THINNING SOUTHERN BOTTOMLAND HARDWOOD STANDS: INSECT AND DISEASE CONSIDERATIONS

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Abstract: The effects of thinning on insects and diseases have not been thoroughly examined in southern bottomland hardwood forests. To address this issue, a study was initiated at sites in Mississippi and Alabama. These study sites allowed us to make observations concerning insect and disease activity 1-5 years following thinning. On all sites there was an unthinned control and 1 or more thinned areas. Mississippi study sites received only 1 type of thinning treatment, whereas sites in Alabama were subjected to 3 different thinning treatments: (1) light thinning to 70-75% residual stocking, (2) heavy thinning to 50-55% of residual stocking, and (3) B-line thinning to a desirable residual stocking for bottomland hardwoods (Putnam et al. 1960). Study sites in Mississippi were surveyed for insects and diseases before and after thinning operations. Woodboring beetles (Coleoptera: Buprestidae, Cerambycidae, Scolytidae, and Platypodidae) were of primary interest as some species are associated with tree mortality and wood-degrade. Signs and symptoms of pathogens associated with rot and/or decay were tabulated. Potential effects of insects and diseases should be of interest and concern to resource managers. We report here on the numbers of insects and diseases recorded during individual tree surveys, as well as on the results of insect sampling conducted in thinned and unthinned stands. Observations on tree wounding, as a result of thinning, are reported. Conclusions and hypotheses will be drawn and stated as to the management and ecological significance of these findings. Directions for future investigations also will be recommended.

Keywords: disease, pathogens, thinning, tree wounding, woodboring beetles.

Management of hardwood forests in the southern USA is intensifying, as economic opportunities increase. Conversely, forest management activities are, at the same time, becoming less intense in other areas as societal values are considered. In particular, interests in ecosystem management, forest health, and habitat restoration are increasing. There also is considerable interest in the sustainability of southern forests for purposes of producing fuel, fiber, lumber products, and chemicals. As a result of these latter interests, and in connection with broader ecological interests, the effects of harvesting, periodic flooding (including greentree reservoirs), and fire are of concern (Nebeker et al. 1998). In each case, insects and disease-causing organisms have increased or decreased opportunities to affect a residual stand as various physiological stresses are added to or removed from the system. Consequently, there is a growing demand to understand these complex relationships.

The relationship between silvicultural practices, (e.g., thinning, and pest organisms including insects and diseases) has been investigated extensively in pine forests but to a lesser degree in hardwood forests. Thinning guidelines, with pest management recommendations, have been developed for pine stands (Nebeker et al. 1985). Similar information regarding the broader effects that silvicultural practices have on assemblages of pest species populations within southern bottomland hardwoods is lacking.

Our objective was to investigate the potential positive and negative aspects of thinning southern bottomland hardwood stands in relation to insect and pathogen populations. Of critical interest were the effects on the residual stand resulting from insect damage and diseases that develop as a consequence of thinning practices. This is especially important with the increasing economic opportunities now developing in southern forests. The effect of stand modification practices on current or potential pest problems will be discussed with respect to current and past research concerning insects and diseases. Management approaches will be suggested that will help minimize losses from insects and diseases.

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STUDY AREAS

This study was conducted in 4 bottomland hardwood stands located in northeastern and southwestern Mississippi and western Alabama. Two study sites were established in Mississippi; 1 within the Delta National Forest (Sharkey County) and a second on a privately owned bottomland hardwood stand in Monroe County. Thinning treatments at both sites were performed in 1997. In Alabama, 2 study sites were established in bottomland hardwood stands on land owned by Gulf States Paper Corporation. The Alabama sites were located near Aliceville in Pickens County and Demopolis in Marengo County. Thinning at the Aliceville site took place September 1994, while thinning treatments near Demopolis were performed September 1995.

METHODS

Plot Design and Thinning Treatments

At the Delta National Forest, 2 rectangular 0.96-ha treatment areas were established in Compartment 38. Treatments consisted of an unthinned control and a commercial thinning. Both treatment areas were divided into four 0.24-ha measurement subplots and surrounded by a 19.8 m buffer strip. Measurement subplots were further subdivided into 6 square 0.04-ha sectors for ease of measurement. Corners of all sectors and of the measurement subplot were permanently marked with PVC pipe driven into the ground. All 48 sectors were established and inventoried prior to the commercial thinning. The second Mississippi study site in Monroe County had been thinned in 1997, with the remainder left unthinned (control). No measurement plots were established at this site and stands were simply identified as unthinned or thinned.

