Accumulations of Coarse Woody Debris in Southern Forests

James W. McMinn and Richard A. Hardt

Abstract

Accumulations of coarse woody debris (CWD) were estimated from Forest Inventory and Analysis information for Georgia and South Carolina and from the literature covering detailed studies. Mean accumulations by broad ownership class and forest type for Georgia and South Carolina ranged from 2.2 to 10.7 mega grams per hectare (Mg/ha). Accumulations in individual studies ranged from 0.4 Mg/ha in mature pitch pine on poor sites to 91.2 Mg/ha in young cove hardwoods regenerated by clearcutting. The information presented in this review suggests that attempts to quantify CWD accumulations should account for physiography, ownership, forest type, stand age, stand origin (artificial vs. natural), and disturbance.

Introduction

In this paper are presented estimates of the accumulations of coarse woody debris (CWD) in southern forests from two perspectives. The first, a broad overview is derived from information in Forest Inventory and Analysis (FIA) publications. The second is from the literature covering more detailed studies of CWD on a small scale.

The Broad Perspective

Coarse woody debris as such is not inventoried in the periodic surveys conducted by USDA Forest Service FIA (formerly known as "Forest Survey") units. However, in each survey, mortality is estimated for trees that are at least 12.7 cm in diameter at breast height (d.b.h.). The mortality is reported as annual volume by various strata. Publications with compatible information for estimating recruitment and standing crop were limited to Georgia and South Carolina. Compatible volume and area information was available for three broad ownership classes and five broad forest types in those two States (Anderson and others 1990; Brantley and others 1993; Tansey 1987; Thompson 1989). Ownership classes were public, nonindustrial private forest lands (NIPF), and forest industry. Broad forest types (called "broad management classes" in FIA publications) were pine plantation, natural pine, oak-pine, upland hardwood, and lowland hardwood. The published data consisted of total volumes for all species within each combination of ownership class and forest type.

Volumes were converted to mass using an overall average (0.525) of wood-specific gravities reported for Southern species (Koch 1972, 1985). Standing crop mass was derived using the single exponential decay model with a k-value of 0.075; this value was derived from loblolly pine data in the Piedmont of South Carolina (Barber and Van Lear 1984). (This was the only exponential decay model found in the literature for the geographic area of interest.) Based on the descriptions by Barber and Van Lear (1984) and FIA personnel,[1] standing crop volume was assumed to be 15 times the annual recruitment. However, all values were considered low because all age classes with trees meeting the minimum diameter limit were included in these average estimates.

Mean CWD accumulations by ownership and state ranged from 4.1 mega grams per hectare (Mg/ha) on forest industry land in South Carolina to 7.7 Mg/ha on public lands in South Carolina (table 1). Accumulations were lower on forest industry land than on public or nonindustrial private lands, and higher in South Carolina than in Georgia on public and NIPF. Lower mortality would generally be expected on forest industry land because the average stand age is lower and the proportion of pine plantations is higher. (The latter generally exhibit lower mortality from intraspecific competition because initial density is controlled.) This explanation is supported by the relatively low accumulations for pine plantations (2.3 Mg/ha and 3.5 Mg/ha in Georgia and South Carolina, respectively) compared to other forest types when averaged over all ownerships (table 2). Natural pine and lowland hardwood types exhibited the highest accumulations (> 8 Mg/ha), while the oak-pine and upland hardwood types exhibited intermediate accumulations.

