DE-AI09-00SR22188 JOURNAL ARTICLE 2004 04-08-P

SIZE OF COARSE WOODY DEBRIS 5 YEARS AFTER GIRDLING AND REMOVAL TREATMENTS IN 50-YEAR-OLD LOBLOLLY PINE PLANTATIONS

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Abstract—In 1996, a study began at Savannah River Site to investigate large-scale replicated forest areas to control coarse woody debris for integrated biodiversity objectives. Research design was a randomized complete block with four treatments replicated in four blocks, resulting in 16 plots. The treatments applied to 50-year-old loblolly pine stands were (1) control, (2) girdling of 25 percent of trees to create catastrophic simulation, (3) annual removal of down woody debris > 10 cm in diameter, and (4) annual removal of both standing and down woody debris > 10 cm in diameter. The study tracks coarse woody debris recruitment and loading, rates of decomposition, and effects on the forest ecosystem.

INTRODUCTION

The logs and snags in a forest, coarse woody debris (CWD), provide habitat, food, refuge, and nesting sites for many organisms across trophic levels (Harlow and Guynn 1983, Harmon and others 1986, Maser and others 1979, McComb and others 1986). Research studies have found that many organisms rely on CWD for all or part of their survival. CWD research is limited in the Southeast to studies focused on only a few organisms (Harlow and Guynn 1983, McComb and others 1986, McMinn and Crossley 1996). Forest management has become more intensive over the last century, and as a consequence, extensive CWD has been removed from the southern forest. Foresters need to understand how CWD maintains biodiversity and how management practices provide desired levels of CWD. The objective of this study is to establish large-scale replicated forest areas to control CWD to understand its characteristics and dynamics. This study will clarify the relative influence CWD exerts on faunal communities of the managed southeastern pine forest ecosystem. This research will track CWD recruitment and loading, rates of decomposition, and the effects of CWD presence and abundance on the forest ecosystem.

PROCEDURES

The study design is a randomized complete block design with 4 treatments replicated in 4 blocks, yielding 16 plots. Treatments were applied in 1996 and annually thereafter to 9-ha plots within loblolly pine (*Pinus taeda* L.) plantations that were established between 1950 and 1953:

(1) Control (CON) does not manipulate CWD, but allows natural dynamics
(2) Catastrophic simulation (CAT) will be a control for a baseline period, then create a snag pulse by girdling 25 percent of the living trees in the year 2001
(3) Down removal (DOW) removes the down woody debris > 10 cm in diameter to adjoining log decks annually and burns it while the standing woody debris is left remaining; in 2001, this treatment will fell 25 percent of the living trees to create a log pulse, and no removal will occur
(4) All removal (ALL) removes all woody debris > 10 cm in diameter, including snags, to adjoining log decks annually and burns it.

All previous CWD was removed from the study areas, and plots received herbicide spraying in 1996 to reduce vegetative cover variation. Plot 5 received yearly herbicide spraying to keep kudzu (*Pueraria lobata*) under control until 2001. The plots were prescribed-burned in February and March 2000, except for the four plots in compartment 54, which were burned in March 2001. Phase 2 of the project was implemented in 2001 on the CAT and DOW treatments. The CAT plots have had a quarter of the living trees' basal area girdled and injected with herbicide to create standing woody debris. DOW plots had the same amount felled to create downed woody debris. The CON and ALL plots were thinned by the same amount of basal area as the woody debris creation plots in order to keep light regimens the same. This paper includes pretreatment data from 1997 to 2001 before the 2001 treatments/thinning were conducted. The selected trees in the CAT treatment were girdled before the 2001 inventory, but this report does not include their data. Decay classes refer to the amount of wood decay, not bark or standing integrity (Sabin 1991).

