Effects of Thinning on Development of Southern Pine Beetle Infestations in Old Growth Stands

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ABSTRACT: *A study was conducted to quantify the relationship between southern pine beetle infestation growth and the intertree spacing in old growth pine stands. The problem with extrapolating the results of previous studies to old growth stands is that it is unclear whether the same mechanism will operate in stands of older trees characterized by double the diameter (20–25 cm vs. 40–60 cm). In this study we focused on experimentally answering the question of how three levels of thinning (resulting in different average intertree distances) affect the rate of SPB infestation growth in mature loblolly pine stands, over 60 yr old and over 40 cm average dbh. We also included a hardwood removal treatment. Both intermediate and severe thinning had a strong negative effect on the rate of infestation growth. The effects of intermediate and severe thinning were similar; there was no statistically detectable difference between these two treatments. Hardwood removal appeared to decrease infestation growth rate compared to no thinning, but this effect was not statistically significant. South. J. Appl. For. 23(4):193–196.*

With an emphasis on managing public lands for multiple values, including recreation, esthetics, biological diversity, and water quality, as well as timber production, Land and Resource Management Plans in the USDA Forest Service Southern Region contain provisions for longer than traditional (i.e., up to 100–150 yr) rotation of pines. Existing old-growth communities in southeastern forests are relatively rare, making up less than 1% of total forest area (USDA Forest Service 1997). Efforts are underway to restore this threatened component of forest ecosystems in the southern United States. One reason for seeking to restore and maintain "old-growth" pine stands is to increase habitat for wildlife species, such as the red-cockaded woodpecker (*Picoides borealis* Vieillot), which require older, larger pines for nest cavity excavation (Hooper et al. 1980). Mature pines are known to be susceptible to attack by southern pine beetle (SPB, *Dendroctonus frontalis* Zimmermann) (Kozlowski 1971, Lorio 1993). Numerous studies have shown that the probability of SPB attack may be reduced by thinning, lower density and stocking (see Nebeker et al. 1985 and references therein), but very little is known about the influence of thinning on SPB development in old-growth stands.

It is particularly important to quantify the relationship between SPB infestation development and the intertree spacing in pine stands. Earlier work by Gara and Coster (1968), Coster and Gara (1968), and Johnson and Coster (1978) suggested that the only trees attacked are those situated within critical distance from a pheromone source (an attractive mass-attacked host tree). This distance was estimated as 6–8 m. The problem with extrapolating the results of these authors to old growth stands is that their work was conducted in stands characterized by trees with average diameter at breast height (dbh) of 20–25 cm. It is unclear whether the same mechanism will operate in stands of older trees characterized by double the diameters (40–60 cm). In addition, previous studies indicated that the

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spacing threshold below which SPB attack is impeded is affected by the population level of SPB (e.g., endemic vs. epidemic) (Johnson and Coster 1978). Older, larger trees, after succumbing to SPB attack, are likely to be more significant sources of new SPB adults than smaller trees, because larger trees have larger surface area of bark. This is another reason to question whether the relationship between pine spacing and SPB infestation development will be unchanged in old growth stands.

Thinning may affect two aspects of SPB infestation dynamics: the probability that a SPB infestation would be initiated, and the rate of infestation spread (the number of trees killed per infestation over time). Although use of these terms is inconsistent throughout the literature, these processes may be equated to risk or likelihood of infestation and hazard or vulnerability to infestation (Coulson and Witter 1984, p. 244). In this study, we focus on the second process, by attempting to experimentally answer the question of how various degrees of thinning (resulting in different average intertree distances) affect the rate of SPB infestation growth. Our approach was to apply three thinning treatments (none, intermediate, and severe) to randomly selected experimental stands, induce SPB attack within each experimental stand, and then measure the resulting rate of SPB infestation expansion. Because management for the federally listed endangered red-cockaded woodpecker calls for removing the hardwood component from foraging areas (USDA Forest Service 1995), we included a hardwood removal treatment.

Methods

During 1992 we located five stands within the Homochitto Ranger District of the National Forests in Mississippi. The requirements for these stands were that they be approximately 60 yr old and have a basal area of 25–28 m^2/ha with a relatively homogeneous cover of pine uninterrupted by roads, hardwood stringers, old SPB infestations, and no narrower than 74 m at any point. Within each stand we selected four experimental areas of approximately equal size with a mean area of 0.92 ha and a standard deviation of 0.11 ha. Stand composition was predominantly loblolly (*Pinus taeda* L.), older than 50 yr old (50–70), and average dbh greater than 40 cm. Hardwoods included several species of oak (*Quercus* spp.), hickories (*Carya* spp.), sweetgum (*Liquidambar styraciflua* L.), blackgum (*Nyssa sylvatica* Marsh.), red maple (*Acer rubrum* L.), and flowering dogwood (*Cornus florida* L.). In February through May of 1993, each of the experimental areas was randomly assigned to one of the following four treatments:

1. No manipulation (control). Approximately 25–28 m^2/ha pine basal area (BA) and approximately 9 m^2/ha hardwood BA characterized these stands.