Relative accumulations among the forest types were similar for the two States when averaged over all ownerships, but were dissimilar when broken out by ownership class. On

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Table 1—Estimated mass and volume of coarse woody debris over all forest management classes by ownership and State

	Mass		Volume	
Ownership	Annual input	Standing crop	Annual input	Standing crop
	---- *Mg/ha* ---		--- *m³/ha* ---	
		Georgia		
Public	0.410	5.667	0.781	11.715
NIPF*	0.478	6.607	0.911	13.665
Forest industry	0.327	4.520	0.622	9.330
		South Carolina		
Public	0.555	7.672	1.057	15.855
NIPF*	0.551	7.616	1.050	15.750
Forest industry	0.300	4.147	0.570	8.550

*Nonindustrial private forest land.

public lands in Georgia, the upland hardwood type exhibited the lowest accumulations at 2.2 Mg/ha; pine plantation and oak-pine accumulations were somewhat higher; and natural pine and lowland hardwood accumulations were quite high (> 9 Mg/ha). In South Carolina, only the pine plantation type exhibited low accumulations while all other forest types had relatively high accumulations; lowland hardwood exhibited the highest accumulation at 10.7 Mg/ha (table 3). All data were collected prior to Hurricane Hugo. Patterns among types were more similar for the two States on NIPF, except for pine plantations in South Carolina where 5.7 Mg/ha accumulations were unusually high for the forest type (table 4). On forest industry lands, the relative pattern among types was generally similar for the two States; however, higher accumulations in the natural pine, oak-pine, and upland hardwood types were exhibited in Georgia than in South Carolina (table 5).

Several parallels can be found between these values and those in a more rigorous study designed to estimate snag densities from FIA data in Florida (McComb and others 1986). In that study, snags (12.7-cm d.b.h. and 1.3-m tall) were more abundant (1) in oak-hickory and oak-tupelo-baldcypress than in longleaf or slash pine; (2) in natural stands than in pine plantations; (3) on public than on private lands; and (4) on stream margins and in deep swamps than on flatwoods, rolling uplands, and sandhills.

Table 2—Estimated mass and volume of coarse woody debris over all ownerships by broad forest management class and State

	Mass		Volume	
Forest type	Annual input	Standing crop	Annual input	Standing crop
	---- *Mg/ha* ---		--- *m³/ha* ---	
		Georgia		
Pine plantation	0.169	2.336	0.322	4.830
Natural pine	0.643	8.888	1.225	18.375
Oak-pine	0.344	4.755	0.656	9.840
Upland hardwood	0.386	5.336	0.736	11.040
Lowland hardwood	0.622	8.598	1.185	17.775
		South Carolina		
Pine plantation	0.254	3.511	0.484	7.260
Natural pine	0.612	8.460	1.165	17.475
Oak-pine	0.437	6.041	0.832	12.480
Upland hardwood	0.428	5.916	0.815	12.225
Lowland hardwood	0.635	8.778	1.209	18.135

Detailed Studies

The more detailed studies define the CWD accumulations expected under different conditions at various stages of stand development. Accumulations of CWD—snags and logs—are quantified in the scientific literature by mass, volume, or the number of pieces per unit area. Commonly, accumulations have been reported by mass (Mg/ha) or volume (m³/ha), and snags have been reported by number (no./ha).

Table 3—Estimated mass and volume of coarse woody debris on public land by broad forest management class and State

Forest type	Mass: Annual input	Mass: Standing crop	Volume: Annual input	Volume: Standing crop
	- - - - *Mg/ha* - - -		- - - *m³/ha* - - -	
Georgia				
Pine plantation	0.275	3.801	0.524	7.860
Natural pine	0.670	9.261	1.275	19.125
Oak-pine	0.263	3.635	0.502	7.530
Upland hardwood	0.160	2.212	0.306	4.590
Lowland hardwood	0.665	9.192	1.267	19.005
South Carolina				
Pine plantation	0.177	2.447	0.337	5.055
Natural pine	0.617	8.529	1.176	17.640
Oak-pine	0.629	8.695	1.197	17.955
Upland hardwood	0.575	7.948	1.096	16.440
Lowland hardwood	0.773	10.685	1.057	15.855

Table 4—Estimated mass and volume of coarse woody debris on nonindustrial private land by broad forest type and State