Studies

All compartments were used in data calculations and analysis. Plot summary tables and/or raw data are presented for each year. Means were determined for diameter/diameter at breast height (d.b.h.), length/height, and decay. Total number in each categorical data class was determined by year. All density, basal area, and volume values were calculated on a per-ha basis. Volume was computed for logs and snags < 2 m tall using Huber's formula: volume = cross-sectional area at log midpoint*length. Logs that were elliptical or flat were assumed to be 60 percent and 20 percent of the volume computed, respectively. For snags at least 2 m tall and trees, volume was computed by regional volume equations (Saucier and Clark 1985).

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Citation for proceedings: Connor, Kristina F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 594 p.

In order to determine any significant treatment andcompartment effects, analysis of variance (ANOVA) was performed. CON and CAT treatments were combined in the data reduction analysis, but not in the base analysis. Combining ALL and DOW treatments strengthened down-removal effects, and combining CON, CAT, and DOW treatments when looking at standing removal effects. Combined analyses are not reported unless there were significant differences for separate vs. combined treatments. If the *P*-value was < 0.0500, LSD tests were run to determine significant differences between treatments or compartments. Paired t-tests determined any differences between years. Chi-square analysis determined differences in categorical data between years or new pieces characteristics vs. removed pieces.

RESULTS AND DISCUSSION

Characteristics of CWD

A total of 3,789 pieces of CWD were tagged in 1997, 3,754 pieces in 1998, 3,756 pieces in 1999, 3,674 pieces in 2000, and 3,781 pieces in 2001, with 87 to 89 percent of the pieces down. Throughout the sampling period, most CWD stayed in the inventory without a change in inventory status (80 to 84 percent). Snags fell at a rate of 8 to 11 percent annually, especially increasing after the prescribed burns. The prescribed burns also consumed more snags and logs below the size limits for CWD than previous years (5 to 9 percent vs. 2 to 3 percent, respectively). Annually, only 2 to 3 percent of the existing logs and snags fragmented. The amount removed decreased over time, and all previous CWD was removed from the areas, including decayed logs.

In all years, pine constituted most of the pieces present, with oak (*Quercus* spp.) and black cherry (*Prunus serotina*) the next most abundant species. This composition reflected the living canopy, except that most of the black cherry stems were found dead in the plots.

Down Woody Debris

Length and diameter—Overall mean midpoint diameter increased over time from 15.4 cm in 1997 to 16.1 cm in 2001 as the logs decayed and their sides collapsed (table 1). The overall mean diameter increase was not significant ($P = 0.67$); the nonremoval plots significantly increased ($P = 0.01$). There were no significant differences at the 0.05 level between treatments or compartments for diameter. The overall mean length to a 10-cm diameter remained relatively static over time, ranging from 3.2 m in 1998 to 3.4 m in 2001 (table 1). There were no significant differences between treatments for length. Without much variation between years, in distribution most logs were small in diameter and short in length. Most of the smaller CWD were recruited after thinning in 1995 and 1996 and herbicide applications in 1996. Some of these logs are becoming too small to stay in the inventory; i.e., < 0.6 m in length or 10.0 cm in midpoint diameter, so the smaller size classes have reduced in number.

Additional characteristics—In 1997, 50 percent of the logs were assigned a decay class of 1 (sound), while only 20 percent were assigned decay class 3 (decayed). In 1998, 40 percent of the logs were class 1 logs, while

Table 1—Mean midpoint diameter, length, and decay for down woody debris by treatment and compartment for 1997 through 2001 for the Coarse Woody Debris Template Study in 50-year-old managed loblolly pine stands at the Savannah River Site, SC