2. Intermediate thinning. One-quarter of pine stems was removed, resulting in 21 m^2/ha pine BA. All hardwoods were retained.

3. Severe thinning. One-half of the pine stems was removed, resulting in 14 m^2/ha pine BA. All hardwoods were retained.

4. Hardwood removal. All pine stems were retained. All hardwoods were removed.

Pine thinning was achieved through a commercial sale Research personnel with hand tools performed hardwood removal. During the winter of 1993–1994, one stand was severely affected by tornado damage. Because a number of trees that were downed within the experimental plots, effectively changing the basal area, this stand was dropped from the study.

One year after thinning, on March 11, 1994, a centrally located pine tree was baited with a mixture of SPB aggregation pheromone (frontalin) and turpentine (as described in Schowalter and Turchin 1993), in each experimental plot within three of five stands. Within a week, all baited trees were successfully attacked by SPB, at which point the bait was removed, and the growth of the infestation was allowed to proceed naturally. All stands were monitored at biweekly intervals, and on August 4, 1994, infestation growth was quantified by counting all trees that were successfully killed by SPB. We estimated the average rate of infestation growth per month as a log-transformed ratio of number of killed trees on August 4 to the initial size (1 tree) on March 11, divided by total duration of the experiment (4.8 months) The reason for scaling infestation growth rate per unit time is to make possible comparisons between our results and infestation growths observed by other investigators under different conditions.

SPB activity southwide was relatively low in 1994 compared to preceding and succeeding years of outbreak (1992 through 1995). However, in the six county area that encompasses the Homochitto NF, SPB activity remained relatively high throughout the outbreak period, and infestations per 400 ha of host type ranged from 1 to 3 and above in 1993 and 1994 (Price et al. 1998).

The fourth stand was not baited until June. Only one tree of the baited focus trees was successfully attacked, and as a result, this stand was dropped from further analyses. The probable explanation for this failure is that it appears that the tree baiting technique must occur sufficiently early in the SPB flight season to increase the probability that an infestation will develop. In fact, in July 1993, we attempted to initiate infestations using introduction of infested bolts in addition to baiting. We were unsuccessful in generating successful infestations despite the recent site disturbance and relatively high beetle populations in the area. Schowalter and Turchin (1993) observed the same pattern. During the first year of that study, infestations were initiated in mid-summer with very little infestation growth. During the second year, infestations were initiated in the spring, and infestation development was more substantial.

The effect of thinning on the infestation growth rate (as defined above) was analyzed by ANOVA (SAS Institute Inc 1982). The planned comparisons were (1) controls vs. the three treatments, and (2) intermediate vs. severe thinning

Table 1 Total number of trees killed and currently under attack at the termination of the study, and average rate of infestation growth per month by stand for southern pine beetle infestations in old growth loblolly pine.

	Treatment	Residual BA (ca. m^2/ha) Pine	Hardwood	No. trees dead	No. trees attacked*	Infestation growth rate per month†
Stand 1	Control	25–28	9	68	0	0.88
(1923)††	Intermediate	21	9	3	0	0.23
(43.9 cm)§	Severe	14	9	4	0	0.29
	Hardwood	25–28	0	19	0	0.61
Stand 2	Control	25–28	9	12	2	0.52
(1920)	Intermediate	21	9	2	0	0.14
(40.4 cm)	Severe	14	9	3	1	0.23
	Hardwood	25–28	0	4	4	0.29
Stand 3	Control	25–28	9	40	0	0.77
(1933)	Intermediate	21	9	13	0	0.53
(41.5 cm)	Severe	14	9	3	1	0.23
	Hardwood	25–28	0	4	2	0.29

* Trees under attack at the termination of the study could pitch beetles out.
† Average rate of infestation growth per month (number of killed trees divided by duration of experiment; see text for details).
†† Stand origination year.
§ Mean dbh.

Results

Effective treatments were carried out in three mature loblolly pine stands originated between 1920 and 1933 (Table 1) Both the intermediate and severe thinning had a strong negative effect on the rate of infestation growth (Table 1). The effect of intermediate thinning was marginally significant (t-test, $P = 0.06$), while the effect of severe thinning was highly significant (t-test, $P = 0.01$) (Table 2). The effects of intermediate and severe thinning were similar, and there was no statistically detectable difference between these two treatments ($P = 0.68$). Interestingly, hardwood removal appeared to decrease infestation growth rate compared to no thinning, but this effect was not statistically significant ($P = 0.1$).