Forest type	Mass: Annual input	Mass: Standing crop	Volume: Annual input	Volume: Standing crop
	- - - - *Mg/ha* - - -		- - - *m³/ha* - - -	
Georgia				
Pine plantation	0.162	2.239	0.309	4.635
Natural pine	0.648	8.957	1.234	18.510
Oak-pine	0.372	5.142	0.708	10.620
Upland hardwood	0.413	5.709	0.787	11.805
Lowland hardwood	0.646	8.930	1.231	18.465
South Carolina				
Pine plantation	0.412	5.695	0.784	11.760
Natural pine	0.647	8.943	1.232	18.480
Oak-pine	0.464	6.414	0.884	13.260
Upland hardwood	0.448	6.193	0.854	12.810
Lowland hardwood	0.656	9.068	1.250	18.750

Harmon and others (1986) and Spies and others (1988) have postulated a U-shaped temporal pattern for logs following disturbance. High log inputs produced by disturbances, such as logging, fire, or insect attack, may result in a large accumulation in the subsequent young stand (Harmon 1980; Mattson and others 1987; Nicholas and White 1984; Smith 1991). This accumulation largely decays before inputs return to predisturbance levels, resulting in low densities of logs in maturing second-growth. Log accumulations slowly build with increasing inputs, eventually reaching moderate to high levels in old-growth stands (Harmon and others 1986; Hardt 1993; Muller and Liu 1991). However, log accumulations in young stands, dependent on the type of disturbance and stand history, are highly variable (Hardt 1993; Harmon and others 1986; Spies and others 1988). For example, short-rotation harvesting can result in low accumulations of CWD after several rotations (Gore and Patterson 1985; Spies and Cline 1988; Spies and others 1988).

Accumulations of logs in southern forests vary widely with forest type, stand age, and disturbance history (table 6). The greatest accumulations of logs (> 90 Mg/ha) are reported from stands immediately following disturbance (Mattson and others 1987; Smith 1991). The smallest accumulations of logs (as low as 0.4 Mg/ha) have been reported from maturing stands on low productivity sites (Harmon and others 1986; Smith 1991). Log masses reported for old-growth stands in the Southern Appalachians are generally higher than for younger stands, ranging from 17 Mg/ha for a beech stand in Kentucky (Muller and Liu 1991) to 29 Mg/ha for a beech-birch stand in Tennessee (Harmon and others 1986). These

Table 5—Estimated mass and volume of coarse woody debris on forest industry land by broad forest management class and State

Forest type	Mass: Annual input	Mass: Standing crop	Volume: Annual input	Volume: Standing crop
	- - - - *Mg/ha* - - -		- - - m^3*/ha* - - -	
		Georgia		
Pine plantation	0.170	2.350	0.324	4.860
Natural pine	0.600	8.294	1.143	17.145
Oak-pine	0.258	3.566	0.491	7.365
Upland hardwood	0.385	5.322	0.734	11.010
Lowland hardwood	0.553	7.644	1.053	15.795
		South Carolina		
Pine plantation	0.168	2.322	0.320	4.800
Natural pine	0.415	5.737	0.791	11.865
Oak-pine	0.183	2.530	0.348	5.220
Upland hardwood	0.158	2.184	0.302	4.530
Lowland hardwood	0.546	7.547	1.040	15.600

accumulations are comparable to masses reported from other Eastern old-growth stands (Gore 1986; Lang and Forman 1978; MacMillan 1981; Tyrrell 1991), but are an order of magnitude lower than log masses reported for the Douglas-fir region of the Pacific Northwest (Harmon and others 1986). In a review of log accumulations in temperate deciduous old-growth forests, Muller and Liu (1991) found higher accumulations in cool forests and speculated that higher accumulations resulted from slower decomposition rates. In contrast, Mattson and others (1987) found no significant relationship between elevation and log decay; however, the range in elevation may have been too small to substantially influence temperature.