At each of the 2 study sites in Alabama, 12 rectangular 0.8-ha treatment plots were established as previously described by Meadows and Goelz (1998). One 0.24-ha measurement subplot was established in the interior of each treatment plot and was surrounded by a 19.8 m wide buffer strip. Each measurement subplot was divided into 6 0.04-ha^2 sectors for ease of measurement. All corners were permanently marked with PVC pipe driven into the ground. Thinning intensity was defined by 3 levels of residual stocking, based on the stocking guide for southern bottomland hardwoods developed by Goelz (1995). The study consisted of an unthinned control and 3 treatments: (1) light thinning to 70-75% of residual stocking; (2) heavy thinning to 50-55% of residual stocking; and (3) B-line thinning to a desirable residual stocking following partial cutting in well-managed, even-aged southern bottomland hardwoods, as recommended by Putnam et al. (1960). The thinning operation (Meadows and Goelz 1998) consisted of a combination low thinning and improvement cutting in which the objective was to remove most of the pulpwood-sized trees as well as sawtimber-sized trees that were damaged, diseased, of poor bole quality, or of an undesirable species. Hardwood tree classes, as originally defined by Putnam et al. (1960) and modified by Meadows (1996), formed the cutting priority for each treatment. Trees were removed from the cutting stock and cull stock classes first and then from the reserved growing stock class, if necessary, until the target residual stocking was met.

Pre-thinning Inventory

Pre-thinning inventory determined tree species composition, initial stand density, insect activity, and numbers of diseases. The following variables were measured on all trees greater than, or equal to, 13.75 cm diameter at breast height (dbh): species, dbh, crown class, tree class, vigor classes, number of epicormic branches, length and grade of sawlogs, and number of insect and disease signs and symptoms. Locations of sample trees within their respective plots were recorded using an x-y coordinate system. An individual number was painted on each tree at about breast height (bh), and a tag was nailed to the base of each tree. A dot also was painted on each tree at bh to assure consistency in measuring dbh. Primary tree species in the areas are sweetgum (*Liquidambar styraciflua*), willow oak (*Quercus phellos*), Nuttall oak (*Q. nuttallii*), cherrybark oak (*Q. pagoda*), southern red oak (*Q. falcata*), Shumard oak (*Q. shumardii*), shagbark hickory (*Carya ovata*), mockernut hickory (*C. tomentosa*), sugarberry (*Celtis laevigata),* and various elms (*Ulmus spp.).* Other species scattered throughout the stands included white oak (*Q. alba*), swamp chestnut oak (*Q. michauxii*), overcup oak (*Q. lyrata*), and green ash (*Fraxinus pennsylvanica*).

Post-thinning Inventory

Post-thinning inventory was conducted in the same manner as the pre-thinning inventory except that additional data were collected concerning thinning related wounding to the canopy, upper-bole (above bh), lower-bole (below bh but above the root collar zone), root collar, and roots. Commonly

Table 1. Percentages of total numbers of trees, insect borer wounds, and disease indicators (signs and symptoms), by tree species, resulting from the summer 1997 pre-treatment survey of the unthinned plot and the plot designated to be thinned in Compartment 38 of the Delta National Forest, Mississippi, 1997.

Tree Species	Percent of total trees	Percent of total borer indicators	Percent of total disease indicators
Unthinned plot			
Sweetgum	51.7	1.3	24.4
Willow oak	28.3	59.9	46.3
Nuttall oak	9.2	28.3	14.6
Sugarberry	5.4	0	9.8
Other	5.4	10.4	4.9
Plot designated to be thinned			
Sweetgum	47.4	8.7	10.7
Willow oak	29.4	39.1	71.4
Nuttall oak	6.6	39.4	7.1
Sugarberry	5.4	0	0
Other	11.4	12.8	10.7

encountered insect signs and symptoms consisted of: insects themselves in various life stages, frass, bore holes, boring dust, scarring (resulting from callus tissue growing over entrance or exit holes), and galleries. Disease signs and symptoms commonly seen included slime flux (weeping or oozing indicative of bacterial wetwood), stained wood, fruiting bodies such as conks and mushrooms, cankers, and fungal mats.

Insect Sampling and Analysis

Townes-style Malaise traps were installed in unthinned and thinned stands at both the Delta National Forest and Monroe County sites, with 1 trap per stand. Malaise traps are tent-like structures that passively trap flying insects and funnel them up into a collecting head filled with a killing agent/preservative. Malaise trap were chosen due to their efficiency in collecting low-flying beetles (Hutcheson 1990), and their ability to provide characteristic beetle samples of specific sites (Hutcheson and Jones 1999). Woodboring beetles were sampled at the Delta National Forest from 20 August to 9 October 1997 shortly following thinning. Sampling at the Monroe County site was conducted from 1 April to 31 October 1998, 1 year following thinning. The collecting heads of all Malaise traps were filled with 70% ethanol as a killing agent/preservative. Traps at both sites were serviced at 1-2 week intervals. Black-light traps also were utilized and were run 1 night a month from August to October 1997 at the Delta National Forest only. Insects collected from both sites were sorted and stored in vials containing 70% ethanol. Specimens belonging to specific woodboring beetle families were removed from the samples and identified to species. Families of interest included the Cerambycidae (longhorned beetles), Buprestidae (metallic woodborers), Scolytidae (bark beetles), and Platypodidae (ambrosia beetles).

