FUELBEDS AND SNAGS IN AN AREA OF MATURE OAKS (*QUERCUS* SPP.) DEVASTATED BY THE RED OAK BORER (*ENAPHALODES RUFULUS* HALDEMAN)

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1 April 2002

ABSTRACT

A recent, large-scale irruption of the red oak borer (*Enaphalodes rufulus* Haldeman), precipitated by a period of general oak decline, has caused widespread mature oak mortality (*i.e.*, borer-devastation) and fuelbed changes on the Ozark Plateau. However, the degrees of oak mortality and coincident fuelbed changes remain undetermined. Through sampling plots (n = 20) in heavily impacted areas of the Bayou Ranger District (Ozark-St. Francis National Forests), the objectives of this project were to inventory: (1) fuelbeds using the Planar Intercept Method and (2) oak mortality by recording snags. Comparing the Bayou project's results to those of a similar project conducted on non-borer-devastated mature hardwood forest in the Buffalo Ranger District (Ozark-St. Francis National Forests), a significantly (t = 3.32, P < 0.05) greater total fuelbed-loading ($\overline{X}$ = 17.09 tons per acre; n = 20) was recorded for the Bayou project than for the Buffalo ($\overline{X}$ = 5.49 tons per acre; n = 20). Also, a significantly (t = 12.98, P < 0.05) greater number of snags ($\overline{X}$ = 17.35 snags per ¼-acre-plot; n = 20) was recorded for the Bayou project than for the Buffalo ($\overline{X}$ = 1.35; n = 20). The recent growth in total fuelbed-loading and oak mortality in borer-devastated areas has created general safety and fire hazards. Therefore, substantial need exists to discuss, design, and implement a plan to monitor current and impending changes in fuelbed properties and oak mortality on the Ozark Plateau.

INTRODUCTION

Oak decline —a complex of ecological stressors which triggers dieback of terminal branches and the eventual death of many mature oaks in a community — is a process that seems to normally occur in aging upland hardwood forests. Oak decline is

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currently occurring extensively on the Ozark Plateau and has recently been critically compounded by a widespread irruption of the red oak borer (Johnson *et al*. 2001). It is normal for mature oaks — especially the red oak group — to be non-fatally attacked in small numbers by this borer. However, the current borer irruption is causing such pervasive oak mortality on the Ozark Plateau that their populations have been devastated in specific areas (Johnson *et al*. 2001). Areas of oak decline — especially borer-devastated ones — produce hazards related to general safety and fire.

To date, only limited information examining fuelbed strata has been collected in borer-devastated areas of the Ozark Plateau. The purpose of this report is to state the results of a recent probe, conducted in such an area of the Bayou Ranger District (Ozark-St. Francis Forests, Sand Gap Quadrangle), which investigated the following categories of fuelbed strata: duff, litter, dead and down woody (DDW) material, and snags. No attempts are made herein to test hypotheses or reach defensible conclusions. With that said, another probe using identical methods was also recently completed for mature hardwood forest in the Buffalo Ranger District (Ozark-St. Francis National Forests, Moore Quadrangle). To facilitate a brief discussion, I compare results from the two probes.

METHODS AND MATERIALS

Study Areas and Sampling Dates

Areas of borer-devastation were determined by ocular estimates of relative snag density. If mature-tree snags with ≥80%-terminal-branch-dieback per individual appeared to comprise ≥50% of total mature trees for a site, then that site was judged to be borer-devastated and, therefore, eligible to have a plot (or plots) installed there and sampled.

In borer-devastated forest, twenty sampling plots (Appendix 1; Figure 1) were installed in three sites situated in close proximity to the Rotary Ann Recreation Area, located on Arkansas Highway 7 North. Plot-centers were each marked by a steel T-post and were placed a minimum of 4 chains apart. Plots 1 through 5 and 11 through 20 can be accessed along Arkansas Highway 7 North. Plots 6 and 7 are in an area directly adjacent to Arkansas Hwy 16, east of Sand Gap. Plots 8 through 10 are close by Forest Service Road 1809, south of Arkansas Highway 16.

Plots 1, 2, and 5 were sampled on 14 February 2002. Plots 3 and 4 were sampled on 12 March 2002. Plots 6 through 10 and 11 through 20 were sampled, respectively, on 5 and 6 March 2002.