Snag accumulations are presented in table 7. Snags are commonly reported by the number per unit area, in part because most snag studies are primarily related to animal habitat (Conner 1978; Harlow and Guynn 1983; McComb and Muller 1983; McComb and others 1986). Accumulations of snags may also follow the same U-shaped temporal pattern as logs where extremely high accumulations follow types of disturbance. However, the episodic nature of snag production may confound patterns of snag accumulations that are associated with forest type or stand condition. The effects of natural disturbances on snag production are highly variable. For example, insects and diseases that kill trees aboveground, such as southern pine beetle, balsam woolly adelgid, Dutch elm disease, and chestnut blight, produce high accumulations of snags (Harmon and others 1986; Smith 1991). On the other hand, diseases that attack trees at the base or belowground, such as root and heart rots, are more likely to create logs directly when weakened trees are windthrown (Harmon and others 1986; Matlack and others 1993).

Timber harvests generally leave stands with few snags (Carmichael and Guynn 1983; Dickson and others 1983; McComb and others 1986), but timber stand improvement that includes girdling may increase snag accumulations (Moriarty and McComb 1983). Regenerating stands may have high accumulations of small snags, a result of density-dependent tree mortality, but as the stands become older the accumulation of larger snags increases. Total snag densities may not differ between second-growth and old-growth stands, but the size distribution will shift. McComb and Muller (1983) reported no significant difference between the densities of snags in Appalachian old-growth and second-growth stands. However, in a survey of snag densities in the pine, pine-hardwood, and hardwood stands in Florida, McComb and others (1986) found that the density of snags (> 12.7-cm d.b.h.) increased as stand age increased. In the Southern Appalachians, Rosenberg and others (1988) found a greater density, basal area, and mean diameter of snags in old stands than in younger stands. Hardt (1993), also working in the Southern Appalachians, found significantly higher densities of large snags (>25-cm d.b.h.) in old-growth than in second-growth stands.

Conclusions

Accumulations of CWD in individual stands are quite variable and, in this review, range from 0.4 Mg/ha in mature pitch pine on poor sites to 91.2 Mg/ha in young cove hardwoods regenerated by clearcutting. However, the influence of some factors associated with ownership and forest type in Georgia and South Carolina is so strong that relatively large differences (2.2 to 10.7 Mg/ha) exist in mean accumulations. Generally, the information derived

Table 6—Log accumulations in some southern forest stands

Stand	Age	Lower diameter limit	Log mass	Log volume	Source
	Years	*cm*	*Mg/ha*	*m³/ha*	
Cove hardwoods, mixed oak, oak-pine; North Carolina	0[a]	5	91.2	—	Mattson and others 1987
	1[a]	5	74.8	—	
	2[a]	5	53.1	—	
Sugar maple; Tennessee	—	10	7.95	—	Onega and Eickmeier 1991
Chestnut oak; Tennessee	40	7.5	11	—	Harmon 1980, as cited in Harmon and others 1986
Tulip-poplar; Tennessee	40	7.5	14	51	Harmon and others 1986
Pine; Tennessee	50+	7.5	7	~30	Harmon and others 1986
	50+	7.5	11	—	Harmon 1980, as cited in Harmon and others 1986
Pitch pine; North Carolina	~100	10	0.4	—	Smith 1991
	3[b]	10	32.7	—	
	8[b]	10	15.2	—	
	11[b]	10	12.7	—	
	16[b]	10	14.5	—	
Mixed oak; North Carolina	< 5	10	—	102	Petranka and others (unpublished manuscript)[c]
	5-39	10	—	63	
	40-79	10	—	65	
	80-119	10	—	82	
	>120	10	—	102	
Tulip-poplar; North Carolina	30	20	—	22.40	Hardt 1993
	30	20	—	91.55	
Cove hardwoods, mixed oak; North Carolina	70+	20	—	45.00	Hardt 1993
	70+	20	—	83.32	
White pine-white oak; South Carolina	200+	20	—	65.64	Hardt 1993
Sugar Maple; North Carolina	200+	20	—	86.17	Hardt 1993
Beech-birch; Tennessee	200+	7.5	29	82	Harmon and others 1986
Mixed-oak; Tennessee	200+	7.5	24	94	Harmon and others 1986
Chestnut oak; Tennessee	200+	7.5	21	132	Harmon and others 1986
Beech; Kentucky	200+	20	17.0	54.8	Muller and Liu 1991
Sugar maple; Kentucky	200+	20	27.1	63.8	Muller and Liu 1991
Chestnut oak-red maple; Kentucky	200+	20	27.1	78.9	Muller and Liu 1991

