

*The Effect of Satellite Chip Mills on Post-Harvest Woody Debris*

**George Hess**

Forestry Department, North Carolina State University

**Dale Zimmerman**

Department of Statistics and Actuarial Science, University of Iowa

**Southern Center for Sustainable Forests**

**Working Paper No 6. Part II**

**Final Report**

**Prepared for the Study on:**

**Economic and Ecological Impacts**

**Associated with Wood Chip Production in North Carolina**

**2000 July 27**

# **The Effect of Satellite Chip Mills on Post-Harvest Woody Debris**

**George R. Hess (corresponding author)**

Forestry Department  
North Carolina State University  
Raleigh NC 27695-8002  
919.515.7437  
[grhess@ncsu.edu](mailto:grhess@ncsu.edu)

**Dale Zimmerman**

Department of Statistics and Actuarial Science  
University of Iowa  
233 Schaeffer Hall  
Iowa City IA 52242  
319.335.0818  
dzimmer@stat.uiowa.edu

**Submitted to:** Southern Journal of Applied Forestry, 2000 May 12  
<http://www.safnet.org/pubs/periodicals.html#regional>

## **Acknowledgments**

Thanks to Rick Hamilton, Dan Richter, and the forestry consultants who helped locate sites, and to the landowners who allowed us to measure them. Dan Richter helped with early development of the measurement protocols. Donna Scheungrab, James McMinn, James Petranka, Robert Muller, and Brian McCarthy made comments on an early draft of the study methods that improved and streamlined our approach to data collection. Theresa Galinski, Laura Blake, and Terri King helped us collect the data. Susan Loeb provided valuable insight into the quantification of woody debris use by wildlife. Richard Lancia made helpful comments on an earlier version of the manuscript. Funding for this study was provided through the Southern Center for Sustainable Forestry by the US Environmental Protection Agency and the North Carolina Department of Environment and Natural Resources.

## The Effect of Satellite Chip Mills on Post-Harvest Woody Debris

### Abstract

During public forums on the ecological impacts of satellite wood chip mills, environmentalists and hunters noted that less downed woody debris is left on sites harvested with a satellite chip mill component than on sites without a chip mill component. We conducted a pilot study to assess these claims, and attempted to determine the significance to wildlife of any differences in the volume and distribution of downed woody debris. We used a transect method to estimate the volume of woody debris on seven harvest sites: four with and three without a satellite wood chip component. The mean volume of fresh coarse downed woody debris (>4" diameter), fresh downed woody debris (>1" diameter), and total downed woody debris (>1" diameter) was lower on sites harvested with a satellite chip mill component than on sites harvested without a satellite chip component. On all sites, debris was found in clusters rather than spread evenly across the site. Although differences in the volume of downed woody debris between sites with and without a satellite chip mill component were statistically significant ( $p < 0.07$ ), we were unable to make definitive statements about the significance of these differences to wildlife. The consensus among experts is that the absence of downed woody debris would be detrimental to biodiversity and ecological processes. However, thresholds of woody debris volume below which wildlife are affected negatively have not been determined.

**Keywords:** woody debris, satellite chip mills, wildlife

### Introduction

Satellite wood chip mills have become a flash point for controversy about forestry practices in the southeastern United States. Satellite chip mills are facilities that accept roundwood, chip it, and transport the chips to pulp mills. In North Carolina, public concern about potential adverse effects of satellite chip mills on forest sustainability and tourism-based economic development led Governor Hunt to request a technical study of these potential effects (Southern Center for Sustainable Forests 2000). One concern voiced by hunters and environmentalists at public meetings associated with the technical study was that sites harvested with a satellite chip mill component are left much "cleaner" than sites harvested without a satellite chip mill component — there is less woody debris left on the site. Our study was designed to assess quantitatively these claims. Because the comments about this issue came from people concerned about the wildlife

implications, we also attempted to assess the significance to wildlife of differences in the amount of downed woody debris.