General Methods

Following Brown (1971, 1974), a forest-floor inventory of weights and depths of fuelbed material was collected using the Planar Intercept Method, whereby particles of specific diameter-size-classes of DDW material, crossed by a vertical transect-line in each plot, were recorded. Also, duff- and litter-depths, respectively, crossed by these transect-lines were recorded. DDW and depth data were then entered into DDWoodyPC (Fire Program Solutions and Acacia Services, 2001), a software application that performed calculations according to the Planar Intersect Method, producing means for fuel-loading weight-values (Figure 2; Table 1) by applying estimates for the specific gravity of recorded DDW material to its estimated volume.

For snag counts, the diameter-at-breast-height (≥6-inch-DBH) and tree-height (≥4-foot-height) for each snag within each quarter-acre fixed-area (58.9-foot radius) plot were recorded. I then derived descriptive statistics from these data for the categories of DBH and height, respectively, per plot.

RESULTS AND DISCUSSION

Bayou Fuel Loading and Depths

Descriptive statistics were derived for: (1) DDW particles grouped into the following diameter-inch-classes: 0.00 - 0.24, 0.25 - 0.99, 1.00 - 2.99, 3.00 - 5.99, 6.00 - 8.99, 9.00 - 20.00, and >20.00 and (2) for duff- and fuelbed-depths (Figure 2; Table 1). For all plots combined, mean DDW-loading was 17.09 tons per acre (Figure 2; Table 1). Mean duff- and fuelbed-depths, respectively, were 0.97 and 3.93 inches. The percent error (standard error ÷ mean; Fire Program Solutions and Acacia Services, 2001) for total DDW-loading was 19.15%.

Bayou Snags

On a per plot basis, I derived descriptive statistics for DBH and height of snags, respectively (Tables 2 and 3; Minitab, Incorporated, 1998). Pooling individual plot-results for snags, I derived mean number of snags per plot, DBH per plot, and mean height per plot (Figure 3; Table 4). For mean number of snags per acre ($\overline{X}$ = 69.40), I divided the total number of snags (n = 347) combined for all plots (n = 20; Tables 2 and 3) by total plot-acres (n = 5 = [20 ¼-acre-plots ÷ 4]) sampled.

Comparison of Bayou and Buffalo Results

A subjective comparison of a borer-devastated forest area with one that is not reveals strong differences in each regarding oak trees and fuelbed strata, respectively, but, it is necessary to quantify differences to gain a strategic grasp of the issues. When comparing DDW-loading- and snag-results for the Bayou probe's borer-devastated plots with those of plots sampled with identical methods in a non-borer-devastated mature hardwood forest area near Big Point in the Buffalo Ranger District (sampled

November 2001 - January 2002), the Bayou probe's data means were generally higher than the Buffalo's (Figure 4).

A significantly ($t = 3.32$, $P < 0.05$) greater total DDW-loading ($\overline{X} = 17.09$ tons per acre; n = 20) for both fine- (0.00-2.99 inches) and coarse- ($\geq$3.00 inches) fuel particles combined was recorded for the Bayou probe than for the Buffalo ($\overline{X} = 5.49$ tons per acre; n = 20). For fine-fuels alone, DDW-loading ($\overline{X} = 3.33$ tons per acre; n = 20) was significantly ($t = 2.74$, $P < 0.05$) greater for the Bayou than for the Buffalo ($\overline{X} = 1.58$ tons per acre; n = 20). Also, for coarse-fuels alone, DDW-loading ($\overline{X} = 13.76$ tons per acre; n = 20) was significantly ($t = 2.81$, $P < 0.05$) greater for the Bayou than for the Buffalo ($\overline{X} = 3.91$ tons per acre; n = 20). Total planar-intersect-loading-report error percentages for the Bayou and Buffalo probes were 19.15% and 22.11%, respectively.

There was a non-significant ($t = 1.49$, $P > 0.05$) difference between means for fuelbed-depths for the Bayou ($\overline{X} = 3.93$ inches; n = 20) and the Buffalo ($\overline{X} = 3.52$ inches; n = 20). For duff-depths, as well, there was a non-significant ($t = -1.28$, $P > 0.05$) difference between means for the Bayou ($\overline{X} = 0.97$ inches; n = 20) and the Buffalo ($\overline{X} = 1.21$ inches; n = 20).