[a] Following clearcut harvest.
[b] Following southern pine beetle attack.
[c] Petranka, J.W. (and others). Effects of timber harvesting on low elevation populations of Southern Appalachian salamanders (unpublished manuscript).

Table 7—Snag accumulations in some southern forest stands

Stand	Age	Lower d.b.h. limit	Snag density	Snag mass	Snag volume	Source
	Years	*cm*	*No./ha*	*Mg/ha*	*M³/ha*	
Pine; Florida	0-30	12.7	2.6	—	—	McComb and others 1986
	31-60	12.7	7.2	—	—	
	61+	12.7	10.7	—	—	
Pine-hardwood; Florida	0-30	12.7	1.4	—	—	McComb and others 1986
	31-60	12.7	8.0	—	—	
Hardwood; Florida	0-30	12.7	7.1	—	—	McComb and others 1986
	31-60	12.7	11.6	—	—	
	61+	12.7	13.5	—	—	
Bottomland hardwoods; South Carolina	1-100	12.5	9.69	—	—	Harlow and Guynn 1983
Longleaf-loblolly pine; South Carolina	1-100	12.5	3.48	—	—	Harlow and Guynn 1983
Pine plantation; South Carolina	1-40+	10.2	21.3	—	—	Carmichael and Guynn 1983
Pine-hardwoods; South Carolina	20+	10.2	31.2	—	—	Carmichael and Guynn 1983
Cove hardwoods; South Carolina	40+	10.2	37.3	—	—	Carmichael and Guynn 1983
Upland hardwoods; South Carolina	40+	10.2	50.3	—	—	Carmichael and Guynn 1983
Bottomland hardwoods; Louisiana	45	10	3	—	—	McComb 1979, as cited in McComb and others 1986
	80	10	11	—	—	
Pine-hardwoods; Mississippi	85	10	6.4	—	—	McComb 1979, as cited in McComb and others 1986
Mixed mesophytic; Kentucky	60	10	14.8			Moriaty and McComb 1983
	60[a]	10	18.0	—	—	
Pitch pine; North Carolina	~100	10	25	—	—	Smith 1991
	3[b]	10	576	—	—	
	8[b]	10	156	—	—	
	11[b]	10	231	—	—	
	16[b]	10	231	—	—	

continued

Table 7—Snag accumulations in some southern forest stands (continued)

Stand	Age	Lower dbh limit	Snag density	Snag mass	Snag volume	Source
	Years	*cm*	*No./ha*	*Mg/ha*	*m³/ha*	
Sugar maple; Tennessee	—	10	—	1.92	—	Onega and Eickmeier 1991
Chestnut oak, Oak Hickory; Virginia	60-79	10	62.2[c]	—	—	Rosenberg and others 1988
	80-99	10	69.3[c]			
	100+	10	63.6[c]	—	—	
Mixed mesophytic; Kentucky	35	10	83.8	—	—	McComb and Muller 1983
	200+	10	42.8	—	—	
Mixed mesophytic; Kentucky	200+	20	12.19	5.2	12.0	Muller and Liu 1991
Tulip-poplar; North Carolina	30	25	0	—	—	Hardt 1993
	30	25	2.5	—	—	
Cove hardwoods, mixed oak; North Carolina	70+	25	16.7	—	—	Hardt 1993
	70+	25	15.2	—	—	
White pine-white oak; South Carolina	200+	25	17.5	—	—	Hardt 1993
Sugar maple; North Carolina	200+	25	17.1	—	—	Hardt 1993

[a] Following timber stand improvement.
[b] Following southern pine beetle attack.
[c] Snags greater than 10-cm d.b.h.

from inventory data and more detailed research suggests that future studies of CWD accumulations should take into account physiography, ownership, forest type, stand age, stand origin (artificial vs. natural), and disturbance.