Woody debris is the trees or branches that have fallen to the ground, standing dead trees (snags), and decomposing large roots found in forests of all ages, including harvest sites (Table 1; McMinn and Hardt 1996; van Lear 1996; Hagan and Grove 1999). The amount and spatial distribution of downed woody debris affects the species diversity and abundance of wildlife that occupies forests (see reviews in McMinn and Crossley 1996). Woody debris plays many critical roles in forest ecosystem function and is important to the diversity of life in forests (see reviews in McMinn and Crossley 1996; Hagan and Grove 1999). Downed woody debris serves as seed germination sites (Sharitz 1996), moisture reservoirs, and as a habitat component for earthworms (Hendrix 1993), fungi (Nakasone 1996), macroinvertebrates (Caldwell 1996), insects (Hanula 1996), reptiles and amphibians (Whiles and Grubaugh 1996), birds (Lanham and Guynn 1996), and small mammals (Loeb 1996, 1999). In particular, birds, reptiles, amphibians, and small mammals use downed woody debris for a number of purposes, including foraging, nesting, movement, hiding, and thermoregulation (Table 2). Retention of coarse downed woody debris — debris more than 4 inches (10 cm) in diameter — is especially important at harvest sites, because it persists during the initial stages of forest regeneration.

## **Objectives**

We conducted a pilot study to obtain preliminary evidence of differences in the volume and spatial distribution of downed woody debris between sites harvested with and without a satellite wood chip component. We attempted to determine the significance to wildlife of differences in the volume and distribution of downed woody debris.

## **Methods**

Downed woody debris was measured on seven harvest sites in the North Carolina Piedmont during a nine-month period starting in June 1999. Several forestry consultants identified sites that had been clearcut after October 1998. Once landowner permission was granted, we obtained maps of the site, information about the forest type and acreage, and asked if any of the wood harvested had been sent to a satellite chip mill. Pulpwood was harvested on all sites. No wood was sent to satellite chip mills from three of the sites; a small portion of the total harvest was sent to a satellite chip mill from one site; and three sites included a significant satellite chip mill component.

Data were collected at twenty-five sampling points on each harvest site. Sampling points were located systematically (Figure 1), with the spacing between points determined by the size of the tract. The spacing was calculated to provide complete coverage of the tract, as follows:

$$Spacing (ft) = \sqrt{\frac{Area (ft^2)}{25}} \quad (1)$$

At each sampling point, the following data were collected:

- (1) diameter of and distance to the nearest piece of fine downed woody debris (to determine randomness of spatial distribution);
- (2) diameter of and distance to the nearest piece of coarse downed woody debris (to determine randomness of spatial distribution); and
- (3) diameter, type (conifer or hardwood), and age class (fresh or old) of all downed woody debris larger than one inch (2.5 cm) in diameter along a 246 foot (75 meter) transect (to estimate volume and mass of woody debris).

The transect method used for estimating woody debris volume was developed by Warren and Olsen (1964) as a method to estimate quickly the amount of logging residual on clearcut sites. The method was improved by van Wagner (1968) and described in detail by Brown (1974). These methods are based on Buffon's Needle Problem (de Vries 1986) and assume that the terrain is flat, and debris is randomly oriented and flat on the ground. Several techniques correct for violations of these assumptions (e.g., Brown 1974; Brown and Roussopoulos 1974; Pickford and Hazard 1978). Most importantly for our study, Bell *et al.* (1996) found that transects in the shape of an equilateral triangle reduce bias resulting from the non-random orientation of woody debris. Because debris at harvest sites is not likely to be oriented randomly, we used transects in the shape of an equilateral triangle, 82 feet (25 meters) on a side.

Data were subjected to an analysis of variance to determine if the volume of woody debris differed among sites with and without a satellite chip component (treatment). Sites were considered a random effect nested within treatments (chips vs. no chips). The site with a minor chip component was considered a site with a satellite chip component in the analysis of variance. Three tests for randomness were used: Pearson's chi-square criterion (Diggle 1983: 24), Pollard's statistic (Pollard 1971), and Eberhardt's statistic (Eberhardt 1967). Volume and piece counts were used in the tests for randomness.