Diversity indices were calculated to characterize the assemblages of woodboring beetles collected from the unthinned and thinned stands at both study sites. Indices applied were the Shannon-Weiner index (designated as H'; Magurran 1988) and evenness (designated as J'; Pielou 1966). Statistical differences between the 2 stands in terms of the diversity indices were tested following Hutcheson (1970) and procedures from Zar (1996). The coefficient of community (Pielou 1974) was calculated to compare species assemblages between unthinned and thinned stands. Percent similarity also was calculated to compare species abundance between unthinned and thinned stands. Larval host preferences were determined for the collected woodboring beetles species from Yanega (1996), Solomon (1995), MacRae (1991), and Wood (1982).

Table 2. Comparison of pathogens evident 1 year before (pre) and after (post) thinning in stands designated as unthinned and thinned in Compartment 38 of the Delta National Forest, Mississippi, 1998.

Disease type and species	Unthinned		Thinned	
	Pre	Post	Pre	Post
Canker decay, heartwood decay				
Inonotus hispidus	3	2	3	0
Root and butt decay	1	0	0	0
Ganoderma lucidum	0	0	0	1
Inonotus spp.	0	0	0	1
Unidentified pathogen	3	5	10	2
Heartwood decay				
Schizophyllum commune	0	0	0	2
Stereum gausapatum	0	0	0	2
Dead wood decay				
Trichaptum biforme	0	0	0	1
Stereum hirsutum	0	0	0	4
Wetwood				
Various anaerobic bacteria	1	4	0	1
Total disease types	3	3	2	4
Total individuals	8	11	13	14

Table 3. Post-treatment tree species composition and distribution of insect and disease signs and symptoms, along with proportions of individuals affected within each tree species, in parentheses, in control and thinned plots in Compartment 38 of the Delta National Forest, Mississippi, 1998.

	% total of trees		% total of insect borer indicators		% total of disease indicators	
Tree Species	Control	Thinned	Control	Thinned	Control	Thinned
Sweetgum	51.7	34.0	4.7(8.1)	3.5(6.7)	18.2(0.8)	7.1(3.3)
Nuttall oak	9.2	8.0	37.0(72.7)	45.2(71.4)	18.2(9.1)	35.7(42.3)
Willow oak	28.3	46.6	42.6(45.6)	47.8(46.3)	36.4(2.9)	57.2(12.2)
Sugarberry	5.4	3.4	5.3(7.7)	0	9.0(7.7)	0
Other[a]	5.4	8.0	10.4(15.4)	3.5(14.3)	18.2(7.7)	0
Total	240	88	319	115	11	14

[a]Eastern cottonwood, common persimmon, green ash, honeylocust, overcup oak, American elm

RESULTS

Pre-thinning Inventory

A survey of the study area on the Delta National Forest prior to thinning revealed no differences in total numbers of trees, insect signs and symptoms, or disease signs and symptoms between the unthinned and thinned areas. A total of 469 trees were inventoried and numbered. Sweetgum, willow oak, Nuttall oak, and sugarberry were the dominant species in the study area (Table 1). Insect signs and symptoms totaled 742 with 374 borer holes on 240 trees in the unthinned plot and 368 borer holes on 228 trees in the thinned plot. Disease signs and symptoms totaled 69, with 59% being associated with the trees in the control treatment. Two well-developed decay diseases (caused by *Ganoderma lucidum* and *Inonotus hispidus*) and bacterial wetwood infections were in the stand prior to thinning. Willow and Nuttall oaks made up about 36% of the stands on each plot type but had 61% to 88% of the insect and disease indicators (Table 1). By comparison, sweetgum occupied approximately 50% of each type of plot yet sustained less than 25% of the insect and disease indicators.

Post-thinning Inventory

Wounding.—Wounding to the residual trees may occur during any entry into a stand. Generally, this occurs when a harvested tree falls into a residual tree, or when logging equipment causes damage to the residual stems. The scraping and removal of bark exposing xylem is typical of logging damage.

A "turn tree" (residual tree around the base of which a log is dragged) is a good example of typical basal wounding. The wounds provide places for insects to enter and serve as infection courts for pathogens.

Extensive wounding resulted from the thinning operation in the Delta National Forest. In the thinned plots, 84% of the residual stems were damaged in some way. Of the total wounds, 53% were on the lower-bole (basal wounding), followed by root damage (28%), root collar wounding (16%), upper-bole wounding (2%), and branch wounding or breakage (1%). Wounding of the roots, root collar, and lower bole was generally caused by logging equipment or was the result of tree removal (e.g., "turn trees"). Wounding to the upper-boles and branches occurred as cut trees fell into residual trees. During subsequent surveys of these study sites, wounds will be monitored for additional insect and disease activity.

Thinning related damage to the sites in Alabama was less, totaling 44 and 61 harvest related wounds at the Aliceville and Demopolis sites, respectively. At the Aliceville site, 43.2% of the wounds were in the light thinning treatment and 27.3% and 29.5%, respectively, in the Putnam and heavy thinning treatments. The greatest harvesting damage at the Demopolis site was in the heavy thinning treatment where 41% of harvesting related wounds were observed, followed by 31.1% in the Putnam treatment, and 27.9% in the light thinning treatment.