	n					Diameter					Length					Decay[a]				
	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001
	- - - - *n* - - - -					- - - - *cm* - - - -					- - - - *m* - - - -									
Treatment																				
CON	1,436	1,509	1,568	1,617	1,518	14.8	15.1	15.2	15.5	15.9	3.1	3.1	3.3	3.4	3.4	1.78 b[b]	1.83 c	1.89 a	1.90 a	2.01 a
CAT	1,493	1,582	1,653	1,522	1,661	15.4	15.5	15.6	15.9	16.2	3.5	3.4	3.3	3.3	3.4	1.53 c	1.60 d	1.72 ab	1.78 ab	1.93 a
DOW	268	134	43	56	131	17.5	19.4	17.2	18.2	17.4	3.3	2.2	2.8	3.9	4.2	1.79 b	2.06 b	1.20 b	1.18 c	1.39 b
ALL	178	100	9	15	14	16.5	18.2	12.8	17.2	13.2	3.7	3.4	2.4	3.3	2.1	1.95 a	2.34 a	1.39 ab	1.43 bc	1.07 b
P-value						0.3979	0.2640	0.2521	0.3336	0.0874	0.3611	0.1964	0.0894	0.7193	0.1500	0.0000	0.0000	0.0330	0.0100	0.0008
Compartment																				
15	876	877	792	769	803	15.6	15.6	15.4	15.7	16.0	3.3 ab	3.3 ab	3.3	3.1	3.3	1.86 b	1.86 b	1.92	1.93	2.04
30	856	857	841	822	810	13.9	14.1	13.7	14.4	14.5	3.1 b	3.0 b	3.0	3.1	3.2	1.33 d	1.43 d	1.51	1.61	1.78
54	621	613	624	641	708	17.5	17.4	17.5	17.7	18.1	4.3 a	4.0 a	4.5	4.5	4.4	2.18 a	2.18 a	2.05	2.03	2.02
55	1,022	978	1,016	978	1,003	15.5	15.6	15.6	16.0	16.1	2.9 b	2.8 b	2.9	3.0	3.0	1.52 c	1.66 c	1.77	1.80	1.95
P-value						0.0952	0.1484	0.4446	0.7387	0.6237	0.0412	0.0154	0.1284	0.2968	0.5789	0.0000	0.0000	0.3786	0.3776	0.1463
Overall	3,375	3,325	3,273	3,210	3,324	15.4	15.5	15.4	15.8	16.1	3.3	3.2	3.3	3.4	3.4	1.68	1.75	1.79	1.83	1.95

CON = control; CAT = catastrophic simulation; DOW = down removal; ALL = all removal.

[a] Decay classes were from 1 (sound) to 3 (decayed).

[b] LSD test run at significant difference of α = 0.0500. Means with the same letter were not significantly different from other treatments or compartments for that given year.

slightly decayed logs increased from 13 percent to 20 percent, whereas the other decay classes remained relatively static. In 1999, logs continued to decay, with decay class I and 1.5 logs each comprising 30 percent of logs present. The logs further decayed in 2000 and 2001, with only 20 percent and 13 percent of the logs remaining in decay class 1, respectively. In 2001, logs were significantly more decayed than the logs present in 1997 ($P = 0.0000$), with sound logs becoming increasingly decayed into the intermediate decay classes. Logs in the removal treatments have become less decayed than logs in the nonremoval treatments in 2001 (table 1). During the first two removals, very decayed pieces were left in place because they would easily dissociate upon lifting, but since the third removal these pieces were raked apart and thus taken out of the inventory.

In 2001, the typical log was without bark (44 percent), round (51 percent), either a main bole (41 percent), a top (33 percent), or an upturned bole (23 percent), and in full contact with the ground (59 percent). The amount of bark present decreased significantly since 1997 ($P = 0.001$), especially the presence of logs with 80 percent or more bark present. Logs have become less round in cross-sectional shape since 1997 ($P = 0.001$). Seventy percent of the logs in 1997 were round, while only 51 percent were round in 2001. More logs have at least 75 percent of the bole settled to the ground now than in 1997 ($P = 0.000$).