## Results

The mean volume of fresh coarse downed woody debris ( $p=0.023$ ), fresh downed woody debris ( $p=0.066$ ), and downed woody debris ( $p=0.02$ ) was lower on sites harvested with a satellite chip component than on sites harvested without a chip component (Tables 3-5, Figure 2). The mean volume of fresh fine downed woody debris ( $p=0.819$ ) and old downed woody debris ( $p=0.696$ ) did not differ on sites harvested with and without a chip component.

The spatial distribution of downed woody debris was non-random on all sites, regardless of chip status. The debris was highly clustered, with large concentrations of fresh coarse downed woody debris at landings. The null hypothesis of random distribution was rejected emphatically ( $p<0.006$ ) for all sites but two, and at the 10% level for all sites (Table 6).

## Discussion

The findings of significant differences in downed woody debris volume between sites harvested with and without a satellite chip mill component should be considered tentative for a number of reasons.

- Sample size was small and limited to a single geographic region.
- Samples were not selected from a random probability sampling frame.
- Many other factors that were not controlled for could account for the differences.

To better quantify the differences in woody debris loads on harvest sites with and without a satellite chip mill component a more complex study of a larger number of sites is required. A rigorous, statistically-based study requires that samples be drawn at random from a known population. For this pilot study, the population was all sites harvested in the Piedmont after October 1998. North Carolina has no established procedures to identify harvest sites, and available resources precluded construction of a sampling frame for our study (e.g., obtain aerial photographs and identify all recent clearcuts). Thus, it was not possible to draw a random sample. The sites measured were identified through cooperative forestry consultants and landowners. Because they were not a random sample of harvest sites, the potential for bias exists. Measuring a larger number of sites selected in this manner would reduce the potential for bias.

A number of factors other than satellite chip mills could account for differences among harvest sites. These include geographic region, forest type, age of stand, logger, harvesting system, time since harvest, topography, and market conditions. Controlling for these factors while obtaining a reasonable sample size in each category requires a stratified design that provides control for factors known or suspected to influence the quantities being measured.

Although the differences in the volume of downed woody debris between sites with and without a satellite chip mill component are statistically significant, we are unable to make definitive statements about the significance of these differences to wildlife. The consensus among experts is that the absence of downed woody debris would be detrimental to biodiversity and ecological processes (see papers in McMinn and Crossley 1996). Unfortunately, thresholds of woody debris volume below which negative effects accrue have not been determined.

Few quantitative studies relate the volume and spatial distribution of downed woody debris to the presence and abundance of species, particularly for the Southeastern United States. In South Carolina, Loeb (1999) found that species composition among small mammals was similar among salvaged and unsalvaged stands after a tornado, but more small mammals were captured on unsalvaged sites. In Maryland, Barnum et al. (1992) found that white-footed mice preferred travel along logs more than 2 inches (5 cm) in diameter.

From the perspective assessing wildlife impacts, the value of simply conducting more statistically rigorous studies of woody debris loads is questionable. Without concurrent attempts to quantify the use of debris by wildlife, it will not be possible to determine thresholds below which the removal of woody debris causes significant changes in wildlife species and abundance. Such quantitative studies are high on the research agendas of coarse woody debris researchers (see papers in McMinn and Crossley 1996).

**Literature Cited**

Barnum, S.A., C.J. Manville, J.R. Tester, and W.J. Carmen. 1992. Path selection by *Peromyscus leucopus* in the presence and absence of vegetative cover. *Journal of Mammalogy* 73: 797-801.

Bell, G., A. Kerr, D. McNickle, and R. Woollons. 1996. Accuracy of the line intersect method of post-logging sampling under orientation bias. *Forest Ecology and Management* 84: 23-28.

Brown, J.K. 1974. Handbook for inventorying downed woody material. USDA Forest Service General Technical Report. INT-16.

Brown, J.K. and P.J. Roussopoulos. 1974. Eliminating biases in the planar intersect method for estimating volumes of small fuels. *Forest Science* 20: 350-356.

Caldwell, R.S. 1996. Macroinvertebrates and their relationship to coarse woody debris: with special reference to land snails. Pages 49-54 in McMinn and Crossley 1996.

de Vries, P.G. 1986. *Sampling Theory for Forest Inventory*. Springer-Verlag, Berlin.