Insect and Disease Survey.— All numbered trees in the unthinned and thinned plots were examined in November 1998 on the Delta National Forest, March 1998 at Demopolis, and March 1999 at Aliceville for signs of insects and diseases. One year after thinning on the Delta National Forest,

Table 4. Tree species composition of control and thinned plots at the Aliceville (1999) and Demopolis (1998), Alabama sites.

	% total of trees - Aliceville				% total of trees - Demopolis			
Tree species	Control	Light	Putnam	Heavy	Control	Light	Putnam	Heavy
Sweetgum	23.7	12.0	6.0	13.2	25.2	25.2	19.2	22.1
Green ash	13.1	4.0	10.4	3.3	4.7	10.2	3.8	10.5
Mockernut hickory	13.1	38.0	8.5	26.4	4.3	3.1	6.7	1.2
Shagbark hickory	6.7	9.3	12.0	9.9	2.4	6.3	7.7	1.2
Cherrybark oak	13.7	13.3	36.7	15.3	4.7	9.4	16.3	16.3
Swamp chestnut oak	0	0	0	0	13.8	9.5	10.6	9.3
Water oak	3.6	3.4	12.8	4.4	5.5	9.5	9.6	10.5
Willow oak	2.4	4.0	2.5	12.1	20.5	8.7	17.3	12.8
Other[a]	23.7	16.0	11.1	15.4	18.9	18.1	8.8	16.1
Total trees	329.0	150.0	117.0	91.0	254.0	127.0	104.0	86.0

[a]American elm, blackgum, flowering dogwood, ironwood, red maple, red mulberry, sassafras, laurel oak, overcup oak, southern red oak.

forest compartment surrounding the study plots is the subject of a related study (Meadows et al. 2002).

Of the 434 borer holes caused by insects, 319 were recorded on 87 trees in the unthinned plot and 115 were noted on 27 trees in the thinned plot (Table 3). Even though the number of total borer holes was less in the thinned plot, the number of borer holes per sample tree increased from 3.7 in the unthinned plot to 4.3 in the thinned plot. This is an indication of the number of new insect borer attacks on logging wounds. Bacterial wetwood in oaks can often be diagnosed because of the slime flux oozing from wood borer attacks. New borer attacks are either not of the type usually associated with wetwood, or have not advanced to the point where the infections begin to ooze out of the holes.

The tree species composition following thinning treatments is presented in Table 4 for the study sites in western Alabama near Demopolis and Aliceville. These sites provide an excellent opportunity to examine insect and pathogen activity 3 and 5 years, respectively, after thinning treatments. Disease

logging wounds on some trees showed evidence of incipient pathogen activity (Table 2), and some had entrance holes caused by woodborers, most notably by ambrosia beetles (*Platypus spp.).* There were 11 occurrences of *G. lucidum, I.* spp., *Schizophyllum commune, Stereum gausapatum, S. hirsutum*, or *Trichaptum biforme* on year-old logging wounds. *Stereum hirsutum* and *T. biforme*, unlike the other 4 fungi, are saprophytic on dead wood. Many of the logging wounds at tree bases varied in size from 1000 cm^2 or larger and had exposed, dead wood.

Ratio of disease indicators per total number of sample trees was 4.6% (11/240) on the unthinned plot and 15.9% (14/88) on the thinned plot. New infections accounted for the difference in the number of disease types between the unthinned (3) and thinned (4) plots, as well as the difference in percentages of individual disease indicators between plot types (Table 2).

The increased number of infection courts resulted from logging damage incurred the previous year. Of the 25 disease indicators recorded on the Delta National Forest in the unthinned and thinned plots, 76% (19/25) occurred on willow or Nuttall oaks (Table 3). A similar finding (68%; 47/69) was noted in the pre-treatment data (Table 1).

Data in Table 2 also show the effect thinning had on controlling disease. Three *I. hispidus* infections were removed from the thinned plots, and 2 of the 10 unidentified rots (basal rots with no apparent fruiting bodies), also were eliminated. The use of thinning to control hispidus cankers from the larger

Table 5. Post-treatment survey of insect and disease signs and symptoms at the Demopolis, Alabama site, 1998.

Treatment	% total of insect borer indicators	Number	% total of disease indicators	Number
Control	59.0	924	46.7	14
Light	17.0	267	10.0	3
Putnam	11.6	181	26.6	8
Heavy	12.4	195	16.7	5
Total		1567		30

Table 6. Post-treatment survey of insect and disease signs and symptoms at the Aliceville, Alabama site, 1999.

Treatment	% total of insect borer indicators	Number	% total of disease indicators	Number
Control	43.3	324	65.6	21
Light	15.8	118	15.6	5
Putnam	25.0	187	6.3	2
Heavy	15.9	119	12.5	4
Total		748		32

Table 7. Post-treatment distribution of insect and disease signs and symptoms, along with the proportion of individuals affected within each tree species, in parentheses, in control and thinned plots at the Aliceville, Alabama site, 1998.