A significantly ($t = 12.98$, $P < 0.05$) greater number of snags ($\overline{X} = 17.35$ snags per ¼-acre-plot; n = 20) was recorded for the Bayou than for the Buffalo ($\overline{X} = 1.35$; n = 20). As mentioned previously, the mean number of snags per acre for the Bayou was 69.40. For the Buffalo, the mean number of snags per acre was 5.40. Pooling individual plot-results for each probe, respectively, a significantly ($t = 6.13$, $P < 0.05$) greater mean height ($\overline{X} = 47.74$ feet; n = 347) was reported for the Bayou's snags than for the Buffalo's ($\overline{X} = 27.39$ feet; n = 27). Pooling respective-probe plot-results again, there was a non-significant ($t = -1.03$, $P > 0.05$) difference between DBH-values for the Bayou ($\overline{X} = 9.91$ inches; n = 347) and the Buffalo ($\overline{X} = 10.98$ inches; n = 27).

At first blush, there appears to be strong evidence supporting the view that substantial and dynamic changes in fuel-loading and oak mortality are occurring in borer-devastated areas. However, the Bayou and Buffalo probes were designed as independent investigations — not to be linked in a controlled experiment. Indeed, comparisons of the two generate more questions than they answer (*e.g.*, To what degree did wind, ice, and snow change types and amounts of DDW-loading for both areas between sampling periods? Simultaneous sampling would have provided more accurate results.). However, I have not introduced these comparisons here to draw conclusions, but to provide foundation for future, broader discussion. I contend the evidence is strong enough to suggest a real and present need exists to craft a simple, well-designed plan to infer fuelbed properties and degrees of oak mortality using limited observations of mature hardwood forest areas on the Ozark Plateau.

ACKNOWLEDGMENTS

I thank Mark Morales and John Andre (Ozark-St. Francis National Forests, Bayou Ranger District) for help related to study-site selection, Geographic Information Systems, and equipment provision during the Bayou probe. For similar efforts on the Buffalo probe, I am grateful to Jan Self, David Rupe, Travis Faught, Drew Atkinson, and Dan Keyes (Ozark-St. Francis National Forests, Buffalo Ranger District).