Discussion

Within the Southern Region, the definition of old growth differs among forest community types, and criteria include age, size, stand density, and basal area, and depend on the attributes of physiography. Among pine communities, age varies between 80 for slash pine (*P. elliottii*) to 110 yr for longleaf (*P. palustris*) (USDA Forest Service 1997). Only one definition for loblolly is included in this recent report of the Region 8 Old Growth Team, which is for the Piedmont with an age of 79–189 yr and dbh of 30–99 cm. It has long been a concern of the forest manager, as pine rotations lengthen to achieve values of old growth, that the hazard rating systems give erroneous recommendations in mature pine stands due to the basal area per large stem diameter. These systems were developed more than 20 yr ago when the average of the southern forest was less than 50 yr old. According to these systems, mature stands (>50 yr old and large diameter) are rated as medium or high hazard, and following hazard reduction recommendations, these stands should be thinned to below desirable stocking levels. Our study is the first to address this apparent conflict. We provide experimental evidence to support the hypothesis that moderate thinning is sufficient to reduce the hazard, or the rate of bark beetle infestation expansion, in mature pine stands ≥ 60 yr old) to acceptable levels.

As has been observed and demonstrated in previous studies (Brown et al. 1987, Schowalter and Turchin 1993) in younger stands of smaller dbh, these results clearly show a strong effect of thinning on the growth rate of SPB infestations within old-growth stands. Regression of infestation size on the degree of thinning (excluding the hardwood removal treatment) was highly statistically significant (Table 1). The magnitude of the effect is striking—an order of magnitude

Table 2. Statistical tests for effect of thinning treatments on SPB infestation growth rate—ANOVA and *t*-test comparisons.

ANOVA	*SS*	*df*	MS	*F*	*P*-level
Effect	2.458	3	0.819	29.14	0.00012
Error	0.225	8	0.028		

T-test Contrasts	MEAN 1	MEAN 2	*t*-value	*df*	*P*
Control vs. intermediate	0.722	0.302	2.632	4	0.058
Control vs. severe	0.722	0.249	4.352	4	0.012
Control vs. hardwood	0.722	0.397	2.139	4	0.099
Intermediate vs. severe	0.302	0.249	0.444	4	0.680

difference between mean infestation size of severe thinnings and controls. Pairwise comparison suggests that controls and intermediate thinnings are significantly different, but intermediate and severe thinnings are not (Table 2). In fact, apart from the intermediate treatment in Stand 3, intermediate and severe treatments resulted in very similar infestation sizes (Table 1). This suggests that intermediate thinning should be sufficient in most situations to reduce SPB infestation growth. This conclusion, however, should be viewed as tentative at this point, given the limited number of replicates presented here. In addition, these results pertain only to the growth of small (one tree) infestations. Others (Gara and Coster 1968, Johnson and Coster 1978, Schowalter et al. 1981) have found that SPB infestation size influences the success (subsequent growth) of an infestation. Similarly, intertree distance has been shown by these same researchers to play a critical role in infestation expansion. We did not measure intertree distances from our initial one-tree infestation. Clumped distribution of trees in stands is natural and especially likely in old-growth stands, and clumpiness could have influenced infestation size in this study. However, our goal, in keeping with constraints on the forest manager, was manipulation of the average spacing (intertree distance) by removal of a given proportion of trees, rather than trying to achieve a uniform basal area—a virtual impossibility.

The effects of thinning, which underlay the decrease in stand vulnerability, may include reduced competition among trees, greater dispersal or host location distances for beetles, in addition to other alterations of the stand environment (e.g., Gara and Coster 1968, Johnson and Coster 1978, Brown et al. 1987, Schowalter et al. 1981). The removal of hardwoods tests the concept of "resource concentration" (e.g., Kareiva 1983) employed in agricultural pest management program where interplanting nonhost species is used to reduce pest damage. Surprisingly, the hardwood removal treatments resulted in relatively low infestation growth compared to the control stands. However, among the thinned treatments, hardwood removal plots suffered the highest mean infestation size. These results are seemingly inconsistent with other observations and experimental studies (Schowalter and Turchin 1993), but may be indicative of the greater benefits gained by these large pines from reduced competition in ability to fend off mass attack despite increased probability of discovery. Presumably, all things being equal, a higher number of beetles are required to overwhelm a large vs. small diameter tree. In their study of 30–40 yr-old stands, Schowalter and Turchin (1993) found a significant interaction between pine and hardwood basal area. They showed that high densities of both pines and hardwoods did not increase the stand vulnerability to southern pine beetle infestation growth compared to low density pine with or without hardwood; however, high density pine/low density hardwood stands experienced a higher number of trees killed than all other treatments in both years of the study. Conner and Rudolph (1991) have also reported an apparent association between SPB infestations and RCW clusters which have been subjected to the midstory removal mandated by the RCW recovery plan (USDI Fish and Wildlife Service 1985, USDA Forest Service 1995). The interaction between pine and hardwood BA relative to SPB activity is clearly an area that warrants further investigation.

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