Each year had about the same amount of log fragmentation. Around 15 to 18 percent of the logs were associated with a base log, with an additional 2 to 4 percent associated with a snag still standing. For every log that was fragmented, there was an average of 1.7 associates. More pine logs had fragments than hardwood logs (20 percent vs. 12 percent). In 1998, 23 percent of the new logs fragmented from existing logs and 20 percent from snags still standing, while in 1999 only 11 percent of the new logs fragmented from existing logs and 33 percent from snags still standing. In 2000 and 2001, around 20 percent of the new logs fragmented from existing logs and around 25 percent from snags still standing. Furthermore, a quarter of the logs had human-caused mortality or fragmentation, as evidenced by at least one cut side, and an eighth of the logs were found in old log decks. Only 9 percent of the fragments had cut ends.

Cohort Changes

The 1997 cohort logs significantly increased in diameter and decreased in length since 1997 ($P = 0.0045$ and $P = 0.0166$, respectively) (table 2). As logs decay, they tend to lose structural integrity and thus become wider and more elliptical. The 1998, 1999, and 2000 cohorts also slightly increased in diameter, but their length stayed almost the same over time. The 1998, 1999, and 2000 cohorts were longer than the 1997 cohort, since the 1997 cohort

Table 2—Mean midpoint diameter, length, density, and volume for down and standing woody debris by cohort for 1997, 1998, 1999, 2000, and 2001 for nonremoval plots for the Coarse Woody Debris Template Study in 50-year-old managed loblolly pine stands at the Savannah River Site, SC

Inventory year	Down	Standing	Diameter Down	Diameter Standing	Length Down	Length Standing	Density Down	Density Standing	Volume Down	Volume Standing
	n		*cm*		*m*		*no./ha*		*m³/ha*	
1997 Cohort										
1997	2,929	376	15.1c[a]	21.6	3.3a	7.4	91.5a	7.8a	6.66a	2.12a
1998	2,900	320	15.3c	22.0	3.2b	7.3	90.6a	6.7b	6.35b	1.79b
1999	2,810	278	15.3c	22.4	3.1b	6.7	87.8a	5.8c	6.06c	1.40c
2000	2,579	214	15.7b	21.3	3.1b	6.6	80.6b	4.5d	5.69d	1.01d
2001	2,488	166	16.0a	20.2	3.1b	6.2	77.8c	2.5e	5.27e	0.64e
1998 Cohort										
1998	191	76	15.7	19.3	4.1	6.9	6.0	1.6a	0.85	0.38a
1999	194	70	15.6	19.6	4.1	6.4	6.1	1.5a	0.86	0.32a
2000	183	54	15.9	19.0	4.2	6.3	5.7	1.1b	0.83	0.24a
2001	178	40	16.3	18.4	4.2	5.2	5.6	0.8c	0.78	0.13b
1999 Cohort										
1999	217	116	16.2	23.9	4.8b	6.5	6.8	2.4a	1.24	0.75a
2000	209	104	16.5	25.0	4.9ab	6.3	6.5	2.1b	1.23	0.68a
2001	199	88	16.6	25.0	5.0a	5.9	6.2	1.8c	1.16	0.52b
2000 Cohort										
2000	168	59	15.4	24.2	3.7	10.9	5.3	1.2a	0.59a	0.62
2001	166	52	15.5	25.1	3.6	11.0	5.2	1.1b	0.58b	0.56

[a] Paired t-tests run. Means with the same letter were not significantly different ($\alpha = 0.0500$) from other inventory years for that given coarse woody debris type and cohort.

included many logs that have been onsite since before 1997. Over time, all cohorts have become significantly more decayed ($P = 0.0000$, $P = 0.0000$, $P = 0.0001$, and $P = 0.0027$ for 1997, 1998, 1999, and 2000 cohorts, respectively). The 1997 and 1998 cohorts have settled more to the ground ($P = 0.0000$ and $P = 0.0365$, respectively).