	Insect signs and symptoms				Disease signs and symptoms			
Tree species	Control	Light	Putnam	Heavy	Control	Light	Putnam	Heavy
Sweetgum	0	5.9(11.1)	0	0.8(8.3)	20.0(5.1)	25.0(11.1)		0
Green ash	2.5(11.6)	0	3.7(57.1)	0	20.0(9.3)	0	0	20.0(33.3)
Mockernut hickory	2.2(16.3)	13.6(10.5)	2.7(57.1)	0.8(4.2)	10.0(4.7)	25.0(10.5)	0	20.0(4.2)
Shagbark hickory	0	1.7(7.1)	4.7(21.4)	1.7(11.1)	0	0	0	0
Cherrybark oak	55.8(71.1)	51.7(75.0)	44.4(60.5)	17.6(42.9)	5.0(2.2)	25.0(75.0)	0	0
Water oak	25.6(83.3)	14.4(40.0)	34.8(80.0)	21.8(100.0)	0	0	100.0(40.0)	0
Willow oak	9.3(62.5)	3.4(42.9)	2.7(66.7)	44.6(81.8)	5.0(12.5)	0	0	20.0(9.1)
Other[a]	4.6(19.6)	9.3(23.6)	7.0(50.0)	12.7(63.6)	40.0(16.3)	25.0(23.5)	0	40.0(18.2)

[a]Blackgum, flowering dogwood, ironwood, red maple, overcup oak, red mulberry, sassafras, southern red oak, white oak.

Table 8. Post-treatment distribution of insect and disease signs and symptoms, along with the proportion of individuals affected within each tree species, in parentheses, in control and thinned plots at the Demopolis, Alabama site, 1999.

	Insect signs and symptoms				Disease signs and symptoms			
Tree species	Control	Light	Putnam	Heavy	Control	Light	Putnam	Heavy
Sweetgum	0.5(7.8)	1.1(6.3)	0.6(5.0)	0	20.0(3.1)	0	12.5(14.3)	0
Green ash	0.1(8.3)	1.1(15.4)	0	1.0(11.1)	0	33.3(7.7)	0	0
Mockernut hickory	0.3(27.3)	0.8(25.0)	1.7(28.6)	0	10.0(18.2)	0	12.5(14.3)	0
Shagbark Hickory	0.1(16.7)	0	0	0	10.0(16.7)	0	12.5(12.5)	0
Cherrybark oak	4.0(41.7)	13.9(66.7)	13.8(23.5)	9.2(35.7)	20.0(16.7)	0	12.5(5.9)	20.0(7.1)
Swamp chestnut oak	18.5(74.3)	9.8(50.0)	12.7(45.5)	12.4(50.0)	10.0(2.9)	0	12.5(9.1)	0
Water oak	22.8(100.0)	33.1(91.7)	33.6(66.7)	56.4(77.8)	0	33.3(8.3)	37.5(30.0)	20.0(11.1)
Willow oak	44.8(78.8)	27.1(100.0)	34.8(50.0)	16.9(72.7)	10.0(1.9)	0	0	60.0(9.1)
Other[a]	8.9(3.0)	13.1(42.9)	2.8(60.0)	4.1(50.0)	20.0(7.0)	33.3(4.8)	0	0

[a]American elm, blackgum, ironwood, red maple, laurel oak, overcup oak, red mulberry, sassafras, white oak.

indicators were greatest in the control plots (Tables 5 and 6). During the thinning operation most of the diseased trees were removed, and with the limited logging damage, subsequent pathogen activity has been minimal. Insect borer indicators follow a similar trend (Tables 5 and 6) with the greatest activity in the control plots. Nearly twice as many borer indicators were observed at the Demopolis site compared to the Aliceville site, this being attributed primarily to tree species composition. The greater incidence of borer indicators was observed on the oak component of the stands (Tables 7 and 8).

Insect Trapping

At the Delta National Forest, a total of 1,371 individuals representing 21 species were collected from the thinned stand, and a total of 172 individuals representing 14 species were collected from the unthinned stand (Table 9). Cerambycids dominated Malaise trap samples of woodboring beetles. From the Monroe County site, a total of 536 individuals representing 56 species were collected from the thinned stand, and a total of 144 individuals representing 33 species were collected from the unthinned stand (Table 10).

Table 9. Woodboring beetles collected from 20 August to 9 October 1997 in control and thinned plots in Compartment 38 of the Delta National Forest, Mississippi.