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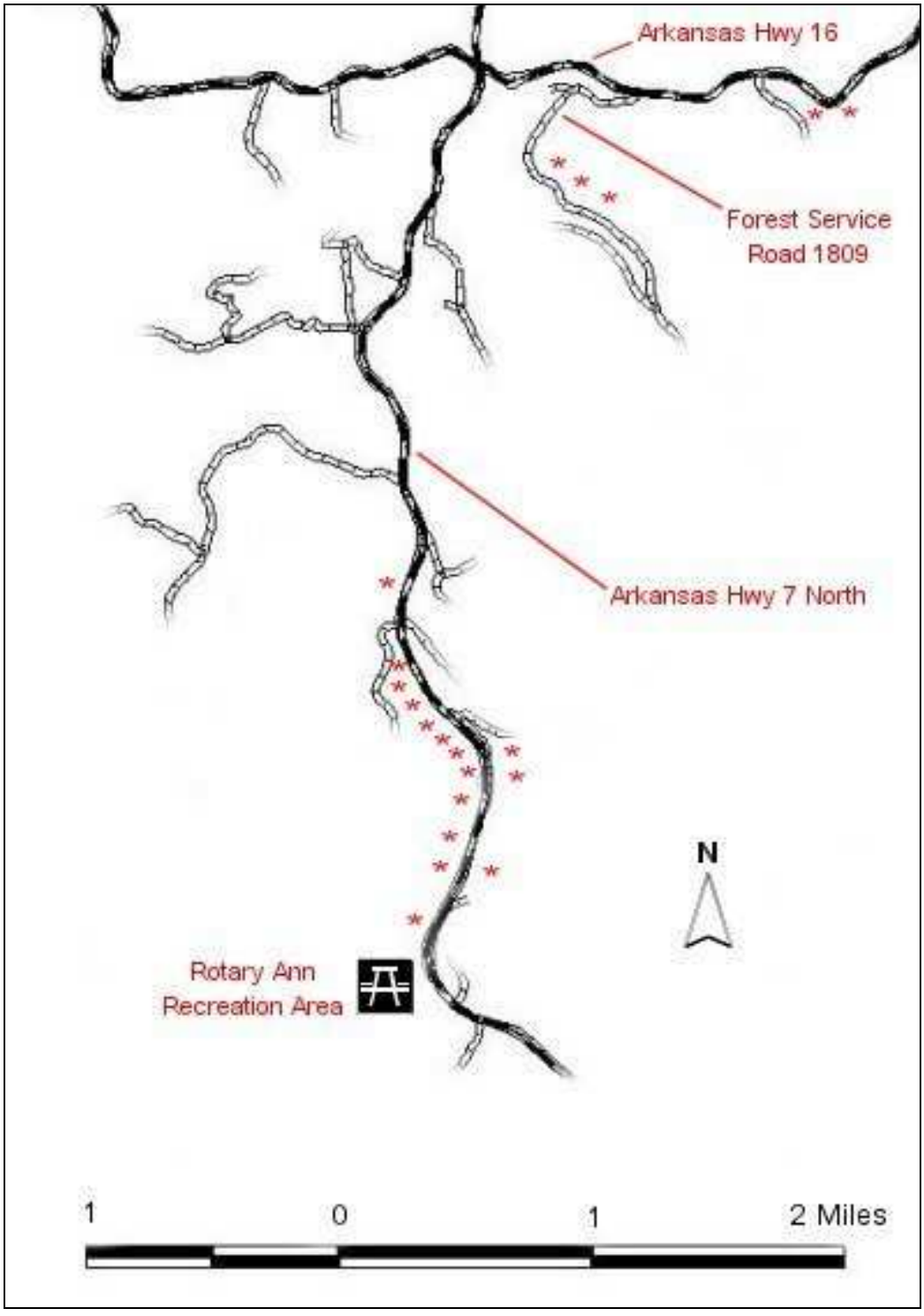

Figure 1. Fuelbed and oak-mortality sampling locations (indicated by asterisks) in mature hardwood forest devastated by the red oak borer in the Ozark-St. Francis National Forests (Bayou Ranger District, Sand Gap Quadrangle). Sampling dates: 14 February 2002; 5-6 and 12 March 2002.