Standing Woody Debris

The overall mean d.b.h. ranged from 22.0 cm in 1999 to 20.9 in 2000 (table 3). In 1999 and 2000, the removal treatment d.b.h. was significantly less than the nonremovals. Otherwise, there were no significant differences between treatment or compartment for d.b.h. The overall mean height to a 10-cm-diameter top decreased from 7.3 m in 1997 to 6.5 m in 2001 (table 3). The nonremovals significantly decreased in height since 1997 ($P = 0.0423$). There were no significant differences between treatments for height, but there were significant differences between compartments for 1998 and 2000. Compartment 54 had significantly shorter snags than compartments 15 and 30. Without much temporal variation, most of the snags were small in d.b.h. and short in height, as is shown in their distributions, but there were several small peaks in the mid- to upper-size classes because of dead overstory pine. Other snag studies in southeastern pine forests have found snags clustered in the lower-size classes in the absence of catastrophic events (Carmichael and Guynn 1983, Harlow and Guynn 1983, McComb and others 1986). Snags are losing some height as tops of large snags fall. During the study period, snags collectively broke 28 to 32 times each year.

In 1997, 50 percent of the snags were assigned a wood decay class of 1, while < 10 percent were assigned decay classes 2.5 and 3. Snags probably fall before their wood has a chance to become very decayed since the removal treatment had less decayed snags (table 3) and snags that have fallen are not very decayed. Logs were more decayed than snags (tables 1 and 3). In 1998, some decay class 1 snags decayed slightly to become classified as decay class 1.5, whereas the other decay classes remained relatively static. In 1999, 2000, and 2001, there were more decay class 1 and 1.5 snags, mostly due to the fall 1998 windstorm damage and the prescribed burning consumption of decayed snags in 2000 and 2001. Decay classes refer to the amount of wood decay, not to bark or standing integrity, which other studies have incorporated into their decay classifications (Maser and others 1979, Raphael and Morrison 1987, Sabin 1991). Most snags had either little bark or a lot of bark. Logs had less in the upper bark presence classes than the snags.

In 2001, most snags had intact boles with at most the very top out (58 percent), though 41 percent had broken boles. Standing integrity changed between years mostly after disturbances. The percentage of snags that were broken increased in 1999 after the 1998 windstorm. In 2001, several trees died from fire, so the amount with intact boles with branches increased. Between 8 and 12 percent of the snags fell annually during the 4 years, while 6 to 15 percent broke part of their boles annually. The highest year of bole breakage was after the windstorm in 1999.

Table 3—Mean diameter at breast height, and decay present for standing woody debris by treatment and compartment for 1997 through 2001 for the Coarse Woody Debris Template Study in 50-year-old managed loblolly pine stands at the Savannah River Site, SC

						D.b.h.					Height					Decay[a]				
	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001
			n					*cm*					*m*							
Treatment																				
CON	132	131	145	130	120	21.8	21.6	22.3 a[b]	21.5a	20.1	7.9	6.9	6.3	6.1	5.6	1.38	1.50a	1.41	1.29a	1.27
CAT	123	130	152	139	134	21.0	21.1	21.7 a	22.2a	21.6	7.4	7.2	6.6	7.2	6.7	1.37	1.36b	1.34	1.28a	1.26
DOW	121	135	167	162	180	22.1	21.9	23.0 a	23.1a	21.3	7.0	7.4	6.8	7.8	6.9	1.45	1.40ab	1.25	1.21a	1.22
ALL	38	33	19	33	23	21.1	15.0	13.5 b	15.4b	17.1	5.9	4.8	3.9	5.6	6.1	1.54	1.30b	1.08	1.03b	1.02
P-value						0.9877	0.3401	0.0077	0.0366	0.1978	0.7535	0.1933	0.0529	0.1060	0.5699	0.3661	0.0182	0.1934	0.0024	0.3039
Compartment																				
15	52	72	70	68	82	27.2	25.7	25.3	23.1	22.7	10.1	8.9a	8.6	10.0a	8.5	1.31	1.22b	1.24	1.14	1.18
30	45	59	62	45	58	23.6	22.3	22.9	24.0	19.5	9.3	7.6a	7.3	8.4ab	5.2	1.31	1.42a	1.33	1.16	1.14
54	188	187	218	224	178	19.3	18.3	21.8	21.7	21.4	6.1	5.6b	6.0	6.0c	6.2	1.44	1.45a	1.33	1.29	1.29
55	129	111	133	127	139	22.0	21.9	20.3	20.6	19.7	7.3	7.6a	5.8	6.7bc	6.1	1.44	1.47a	1.34	1.22	1.23
P-value						0.1175	0.0620	0.5596	0.7620	0.7446	0.1451	0.0056	0.7230	0.0156	0.4346	0.2910	0.0002	0.9610	0.1429	0.0925
Overall	414	429	483	464	457	21.6	21.0	22.0	21.8	20.9	7.3	7.0	6.5	7.0	6.5	1.41	1.41	1.32	1.24	1.24