Family and species	Control	Thinned
Cerambycidae		
Ataxia crypta	0	1
Distenia undata	1	4
Ecyrus dasycerus	1	7
Elaphidion mucronatum	0	6
Enaphalodes atomarius	0	12
Leptostylus aperatus	0	8
L. transversus	0	6
Leptura emarginata	1	0
Neoclytus acuminatus	12	27
N. mucronatus	1	28
N. scutellaris	2	22
Styloleptus biustis	1	9
Urographis fasciatus	2	35
Xylotrechus colonus	8	55
Scolytidae		
Dryocotes betulae	11	97
Hylocurus binodatus	0	8
Monartum mali	4	34
Xyleborus ferrugineus	47	353
Xylosandrus crassiusculus	21	36
Platypodidae		
Platypus compositus	60	621
P. flavicornis	0	1
P. quadridentatus	0	1
Total species	14	21
Total individuals	172	1371

At the Delta National Forest (Table 9), *Urographis fasciatus* and *Xylotrechus colonus* comprised 62% of the total Malaise trap catch of cerambycids in the thinned stand. In the unthinned stand, these 2 species accounted for 35% of collected cerambycids. Of those woodboring beetles examined, cerambycid species were the most frequently collected in Malaise traps from unthinned and thinned stands. Based on black-light trap samples, the most abundant woodboring beetle species collected in the 2 stands was the platypodid, *Platypus compositus*, accounting for 35% of all specimens from the unthinned stand and 45% of all specimens in the thinned stand. The scolytid, *Xyleborus ferrugineus*, also was common in black-light trap samples, accounting for 27% of the total catch from the control and 26% from the thinned stand.

For the 3 beetle families collected at the Delta National Forest, species richness and abundance were higher in the thinned stand (Table 11). There was no difference in species diversity between the thinned

Table 10. Woodboring beetles collected from 1 April to 31 October 1998 in control and thinned stands in Monroe County, Mississippi.

Family and species	Control	Thinned
Cerambycidae		
Aegomorphus modestus	2	0
A. quadrigibbus	1	0
Analeptura lineola	0	3
Anelaphus parallelus	1	3
A. villosus	2	2
Asemum striatum	0	1
Astylidus parvus	1	0
Astylopsis sexguttata	0	1
Ataxia crypta	0	1
Brachyleptura circumdata	0	1
Curius dentatus	6	5
Cyrtophorus verrucosus	0	1
Distenia undata	1	4
Doraschema cinereum	1	0
Elaphidion mucronatum	7	24
Enaphalodes atomarius	2	16
Euberia quadrigeminata	0	2
Euderces pini	0	1
Eupogonius pauper	0	1
Gaurotes thoracica	1	1
Hyperplatys maculata	1	0
Knullinana cicta	0	3
Liopinus alpha	0	1
Microgoes oculatus	1	0
Monochamus carolinensis	0	2
Neoclytus acuminatus	15	48
N. mucronatus	5	18
N. scutellaris	13	95
Oberea praelonga	0	1
O. tripunctata	1	0
Obrium maculatum	0	1
Orthosoma brunneum	12	7
Paralaphidion aspersum	0	2
Psyrassa pertenius	0	1
P. unicolor	0	1
Saperda discoidea	4	1
S. lateralis	2	3
Stenosphenus notatus	0	10
Strangalia bicolor	4	12
S. luteicomis	4	25
S. solitaria	0	7
Styloleptus biustis	1	0
Typocerus acuticauda	0	1
T. lugubris	1	1
T. lunulatus	0	10
T. velutinus	5	30
T. zebra	0	34
Urographis fasciatus	2	7
Xylotrechus colonus	22	45
X. sagittatus	0	2
Buprestidae		
Acmaedera tubulus	0	3
Agrilus arcnatustorquatus	0	1
A. bilineatus	14	27
A. obsoletoguttatus	5	6
Buprestis rufipes	2	0
B. lineata	0	1
Chalcophora virginiensis	0	2
Chrysobotrhis femorata	0	52
C. scitula	0	1
C. sexsignata	1	2
Dicerca obscura	0	1
Texania campestris	0	1
Scolytidae		
Monartum mali	3	2
Orthomicus caelatus	0	1
Xyleborus fuscatus	1	1
Total species	33	56
Total individuals	144	536

Table 11. Species richness and standardized abundance of wood boring beetles collected 20 August to 9 October 1997 from control and thinned hardwood stands in Compartment 38 of the Delta National Forest, Mississippi.

	Number of species		Number of individuals/trap/day	
Treatment	Control	Thinned	Control	Thinned
Cerambycidae	9	13	0.57	2.96
Scolytidae	4	5	22.75	63.25
Platypodidae	1	3	0.75	90.37
Total	14	21	24.07	156.58

Table 12. Species richness and standardized abundance of wood boring beetles collected 1 April to 31 October 1998 from control and thinned hardwood stands in Monroe County, Mississippi.

	Number of species		Number of individuals/trap/day	
Treatment	Control	Thinned	Control	Thinned
Cerambycidae	27	42	0.61	2.26
Buprestidae	4	11	0.14	0.51
Scolytidae	2	3	0.06	0.02
Total	33	56	0.81	2.79

(H' = 1.99) and control (H' = 1.83) stands. Evenness was slightly higher for the unthinned (J' = 0.69) than the thinned stand (J'=0.64), reflecting a more equitable distribution of numbers among collected species. This is understandable as nearly half of the insects trapped in the thinned stand were of a single platypodid species, *P. compositus*. The coefficient of community between the control and thinned stand was 74.3, indicating relatively similar species assemblages. Percent similarity was low at 24.7, indicating little similarity in species abundances between the 2 stands. A difference primarily due to the larger number of individuals collected per species in the thinned stand, especially *P. compositus*.

