands. Although defoliation was comparable in both thinned and unthinned stands, the abundance of *A. bilineatus* was greater in the thinned stand, however, overstory mortality was greater in the unthinned stand. One possibility for the lower mortality in thinned stands is the overall increased vigor of the trees. Because the objective of the thinning was to remove trees of low vigor, residual overstory trees generally were more healthy in thinned than unthinned stands. Attacks of *A. bilineatus* may not have been successful in healthy trees, thus there was no resulting increase in mortality. Further, the greater number of borers in thinned stands also may represent a higher concentration of *A. bilineatus*, i.e., more borers but on fewer trees.

Abundance of *A. bilineatus* reached a maximum in 1992, but most of the overstory mortality occurred in 1991. The high population level resulted from the tree stress as a result of high levels of defoliation in 1990 and 1991. The pulse in mortality in 1991 reflected an increase in successfully attacked trees, that is, the large number of trees from which adult borers emerged. As a result of the mortality, the number of available hosts declined in subsequent years, contributing to a decrease in *A. bilineatus* abundance.

To understand the relationship between *A. bilineatus* and defoliation and the relationship between the insect and overstory mortality, we derived correlation coefficients using 1992 data on *A. bilineatus* with defoliation and mortality data for various years. The relationships between the borer and defoliation (Table 2) generally were weak, and often inverse. Correlations between 1992 levels of *A. bilineatus* and defoliation in were relatively strong only for stand 8 in the three defoliation years.