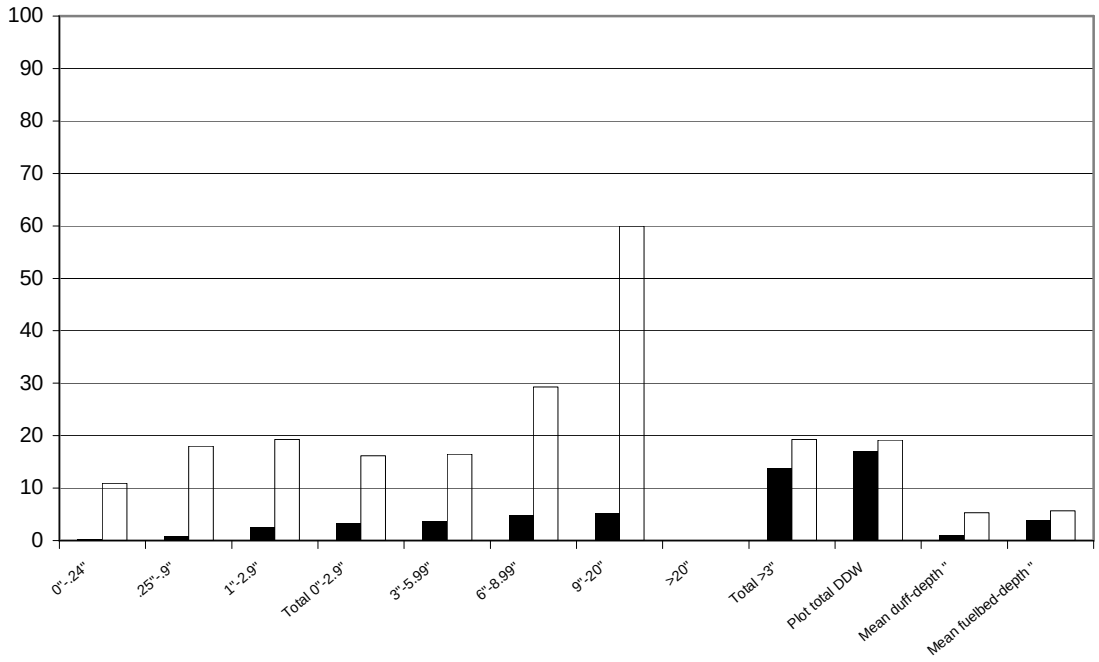

Figure 2. Planar intercept fuel-loading and duff- and fuelbed-depth results for sampling locations in mature hardwood forest devastated by the red oak borer in the Ozark-St. Francis National Forests (Bayou Ranger District, Sand Gap Quadrangle). Sampling dates: 14 February 2002; 5-6 and 12 March 2002. Solid bars indicate: (1) fuel-loading in tons per acre for respective diameter-inch-classes of dead and down woody particles and (2) mean depth in inches for duff and fuelbed. Non-filled bars indicate respective error percentages for all data categories.

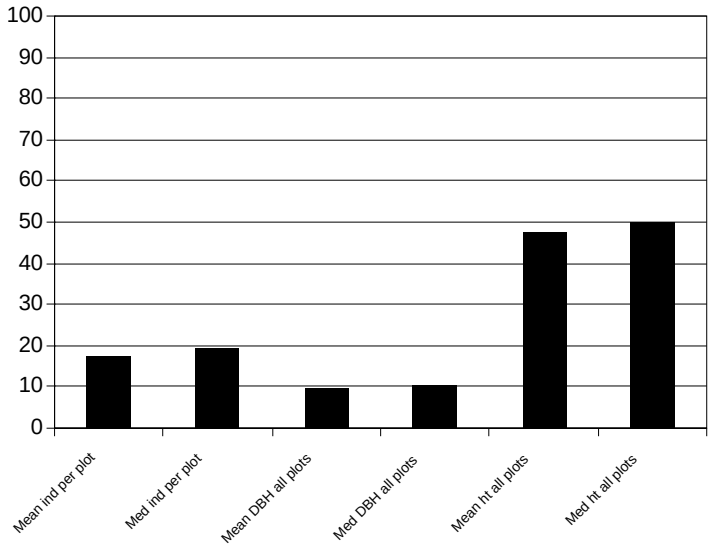

Figure 3. Snag results for sampling locations in mature hardwood forest devastated by the red oak borer in the Ozark-St. Francis National Forests (Bayou Ranger District, Sand Gap Quadrangle). Sampling dates: 14 February 2002; 5-6 and 12 March 2002. Results shown as: (1) mean number of individual snags per quarter-acre fixed plot; (2) median number of individual snags per plot; (3) mean DBH of snags for all 20 plots combined; (4) median DBH of snags for all 20 plots; (5) mean height of snags for all 20 plots; and (6) median height of snags for all 20 plots.