Diggle, P. J. (1983). *Statistical Analysis of Spatial Point Patterns*. London: Academic Press.

Eberhardt, L. L. (1967). Some developments in distance sampling. *Biometrics*, 23, 207-216.

Hagan, J.M. and S.L. Grove. 1999. Coarse woody debris. *Journal of Forestry* 97(1): 6-11.

Hanula, J.L. 1996. Relationship of wood-feeding insects and coarse woody debris. Pages 55-81 in McMinn and Crossley 1996.

Hendrix, P.F. 1996. Earthworms, biodiversity, and coarse woody debris in forest ecosystems of the southeastern USA. Pages 43-48 in McMinn and Crossley 1996.

Lanham, J.D. and D.C. Guynn, Jr. 1996. Influences of coarse woody debris on birds in southern forests. Pages 101-107 in McMinn and Crossley 1996.

Loeb, S. C. 1996. The role of coarse woody debris in the ecology of southeastern mammals. Pages 108-118 in McMinn and Crossley 1996.

Loeb, S.C. 1999. Responses of small mammals to coarse woody debris in a southeastern pine forest. *Journal of Mammalogy* 80: 460-471.

McMinn, J.W. and D.A. Crossley (eds.). 1996. Biodiversity and Coarse Woody Debris in Southern Forests. USDA Forest Service General Technical Report. SE-94.

McMinn, H.W. and R.A. Hardt. 1996. Accumulation of coarse woody debris in southern forests. Pages 1-9 in McMinn and Crossley 1996.

Nakasone, K.K. 1996. Diversity of lignicolous Basidiomycetes in coarse woody debris. Pages 35-42 in McMinn and Crossley 1996.

Pickford, S.G. and John W. Hazard. 1978. Simulation studies on line intersect sampling of forest residue. *Forest Science* 24: 469-483.

Pollard, J. H. (1971). On distance estimators of density in randomly distributed forests. *Biometrics*, 27, 991-1002.

Sharitz, R.R. 1996. Coarse woody debris and woody seeding recruitment in southeastern forests. Pages 29-34 in McMinn and Crossley 1996.

Southern Center for Sustainable Forests. 2000. Ecological and Economic Impacts Associated with Wood Chip Production in North Carolina. Southern Center for Sustainable Forests, Duke University and North Carolina State University, Raleigh, NC.

van Lear, D.H. 1996. Dynamics of coarse woody debris in southern forest ecosystems. Pages 10-17 in McMinn and Crossley 1996.

van Wagner, C.E. 1968. The line intersect method in forest fuel sampling. *Forest Science* 14: 20-26.

Warren, W.G. and P.F. Olsen. 1964. A line intersect technique for assessing logging waste. *Forest Science* 13: 267-276.

Whiles, M.R. and J.W. Grubaugh. 1996. Importance of coarse woody debris to southern forest herpetofauna. Pages 94-100 in McMinn and Crossley 1996.

**Table 1:** Woody debris definitions used for this study.

**Downed woody debris** — logs or branches more than one inch in diameter that have fallen or been knocked to the ground, and that are not connected to any standing live or dead tree.

**Fresh downed woody debris** — downed woody debris that appears to have been created by the harvest.

**Old downed woody debris** — downed woody debris that appears to have been on the ground before the harvest.

**Fine downed woody debris** — downed woody debris between one and four inches in diameter.

**Coarse downed woody debris** — downed woody debris more than four inches in diameter.

**Table 2.** Use of downed woody debris by birds, reptiles, amphibians, and mammals.

<b>Species Group</b>	<b>Documented Uses (citation)</b>
Birds	Perching, breeding, nesting, drumming, roosting (Lanham and Gynn 1993)
Reptiles (lizards, snakes, turtles)	Reproduction (nesting and egg deposition), feeding substrate, thermoregulation (hibernation, protection from temperature extremes, warming), protection from desiccation (Whiles and Grubaugh 1993)
Amphibians (salamanders, frogs, toads)	Reproduction (nesting, egg deposition, and calling), feeding substrate, thermoregulation (hibernation, protection from temperature extremes, warming), protection from desiccation (Whiles and Grubaugh 1993)
Mammals	Foraging, burrowing, nesting, denning, travel routes, predator avoidance, protection from desiccation (Loeb 1993)