At the Monroe County site, cerambycids dominated Malaise trap samples of wood-boring beetles, accounting for 75% of the species and 83% of the individuals taken in the thinned stand. In the unthinned stand, cerambycids represented 79% of the species collected and 94% of the individuals. The most commonly collected cerambycids in the thinned stand were *Neoclytus acuminatus, N. scutellaris*, and *X. colonus* comprising 43% of the specimens taken. These 3 species accounted for 42% of the cerambycids collected in the unthinned stand. *Chrysobotrhis femorata* was the most frequently trapped buprestid in the thinned stand, but the species was absent from the unthinned stand.

Although larger numbers of species and individuals were collected from the thinned stand (Table 12), there was no significant difference between the unthinned and thinned stands in terms of species diversity (H' = 3.03 and 3.07, respectively). Evenness was slightly higher for the control (J' = 1.97) than in the thinned stand (J '= 1.75). The coefficient of community for the control and thinned stands at this study site was 55.6, indicating a lower degree of similarity between species assemblages. In particular, the thinned stand contained more species overall than the unthinned stand, and of all species encountered, 55% only were collected in the thinned stand. Percent similarity was 31.8 indicating a low level of similarity in terms of species abundance between the 2 stands. Again, much of the difference is tied to the thinned stand where larger numbers of individuals were collected for certain species.

Woodboring beetles play a number of important roles in forest ecosystems, from the decomposition of dead woody material (Harmon et al. 1986) to affecting the vigor and mortality of forest trees (Drooz 1985). To examine the ecological role of woodboring beetles in the context of forest health, larval host preferences and standardized abundances were determined for the most frequently trapped genera from both the Delta National Forest and Monroe County sites. From the Delta National Forest, 3 cerambycid, 1 platypodid, and 4 scolytid genera were examined (Table 13). Seven cerambycid and 2 buprestid genera were examined from the Monroe County site (Table 14).

For both sites, hardwood tree species represent the primary larval hosts for all examined genera. Most species within these genera prefer weakened, stressed, or dying host trees, as well as freshly felled and dead wood. The cerambycids (*N. acuminatus, N. scutellaris, U. fasciatus*, and *X. colonus)*, typically prefer weakened trees or downed woody material as larval hosts (Solomon 1995). *Platypus compositus* does not feed on wood directly, but rather burrows into severely weakened and freshly felled hardwood trees and cultivates fungi upon which adults and larvae feed. The buprestid, (*C. femorata*) often attacks trees stressed by disease, drought, other insects, or whose bark has been damaged (Solomon 1995).

DISCUSSION

The magnitude of logging damage is dependent upon the principal variables as follows: (1) silvicultural system, (2) type of equipment and configuration, (3) tree species, (4) spacing (density), (5) size class (age), (6) season of harvest (soil moisture conditions), and (7) operator carelessness (Nebeker et al. 1998). Types of damage encountered include limb breakage and wounding, bole wounding (upper and lower bole), root wounding, and root breakage.

Table 13. Standardized abundance and larval host preference of the most frequently collected woodboring beetles from control and thinned stands in Compartment 38 of the Delta National Forest, Mississippi.

Family and genus	Number of individuals/trap/day Control	Thinned	Larval host preference[a]
Cerambycidae			
Neoclytus	0.30	0.71	W/SH, DH
Urographis	0.01	0.07	W/SH, DH
Xylotrechus	0.15	0.75	W/SH, DH
Scolytidae			
Dryocoetes	0	0.05	W/SH, DH
Monartum	0.04	0.21	W/SH, DH
XYleborus	0.03	0.36	W/SH, DH
Xylosandrus	0.10	0.22	HH, W/SH
Platypodidae			
Platypus	0.09	0.16	W/SH, DH

[a]Larval host preferences: HH = healthy hardwoods, W/SH = weakened/stressed hardwoods, DH = dead hardwoods.

Table 14. Standardized abundance and larval host preference of the most frequently collected woodboring beetles from control and thinned stands in Monroe County, Mississippi.

Family and genus	Number of individuals/trap/day Control	Thinned	Larval host preference[a]
Cerambycidae			
Elaphidion	0.06	0.11	DH
Enaphalodes	0.01	0.07	DH
Neoclytus	0.15	0.75	W/SH, DH
Stenosphenus	0	0.05	DH
Strangalia	0.04	0.21	HU
Typocerus	0.03	0.36	DH, P
Xylotrechus	0.10	0.22	W/SH, DH
Buprestidae			
Agrilus	0.09	0.16	W/SH, DH
Chrysobothris	0	0.26	W/SH, DH

[a]Larval host preferences: W/SH = weakened/stressed hardwoods, DH = dead hardwoods, HU = hardwood of unknown condition, P = pine.