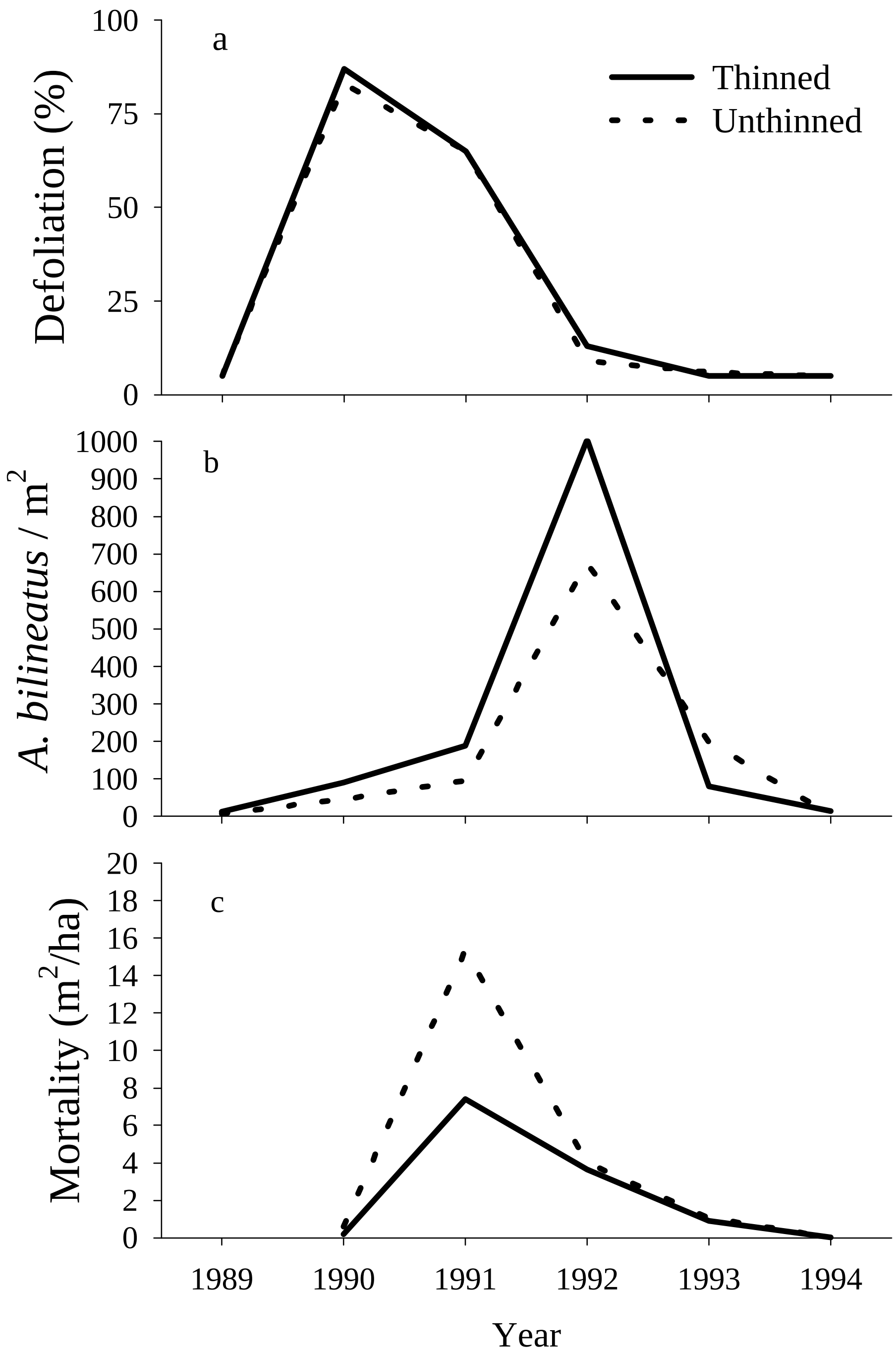

Figure 1. Trends in a pair of defoliated stands from 1989 to1994 on the West Virginia University Forest in (a) defoliation of overstory trees (b), abundance of *Agrilus bilineatus* (c), and overstory mortality.

Table 2. Pearson correlation coefficients of 1992 plot-level abundance of *Agrilus bilineatus* and defoliation.

	Defoliation year		
Stand No.	1990	1991	1992
7	-0.143	-0.549	-0.185
8	0.409	0.801	0.630
13	0.093	-0.155	0.072
14	-0.103	-0.529	-0.275
15	-0.252	0.084	0.268
16	-0.141	0.190	0.065

The relationship between *A. bilineatus* and overstory mortality generally was better than those with defoliation (Table 3). The highest correlations were between 1992 *A. bilineatus* and 1993 mortality in stand 8, and between 1992 *A. bilineatus* and 1992 mortality in stand 15. Given the life history characteristics of the insect, it is not surprising to find a good relationship between *A. bilineatus* abundance in one year and with overstory mortality in the next. However, *A. bilineatus* abundance rarely accounted for mortality in the same year unless populations have been increasing in the previous year. In stand 15 there was a strong relationship between 1992 borer abundanse and tree mortality for all three years: 1991, 1992, 1993. Some trees may take up to 3 years to die following inital attack by *A. bilineatus* (Haack and Acciavatti 1992). Thus, the pattern could be consistent for several years in succession. The most notable finding was the lack of a relationship between *A. bilineatus* and overstory mortality in most stands, for most years. These coefficients were generated using plot-level data, so it is possible that the plot-level relationship is insufficient to explain the dynamics of *A. bilineatus* in these stands. The plot and stand-level correspondence of borer abundance with defoliation and mortality may have more to do with attraction, dispersal, and aggregation – variables not addressed here.

Table 3. Pearson correlation coefficients of 1992 plot-level abundance of *Agrilus bilineatus* and mortality for stands that were defoliated.

	Mortality Year				
Stand No.	1990	1991	1992	1993	1994
7	-0.348	-0.417	0.186	-0.371	0.000
8	-0.302	0.368	0.715	0.895	-0.231
13	-0.341	-0.246	0.211	0.017	-0.203
14	0.330	0.016	0.446	-0.405	0.381
15	-0.393	0.550	0.752	0.555	-0.231
16	-0.140	-0.091	-0.001	-0.332	0.006

The abundance of *A. bilineatus* was consistently greater in thinned than in unthinned stands. The likely reason for this is stress from the logging operation, namely damage to residual trees or soil compaction. Several studies have shown that injured oaks attract more adult borers than uninjured oaks (Dunbar and Stephens 1975, Cote and Allen 1980, Haack and Benjamin 1982). Another possible explanation for an increase in *A. bilineatus* abundance in thinned stands is an increase in light in the canopy which in turn caused an increase in adult activity in thinned stands. Although thinning may promote activity of adult *A. bilineatus* and subsequent population buildup, it does not result in corresponding overstory mortality. Under circumstances where stress is minimal, and defoliation is not imminent, reducing overstory trees of low vigor and low starch reserves (Dunn *et al*. 1990), may keep populations of twolined chestnut borer low, in addition to reducing overstory mortality.

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