**Table 3.** Mean values of downed woody debris on sites with and without a satellite chip mill component.

<b>Debris Category</b>	<b>With Chip Component (feet<sup>3</sup> / acre)</b>	<b>Without Chip Component (feet<sup>3</sup> / acre)</b>
Fresh Coarse (>4" diameter) *	406	844
Fresh Fine (1-4" diameter)	428	444
Fresh (>1" diameter) *	834	1,288
Old (>1" diameter)	141	183
Total (>1" diameter) *	975	1,471

\* Differences statistically significant at the 10% level (see Table 4 for details).

**Table 4.** Analysis of variance (nested design, random effects for Site[Chips]) for categories of downed woody debris (feet<sup>3</sup> / acre).*Fresh coarse downed woody debris*

<b>Source</b>	<b>DF</b>	<b>MS</b>	<b>F Ratio</b>	<b>Prob&gt;F</b>
Chips	1	8,186,757	10.5034	0.0230
Site[Chips]	5	778,670	2.5630	0.0291
Error	167	303,394		

*Fresh fine downed woody debris*

<b>Source</b>	<b>DF</b>	<b>MS</b>	<b>F Ratio</b>	<b>Prob&gt;F</b>
Chips	1	10,358	0.0579	0.8194
Site[Chips]	5	178,551	4.3462	0.0010
Error	167	41,082		

*Fresh downed woody debris*

<b>Source</b>	<b>DF</b>	<b>MS</b>	<b>F Ratio</b>	<b>Prob&gt;F</b>
Chips	1	8,779,508	5.5131	0.0658
Site[Chips]	5	1,590,648	3.4337	0.0056
Error	167	463,248		

*Old downed woody debris*

<b>Source</b>	<b>DF</b>	<b>MS</b>	<b>F Ratio</b>	<b>Prob&gt;F</b>
Chips	1	78,769	0.1711	0.6963
Site[Chips]	5	459,675	12.6216	<0.0001
Error	167	36,420		

*Downed woody debris*

<b>Source</b>	<b>DF</b>	<b>MS</b>	<b>F Ratio</b>	<b>Prob&gt;F</b>
Chips	1	1.053x10 <sup>-7</sup>	11.4281	0.0197
Site[Chips]	5	920,306	1.8504	0.1057
Error	167	497,344		

**Table 5.** Downed woody debris volume on seven harvest sites in the North Carolina Piedmont, with 95% confidence intervals. Terms are defined in Table 1. Data are sorted by increasing volume of fresh coarse downed woody debris.