D.b.h. = diameter at breast height; CON = control; CAT = catastrophic simulation; DOW = down removal; ALL = all removal.

[a] Decay classes were from 1 (sound) to 3 (decayed).

[b] LSD test run at significant difference of $\alpha = 0.0500$. Means with the same letter were not significantly different from other treatments or compartments for that given year.

For the vast majority of the snags, mortality causes could not be determined. The main cause of determinable mortality was wind, followed by fire (in 2001), suppression, insects, and lightning. In the fall of 1998, a windstorm blew down and broke several pines in some of the plots. Thus, wind-caused mortality increased in 1999. Over time, we might be able to determine how frequent wind mortality is in these loblolly pine forests. Suppression-caused mortality is increasing now and would increase over time without thinning. Fire seems to reduce the amount of snags by consuming all or part of them, but it also creates snags in the years following burning, although it tends to kill small hardwoods and consume large pine snags.

Over 80 percent of the snags had no cavities present. If cavities were present, most snags usually had only one or two. If wind is a major cause of death in these forests, snags may be broken or blown down before many are suitable for cavity establishment or shortly after cavities form. Also, most cavities are found in large-diameter and tall trees (Sabin 1991), and our plots do not have many large snags. More than 50 percent of our snags with cavities were > 25 cm d.b.h., especially snags with multiple cavities. Carmichael and Guynn (1983) found cavities in only 9 percent of the snags surveyed on the Clemson Experimental Forest in the upper Piedmont of South Carolina.

Determinable mortality varied by year, with wind mortality being highest in 1999 and suppression and fire mortality increasing in 2000 and 2001. Over all years, wind caused more snag generation than any other cause (29 percent). Lightning killed only 4 percent of the new snags, but insects killed one to several trees around the lightning-struck tree. In summary, when new snags originate in our stands, they are usually sound and have bark, intact boles, and no cavities. As snags are lost, they are somewhat decayed and have broken boles, and some have cavities.

The snags of each cohort year did not significantly change in d.b.h. or height over time, though the 1997 and 1998 cohorts did decrease over a m in height (table 2). Over time, the cohorts have become more decayed (significantly for the 1997 cohort, $P = 0.000$) and lost most branches on intact snags (significantly for the 1997 and 1998 cohorts, $P = 0.000$ and $P = 0.0028$, respectively). The 1997, 1998, and 1999 cohorts significantly increased in presence of cavities, but some were lost due to breakage ($P = 0.0047$, 0.0000, and 0.0008, respectively). After 2 to 3 years since recruitment, the 1998 and 1999 cohorts finally started having several snags with multiple cavities.