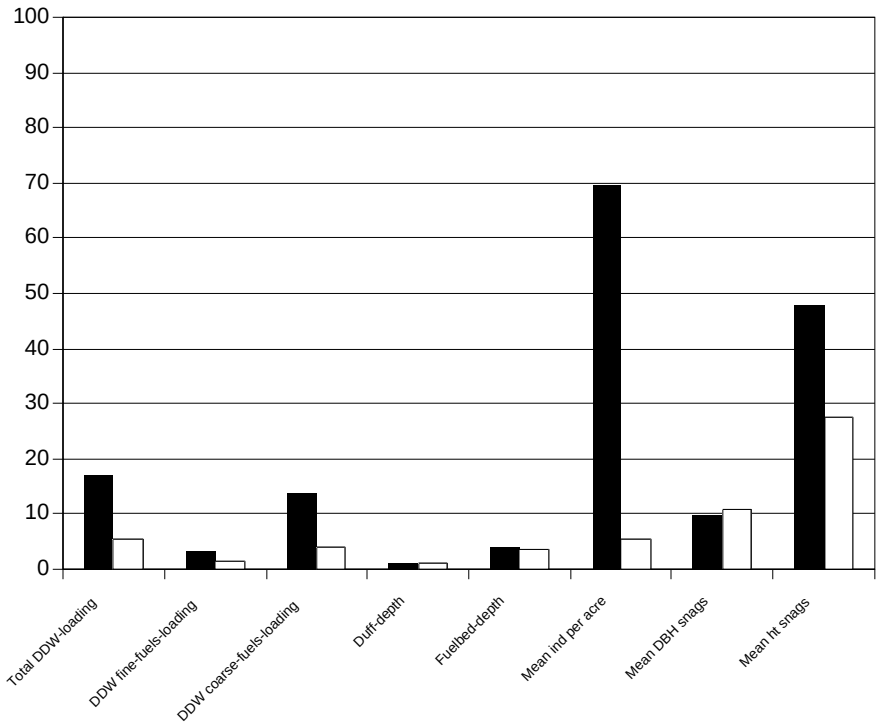

Figure 4. Comparisons of results for planar intercept fuel-loading (tons per acre), duff- and fuelbed-depths (inches), and snags (number of individual snags per acre in absolute values; DBH in inches, height in feet) for sampling locations in the Ozark-St. Francis National Forests for borer-devastated (Bayou Ranger District, Ozark-St. Francis National Forests; indicated by black bars) *versus* non-borer-devastated (Buffalo Ranger District, Ozark-St. Francis National Forests; indicated by white bars) mature hardwood forest areas.

Table 1. Planar intercept fuel-loading and duff- and fuelbed-depth results for sampling locations in mature hardwood forest devastated by the red oak borer in the Ozark-St. Francis National Forests (Bayou Ranger District, Sand Gap Quadrangle). Sampling dates: 14 February 2002; 5-6 and 12 March 2002.

Fuel Loading and Depth Results:

	<-----Tons Per Acre----->										Mean	Mean
	0"-	.25"-	1"-	Total	3"-	6"-	9"-		Total	Plot	Duff Depth	Litter Depth
Plot	.24"	.9"	2.99"	0"-2.99"	5.99"	8.99"	20"	>20"	>2.99"	Total	Inches	Inches
1	0.08	0.63	2.99	3.70	0.00	0.00	0.00	0.00	0.00	3.70	1.00	2.33
2	0.08	0.93	1.48	2.49	2.77	0.00	0.00	0.00	2.77	5.26	0.75	2.00
3	0.10	0.31	0.00	0.40	4.30	0.00	0.00	0.00	4.30	4.71	0.70	4.33
4	0.08	1.24	2.96	4.28	4.40	0.00	0.00	0.00	4.40	8.68	0.60	3.00
5	0.05	0.92	8.77	9.74	4.27	0.00	0.00	0.00	4.27	14.01	1.00	2.33
6	0.05	0.62	1.48	2.15	7.08	6.22	0.00	0.00	13.29	15.44	0.75	4.00
7	0.08	0.92	2.95	3.95	4.30	0.00	0.00	0.00	4.30	8.25	0.90	3.33
8	0.06	0.31	5.95	6.32	4.34	17.37	0.00	0.00	21.71	28.03	1.00	4.33
9	0.06	0.62	4.41	5.09	6.18	0.00	43.97	0.00	50.16	55.25	0.80	4.67
10	0.11	1.24	1.48	2.83	5.31	9.89	0.00	0.00	15.20	18.03	1.00	5.67
11	0.07	1.88	4.48	6.42	5.93	0.00	0.00	0.00	5.93	12.35	1.35	5.00
12	0.05	0.00	0.00	0.05	7.22	0.00	45.09	0.00	52.31	52.36	1.00	4.33
13	0.14	0.00	0.00	0.14	8.52	0.00	0.00	0.00	8.52	8.67	0.80	3.67
14	0.03	0.94	1.49	2.46	1.57	6.28	0.00	0.00	7.85	10.31	1.40	4.33
15	0.05	0.00	2.97	3.02	0.00	0.00	0.00	0.00	0.00	3.02	0.85	3.67
16	0.07	1.56	1.49	3.12	0.00	17.44	0.00	0.00	17.44	20.56	0.85	3.67
17	0.03	0.31	1.49	1.83	7.14	6.27	14.10	0.00	27.50	29.33	1.00	3.67
18	0.05	0.00	4.50	4.55	0.00	14.90	0.00	0.00	14.90	19.45	0.90	4.33
19	0.02	0.32	0.00	0.33	0.00	6.37	0.00	0.00	6.37	6.71	1.30	5.67
20	0.02	0.63	2.99	3.64	2.80	11.19	0.00	0.00	13.80	17.62	1.35	4.33
Mean:	0.06	0.67	2.59	3.33	3.81	4.80	5.16	0.00	13.76	17.09	0.97	3.93
S.D.:	0.03	0.54	2.24	2.40	2.80	6.28	13.83	0.00	14.72	14.63	0.23	1.00
S.E.:	0.01	0.12	0.50	0.54	0.63	1.40	3.09	0.00	3.29	3.27	0.05	0.22
%Err:	10.95	17.97	19.26	16.15	16.45	29.27	59.95	0.00	19.26	19.15	5.29	5.69