Acknowledgment

This work was supported in part by the Savannah River Operations Office, U.S. Department of Energy, through a cooperative arrangement with the USDA Forest Service, Southern Region, Savannah River Forest Station.

Literature Cited

Anderson, Robert L. [and others]. 1990. Incidence and impact of damage and mortality trends to South Carolina timber, 1986. Resour. Bull. SE-114. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 26 p.

Barber, B.L.; Van Lear, D.H. 1984. Weight loss and nutrient dynamics in decomposing woody loblolly pine logging slash. Soil Science Society of America Journal. 48:906-910.

Brantley, Elizabeth A. [and others]. 1993. Incidence and impact of damage and mortality trends to Georgia's timber, 1989. Resour. Bull. SE-134. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 30 p.

Carmichael, D.B., Jr.; Guynn, D.C., Jr. 1983. Snag density and utilization by wildlife in the upper Piedmont of South Carolina. In: Davis, J.W.; Goodwin, G.A.; Ockenfels, R.A., tech. coords. Snag habitat management: Proceedings of the symposium; 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 107-110.

Conner, R.N. 1978. Snag management for cavity nesting birds. In: DeGraaf, R.M., coord. Proceedings of the workshop; management of southern forests for nongame birds; 1978 January 24-26; Atlanta, GA. Gen. Tech. Rep. SE-14. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 120-128.

Dickson, J.G.; Conner, R.N.; Williamson, J.H. 1983. Snag retention increases bird use of a clear-cut. Journal of Wildlife Management. 47:799-804.

Gore, J.A. 1986. Small mammals and habitat structure in an old-growth northern hardwoods forest. Amherst, MA: University of Massachusetts. 211 p. Ph.D. dissertation.

Gore, J.A.; Patterson, W.A., III. 1985. Mass of downed wood in northern hardwood forests in New Hampshire: potential effects of forest management. Canadian Journal of Forest Research. 16:335-339.

Hardt, R.A. 1993. Characterization of old-growth forests in the Southern Appalachian region of the United States and implications for their management. Athens, GA: University of Georgia. 155 p. Ph.D. dissertation.

Harlow, R.F.; Guynn, D.C., Jr. 1983. Snag densities in managed stands of the South Carolina coastal plain. Southern Journal of Applied Forestry. 7:224-229.

Harmon, M.E. 1980. The distribution and dynamics of forest fuels in the low elevation forests of Great Smoky Mountains National Park. Res./ Resour. Manage. Rep. No. 32, Gatlinburg, TN: Uplands Field Research Laboratory, U. S. Department of the Interior, National Park Service. 86 p.

Harmon, M.E.; Franklin, J.F.; Swanson, F.J. [and others]. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research. 15:133-302.

Koch, Peter. 1972. Utilization of the southern pines. Agric. Handb. 420. Washington, DC: U.S. Department of Agriculture. Vol. 1.

Koch, Peter. 1985. Utilization of hardwoods growing on southern pine sites. Agric. Handb. 605. Washington, DC: U.S. Department of Agriculture. Vol. 1.

Lang, G.E.; Forman, R.T.T. 1978. Detrital dynamics in a mature oak forest: Hutcheson Memorial Forest, New Jersey. Ecology. 59:580-595.

MacMillan, P.C. 1981. Log decomposition in Donaldson's Woods, Spring Mill State Park, Indiana. American Midland Naturalist. 106:335-344.

Matlack, G.R.; Gleeson, S.K.; Good, R.E. 1993. Treefall in a mixed oak-pine coastal plain forest: immediate and historical causation. Ecology. 74:1559-1566.