CWD Loadings

In 2001, nonremoval treatments had an average of 99 logs/ha, while removals had 1 log/ha (table 4). The DOW treatment did not receive the annual removal in 2001, so it increased from 3.5 to 8 logs/ha. Since 1997, the nonremovals increased in number, though they slightly decreased since 1999 because of consumption from fire, whereas the removals significantly decreased ($P =$ 0.0019). The removal plots have 1 percent of the density of logs found on the nonremoval plots in 2003. There were no significant differences between compartments, although compartment 54 had the least amount. If snag-fall rates remained constant, 50 percent of the 1997 snags would be down within 3 to 4 years, which is what has happened (table 2). These agree with other snag-fall rates in southeastern forests (Dickson and others 1983, Sabin 1991), though snag-fall rates usually vary from year to year depending on environmental conditions (Harmon and others 1986).

Table 4—Down woody debris loading by treatment and compartment for 1997 through 2001 for the Coarse Woody Debris Template Study in 50-year-old managed loblolly pine stands at the Savannah River Site, SC

	Density					Volume				
	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001
	no./ha					*m³/ha*				
Treatment										
CON	89.8a[a]	94.3a	98.0a	95.1a	94.9a	5.53b	6.50a	7.88a	8.31a	8.18a
CAT	93.3a	98.9a	103.3a	101.1a	103.8a	7.79a	7.91a	8.45a	8.38a	8.76a
DOW	16.8b	8.4b	2.7b	3.5b	8.2b	1.36c	0.39b	0.24b	0.51b	1.21b
ALL	11.1b	6.3b	0.6b	0.9b	0.9b	0.63c	0.34b	0.01b	0.18b	0.03b
P-value	0.0006	0.0002	0.0001	0.0001	0.0000	0.0001	0.0001	0.0004	0.0004	0.0002
Compartment										
15	54.8	54.8	49.5	48.1	50.2	3.43	3.74	3.48	3.41	3.94
30	53.5	53.6	52.6	51.4	50.6	3.46	3.36	3.31	3.71	3.95
54	38.8	38.3	39.0	40.1	44.3	4.26	3.89	5.02	5.39	5.56
55	63.9	61.1	63.5	61.1	62.7	4.15	4.14	4.76	4.86	4.73
P-value	0.5090	0.5721	0.5606	0.5657	0.6063	0.6906	0.8939	0.6256	0.5503	0.6116

CON = control; CAT = catastrophic simulation; DOW = down removal; ALL = all removal.

[a] LSD test run at significant difference of $\alpha = 0.0500$. Means with the same letter were not significantly different from other treatments or compartments for that given year.

The 1997 cohort significantly decreased in density and volume for both logs (P = 0.0020 and P = 0.0003, respectively) and snags (P = 0.0019 and P = 0.0000, respectively) since 1997 (table 2). The 1997 cohort log density has been reduced by 15 percent, while log volume has been reduced by 21 percent. The 1997 cohort snag density and volume have been reduced by 68 and 70 percent, respectively. Pine snags > 25 cm d.b.h. have fallen at a greater rate since 1997, with 52 percent of the density and 59 percent of the volume down. Ninety percent of the volume lost came from snags > 25 cm d.b.h., while only 43 percent of the density lost came from large snags. The 1998, 1999, and 2000 cohorts have decreased in log density and volume, but at most by a tenth. They have significantly decreased in snag density since their origin year by as much as half for the 1998 cohort (P = 0.0174, P = 0.0027, and P = 0.0271, respectively). Only 1998 and 1999 cohorts have significantly decreased in snag volume, with two-thirds of the 1998 cohort volume fallen (P = 0.0.0493 and P = 0.0038, respectively). Thus, in these loblolly pine forests subjected to periodic fire, 50 percent of the snags generated in a given year might only be expected to stand for 3 to 4 years, especially large pine snags.

ACKNOWLEDGMENTS

The study was begun under the direction of James McMinn and was passed on to the present author upon Dr. McMinn's retirement in 2000. Research was funded by the U.S. Department of Energy, Savannah River Biodiversity Program, through the U.S. Department of Agriculture Forest Service. I thank J. Blake for his logistical and research support. Thanks are extended to the following who contributed to the study: E. Andrews, J. Blake, M. Howard, A. Malcolm, B. Miley, J. Miley, and E. Olson.

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