Needle Loading (Tons Per Acre): 0.00

Total Needle and Dead Down Loading (Tons Per Acre): 17.09

Table 2. Descriptive DBH-by-plot snag statistics for sampling locations in mature hardwood forest devastated by the red oak borer in the Ozark-St. Francis National Forests (Bayou Ranger District, Sand Gap Quadrangle). Sampling dates: 14 February 2002; 5-6 and 12 March 2002.

Variable	PLOT NO.	N	Mean	Median	TrMean	StDev
DBH	1	11	12.091	12.000	12.111	2.300
	2	10	14.00	14.00	13.88	3.46
	3	20	9.400	9.000	9.222	2.761
	4	10	11.70	12.00	11.50	3.20
	5	9	13.22	14.00	13.22	3.87
	6	19	9.474	8.000	9.412	2.091
	7	7	8.29	8.00	8.29	2.93
	8	23	9.478	10.000	9.429	2.352
	9	24	8.500	8.000	8.455	1.694
	10	21	8.952	8.000	8.947	1.857
	11	14	8.857	9.000	8.667	3.009
	12	20	8.850	9.000	8.833	2.641
	13	22	9.455	10.000	9.400	2.304
	14	22	10.455	10.000	10.300	3.262
	15	16	10.000	10.000	9.857	2.921
	16	23	11.174	12.000	11.190	2.188
	17	17	10.353	10.000	10.400	2.060
	18	17	10.412	10.000	10.333	3.144
	19	22	8.864	8.000	8.750	2.295
	20	20	9.550	10.000	9.611	1.669

Variable	PLOT NO.	SE Mean	Minimum	Maximum	Q1	Q3
DBH	1	0.694	8.000	16.000	11.000	14.000
	2	1.10	9.00	20.00	11.50	16.50
	3	0.617	6.000	16.000	8.000	11.500
	4	1.01	7.00	18.00	9.50	14.00
	5	1.29	7.00	18.00	9.50	16.50
	6	0.480	6.000	14.000	8.000	12.000
	7	1.11	6.00	14.00	6.00	10.00
	8	0.491	6.000	14.000	8.000	10.000
	9	0.346	6.000	12.000	8.000	10.000
	10	0.405	6.000	12.000	8.000	10.000
	11	0.804	6.000	14.000	6.000	10.500
	12	0.591	6.000	12.000	6.000	12.000
	13	0.491	6.000	14.000	8.000	12.000
	14	0.695	6.000	18.000	8.000	12.000
	15	0.730	6.000	16.000	8.000	12.000
	16	0.456	6.000	16.000	10.000	12.000
	17	0.500	6.000	14.000	9.000	12.000
	18	0.762	6.000	16.000	7.500	12.500
	19	0.489	6.000	14.000	7.750	10.000
	20	0.373	6.000	12.000	8.250	10.000

Table 3. Descriptive height-by-plot snag statistics for sampling locations in mature hardwood forest devastated by the red oak borer in the Ozark-St. Francis National Forests (Bayou Ranger District, Sand Gap Quadrangle). Sampling dates: 14 February 2002; 5-6 and 12 March 2002.