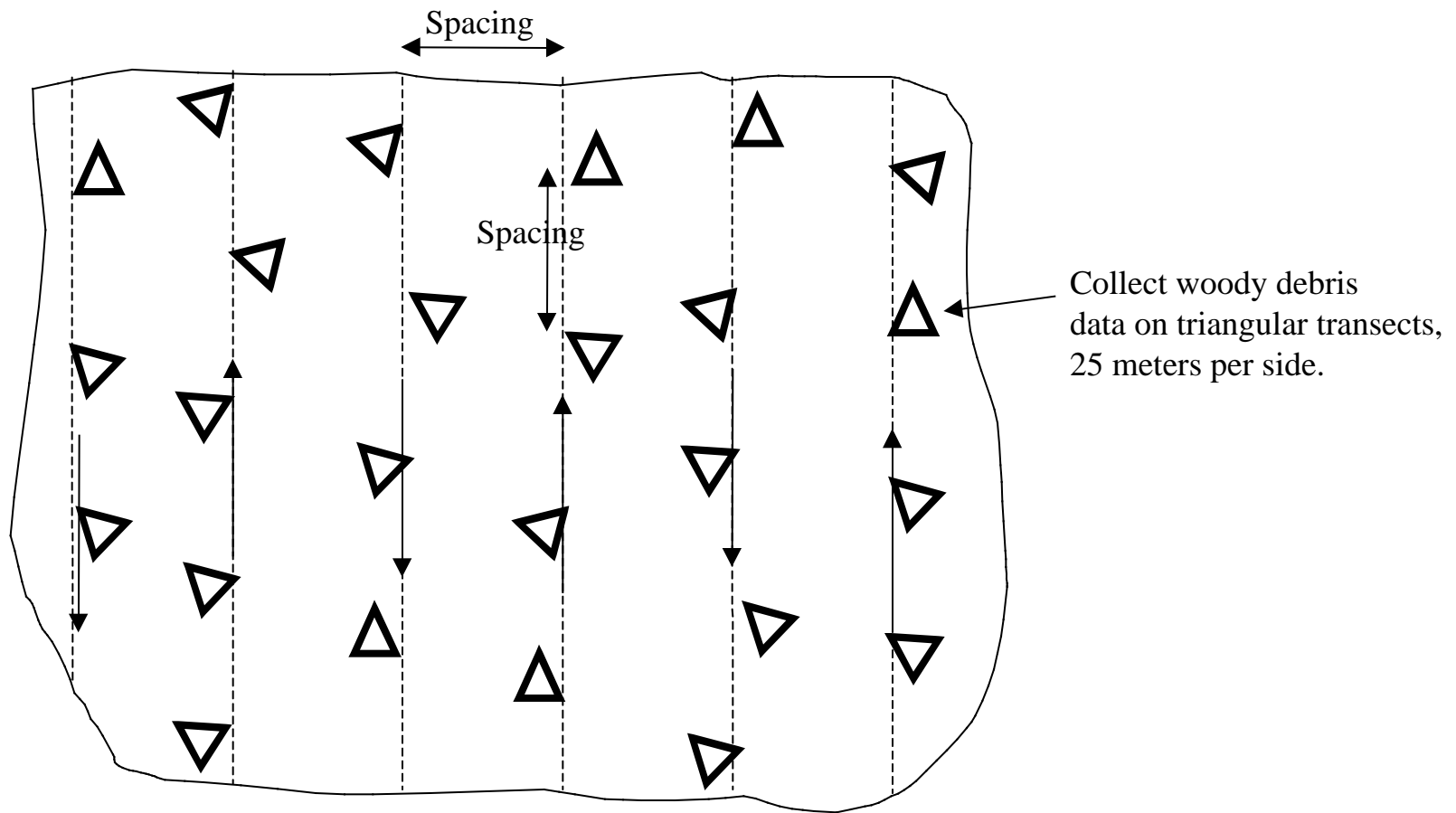
Site	Downed Woody Debris Volume (feet <sup>3</sup> / acre)				Forest Type	Stand Size (ac)	Chip Component
	Fresh Coarse (> 4" diam)	Fresh (> 1" diam)	Old (>1" diam)	Total (>1" diam)			
2	204 ± 78	495 ± 122	328 ± 98	823 ± 166	Pine	8.3	Yes
8	370 ± 89	811 ± 126	22 ± 23	833 ± 131	Pine	20.0	Yes
7	523 ± 106	1022 ± 173	197 ± 81	1219 ± 149	Hardwood	40.0	Yes
4	525 ± 239	1009 ± 315	14 ± 8	1025 ± 313	Pine	160.0	Minor
3	647 ± 342	1016 ± 402	302 ± 99	1318 ± 446	Pine	25.0	No
6	824 ± 237	1310 ± 260	87 ± 31	1397 ± 263	Mixed	47.0	No
5	1060 ± 266	1537 ± 327	160 ± 107	1697 ± 316	Mixed	27.0	No



## Figure Captions

**Figure 1.** Data collection procedure overview. Spacing was determined for each site so that sampling points would cover the entire site (see Equation 1).

**Figure 2.** Mean volume of downed woody debris on each site, in order of increasing volume of fresh coarse downed woody debris. The stacked bars show the contributions to total downed woody debris of fresh coarse (> 4 inches in diameter), fresh fine (1-4 inches in diameter), and old (pre-harvest, > 1 inch in diameter) downed woody debris. Sites 2, 8, and 7 had a satellite wood chip component; site 4 had a minor satellite wood chip component; sites 3, 6, and 5 had no satellite wood chip component.



**Figure 1.** Data collection procedure overview.

**Figure 2.**