Other reports indicate considerable logging damage is a common occurrence in thinning operations. Logging wounds occurred on 62% of the residual stems following a thinning operation in a riverfront hardwood stand in Mississippi (Meadows 1993). The most common types of damage included: (1) broken branches in the residual canopy, (2) upper and lower bole wounding, and (3) exposure and breakage of roots. Such wounding serves as an infection court for disease organisms and as attraction points for various insects that degrade or cause potential mortality of the residual stems. In addition, disease propagules such as fungal spores, bacteria, and viruses may be introduced into trees through wounds created by insects, birds, mammals, or by the equipment used to harvest trees. The subsequent reduced vigor of individual trees also may reduce the overall health of the residual stand, making it susceptible to further attacks by insects and pathogens.

Abundances of pathogens and insects were higher in thinned stands at both the Delta National Forest and Monroe County study sites. Higher abundances in the thinned stands is understandable as large amounts of logging slash, in the form of branches and harvest tops, can be left in the wake of thinning operations. In the context of forest health, beetles that feed on dead wood represent a vital component in the initial breakdown and fragmentation of woody material. Higher abundance of woodboring beetles in the thinned stands also may be a result of insect attraction to damaged or injured host trees. During thinning operations, damage to the residual stand may result. Wounds that occur during stand entry and logging operations may cause stressed trees to release volatile compounds that attract some woodboring beetles (Dunn et al. 1986, Kimmerer and Kozlowski 1982).

The final effects resulting from insects and diseases are unknown. Stands must be monitored for a number of years to document overall changes over time. It is anticipated that these initial decays will be more advanced when examined during future surveys, and that more new infections will have occurred on other logging wounds in the thinned plot. Also, more sites must be monitored to determine if unique situations exist that warrant consideration. Alongside silvicultural practices, effects of other management strategies (greentree reservoirs) applied to bottomland hardwood systems need to be investigated in light of insect and pathogen activity. If prescribed burns are introduced into the southern bottomland landscape, what will be the response of insects and pathogens to this changing landscape?

MANAGEMENT IMPLICATIONS

It is our intent to produce a pest management guide for southern bottomland hardwoods similar to one produced by Nebeker et al. (1985) for southern pines. They state that although the principal goal of thinning is improving the growth and value of stands, other benefits are obtained, such as hazard reduction for insect infestations, disease epidemics, and damage due to abiotic agents. The mechanics by which thinning reduces these hazards is not completely understood. However, observations indicate that thinning can result in positive and/or negative effects, depending on how, where, when, and why it is conducted.

The presence of more than one kind of hazard (e.g., insects and diseases) in a particular area at a given time poses some problems in designing an optimal thinning strategy. Other factors that complicate the situation are the forest type (species composition), stage of stand development, site quality, growth rate, live crown ratio, equipment used, machine operator experience, anticipated direct damage to residual stems, and ultimately the cost effectiveness of the operation. Soil compaction, soil improvement, water quality issues, wildlife habitat enhancement, weed problems, aesthetics, and the like, cannot be ignored if all aspects of thinning are to be taken into account. This is certainly true of the bottomland hardwood landscape.

Clearly, logging damage is one of the most detrimental actions that can occur to a bottomland hardwoods residual stand. The amount of injury and rot caused by insects and diseases during the time before the next thinning, or final harvest, is directly proportional to the percentage of trees damaged during the initial thinning. In general, conducting a partial thinning in an average, healthy bottomland hardwood stand, and causing little logging damage in the process will result in increased tree growth and added stand volumes before the next treatment. Furthermore, opening up a stand (in terms of available sunlight) with adequate, healthy advanced regeneration in the understory will accelerate development of the next stand.

However, a high percentage of logging wounds of sufficient size to become infected and develop severe decay, or be attacked by insects, will decrease the merchantable volume of the next harvest. A vigorously growing tree may be able to produce callus tissue over a small wound (e.g., 100 cm^2, or less) in 1 or 2 growing seasons. This growth walls off incipient infections and prevents the development of severe infections, and/or prevents significant insect damage. A larger wound may never heal and would most likely develop a severe decay or insect problem. Wound dimensions and locations (i.e., azimuths) were recorded for each tree in the Delta National Forest study. Several years from now we plan to report the relationships of wound size and numbers to the further development of insects and disease damage in the Delta National Forest stand.

The high percentage (84%) of logging wounds in the thinned stand was caused by an inexperienced equipment operator (Bellsaw harvester) who made too many entries and re-entries in the plot to remove marked trees. Therefore, we think there is value in educating loggers and forest managers about the importance of preventing disease and insect damage in residual stands by minimizing the number of wounds during thinning.

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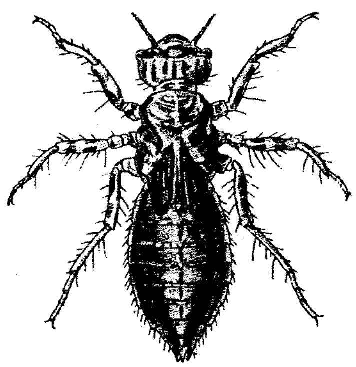

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The State of Our Understanding

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