Variable	PLOT NO.	N	Mean	Median	TrMean	StDev
HEIGHT	1	11	51.82	55.00	52.78	9.56
	2	10	56.50	62.50	58.75	17.00
	3	20	47.00	45.00	47.22	7.68
	4	10	46.00	47.50	47.50	9.94
	5	9	63.33	70.00	63.33	16.01
	6	19	46.58	50.00	47.06	11.06
	7	7	35.00	35.00	35.00	11.55
	8	23	46.74	50.00	47.38	9.49
	9	24	44.42	50.00	45.91	10.40
	10	21	47.14	50.00	47.89	9.02
	11	14	48.93	50.00	50.00	4.01
	12	20	41.50	45.00	42.22	10.14
	13	22	53.41	50.00	53.75	6.79
	14	22	49.77	50.00	49.75	5.23
	15	16	50.94	50.00	51.07	6.38
	16	23	50.04	50.00	51.67	14.08
	17	17	48.53	50.00	49.67	9.96
	18	17	40.59	45.00	41.67	13.79
	19	22	48.18	50.00	48.00	4.77
	20	20	43.75	50.00	44.17	13.07

Variable	PLOT NO.	SE Mean	Minimum	Maximum	Q1	Q3
HEIGHT	1	2.88	35.00	60.00	45.00	60.00
	2	5.38	20.00	75.00	43.75	70.00
	3	1.72	30.00	60.00	41.25	50.00
	4	3.14	25.00	55.00	40.00	55.00
	5	5.34	35.00	80.00	47.50	75.00
	6	2.54	25.00	60.00	40.00	60.00
	7	4.36	20.00	50.00	25.00	50.00
	8	1.98	20.00	60.00	40.00	50.00
	9	2.12	6.00	50.00	40.00	50.00
	10	1.97	20.00	60.00	40.00	50.00
	11	1.07	35.00	50.00	50.00	50.00
	12	2.27	15.00	55.00	40.00	50.00
	13	1.45	40.00	60.00	50.00	60.00
	14	1.11	40.00	60.00	48.75	50.00
	15	1.60	40.00	60.00	50.00	57.50
	16	2.94	6.00	60.00	50.00	60.00
	17	2.42	20.00	60.00	42.50	55.00
	18	3.35	5.00	60.00	30.00	50.00
	19	1.02	40.00	60.00	45.00	50.00
	20	2.92	20.00	60.00	31.25	53.75

Table 4. Descriptive statistics for total snags — all plots combined — observed in 20 quarter-acre plots in mature hardwood forest devastated by the red oak borer in the Ozark-St. Francis National Forests (Bayou Ranger District, Sand Gap Quadrangle). Sampling dates: 14 February 2002; 5-6 and 12 March 2002.

Variable	Mean	Median	StDev
No. Snags	17.350	19.500	5.3732
DBH	9.914	10.000	2.7800
Height	47.744	50.000	10.9400

Appendix 1. Plot-center latitude and longitude coordinates for plots 1 through 20 in mature hardwood forest devastated by the red oak borer in the Ozark-St. Francis National Forests (Bayou Ranger District, Sand Gap Quadrangle).

Plot Number	Latitude	Longitude
Plot 1	N 35° 40.304’	W -93° 05.465’
Plot 2	N 35° 40.290’	W -93° 05.420’
Plot 3	N 35° 41.424’	W -93° 05.996’
Plot 4	N 35° 40.957’	W -93° 05.914’
Plot 5	N 35° 40.420’	W -93° 05.430’
Plot 6	N 35° 43.138’	W -93° 04.202’
Plot 7	N 35° 43.140’	W -93° 04.283’
Plot 8	N 35° 42.904’	W -93° 05.437’
Plot 9	N 35° 42.834’	W -93° 05.375’
Plot 10	N 35° 42.793’	W -93° 05.359’
Plot 11	N 35° 40.259’	W -93° 05.912’
Plot 12	N 35° 40.465’	W -93° 05.795’
Plot 13	N 35° 40.447’	W -93° 05.749’
Plot 14	N 35° 40.744’	W -93° 05.692’
Plot 15	N 35° 40.739’	W -93° 05.641’
Plot 16	N 35° 40.796’	W -93° 05.693’
Plot 17	N 35° 40.805’	W -93° 05.640’
Plot 18	N 35° 40.842’	W -93° 05.713’
Plot 19	N 35° 40.914’	W -93° 05.789’
Plot 20	N 35° 40.926’	W -93° 05.835’