Mattson, K.G.; Swank, W.T.; Waide, J.B. 1987. Decomposition of woody debris in a regenerating, clearcut forest in the Southern Appalachians. Canadian Journal of Forest Research. 17:712-721.

McComb, W.C.; Muller, R.N. 1983. Snag densities in old-growth and second-growth Appalachian forests. Journal of Wildlife Management. 47:376-382.

McComb, William C.; Bonney, Stephen A.; Sheffield, Raymond M. [and others]. 1986. Snag resources in Florida—are they sufficient for average populations of primary cavity-nesters? Wildlife Society Bulletin. 14:40-48.

Moriarty, J.J.; McComb, W.C. 1983. The long-term effect of timber stand improvement on snag and cavity densities in the central Appalachians. In: Davis, J.W.; Goodwin, G.A.; Ockenfels, R.A., tech. coords. Snag habitat management: Proceedings of the symposium; 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 40-47.

Muller, R.N.; Liu, Y. 1991. Coarse woody debris in an old-growth deciduous forest on the Cumberland Plateau, southeastern Kentucky. Canadian Journal of Forest Research. 21:1567-1572.

Nicholas, N.S.; White, P.S. 1984. The effect of southern pine beetle on fuel loading in yellow pine forests of Great Smoky Mountains National Park. Res./Resour. Mgmt. Rep. SER-73. Gatlinburg, TN: Uplands Field Research Laboratory, U.S. Department of Interior, National Park Service. 31 p.

Onega, T.L.; Eickmeier, W.G. 1991. Woody detritus inputs and decomposition kinetics in a southern temperate deciduous forest. Bulletin of the Torrey Botanical Club. 118:52-57.

Rosenberg, D.K.; Fraser, J.D.; Stauffer, D.F. 1988. Use and characteristics of snags in young and old forest stands in southwest Virginia. Forest Science. 34:224-228.

Smith, R.N. 1991. Species composition, stand structure, and woody detrital dynamics associated with pine mortality in the Southern Appalachians. Athens, GA: University of Georgia. 163 p. M.S. thesis.

Spies, T.A.; Cline, S.P. 1988. Coarse woody debris in forests and plantations of coastal Oregon. In: Maser, C.; Tarrant, R.F.; Trappe, J.M. [and others], tech. eds. From the forest to the sea: a story of fallen trees. Gen. Tech. Rep. PNW-220. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 5-24.

Spies, T.A.; Franklin, J.F.; Thomas, T.B. 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology. 69:1689-1702.

Tansey, J.B. 1987. Forest statistics for South Carolina, 1986. Resour. Bull. SE-93. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 53 p.

Thompson, Michael T. 1989. Forest statistics for Georgia, 1989. Resour. Bull. SE-109. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 68 p.

Tyrrell, L.E. 1991. Patterns of coarse woody debris in old-growth hemlock-hardwood forests of northern Wisconsin and western Upper Michigan. Madison, WI: University of Wisconsin. 185 p. Ph.D. dissertation.

United States
Department of
Agriculture

Forest Service

Southern Research
Station

General Technical
Report SE-94

Biodiversity and Coarse Woody Debris in Southern Forests

Proceedings of the Workshop on Coarse Woody Debris in Southern Forests: Effects on Biodiversity

Athens, GA — October 18-20, 1993

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March 1996

Southern Research Station
P.O. Box 2680
Asheville, North Carolina 28802

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Editors:

James W. McMinn, USDA Forest Service,
Southern Research Station, Forestry Sciences Laboratory, Athens, GA,
and D.A. Crossley, Jr., University of Georgia, Athens, GA

Sponsored by:

U.S. Department of Energy, Savannah River Site,
and the USDA Forest Service, Savannah River Forest Station,
Biodiversity Program, Aiken, SC

Conducted by:

USDA Forest Service, Southern Research Station, Asheville, NC,
and University of Georgia, Institute of Ecology, Athens, GA