WOODY FUEL DIMENSIONS WITHIN GREAT SMOKY MOUNTAINS NATIONAL PARK

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ABSTRACT

Diameters and bulk density were examined for downed wood in major forest types found in Great Smoky Mountains National Park. One-hour fuel (0 - 7 mm) diameters were smallest in spruce-fir and hemlock forests, intermediate in yellow pine forests, and largest in hardwood forests. Diameters for 10 hour (7 - 25 mm) and 100 hour (25 - 76 mm) fuels were not significantly different between forest types. Bulk density decreased with a decrease in bark coverage. Consistent, but nonsignificant, differences in downed wood bulk density were observed between forest types. A weighted average formula is presented to adjust stand bulk densities after disturbance.

INTRODUCTION

During the last 20 years, wilderness managers have shifted from a policy of totally suppressing fires to allowing some fires to exert an ecological impact (Dolan et al. 1978, Mutch 1975, Wright 1974). An adequate determination of which fires are desirable is dependent on reliable predictions of fire behavior, smoke dispersal, and successional effects. During the last decade, many predictive models have been introduced to fulfill this need (Albini 1976; Deeming et al. 1978; Steward 1971; Van Wagner 1969, 1973; and Rothermal 1972). Variable inputs to most fire models describe weather, topography, and fuel. A sound knowledge of fuel biomass, continuity, and other fuel parameters will allow fire managers to utilize these models more fully. To adequately describe fuel distributions, one should examine variation along time, disturbance, moisture, elevation, and plant community gradients. The large within-site variation can often obscure variation associated with independent variables unless a large sample size is gathered. However, harvesting, transporting (often backpacking), and processing large numbers of fuel samples is expensive in terms of manpower and time. Moreover, destructive sampling is not compatible with policies of most wilderness areas. A relatively quick but reliable fuel estimate which avoids harvesting is desirable.

Planar intercept sampling, as described by Brown (1974), possesses desirable attributes for woody fuel inventory, and allows workers to inventory wood biomass over a larger area than conventional methods without significant disturbance or bias

(Martin 1975). Essentially, the planar intercept method involves counting the number of wood pieces that intercept a vertical plane of known length. If the diameter of each piece is measured, wood volume can be calculated by the formula:

$$\nu = \frac{\Pi^2 \Sigma d^2}{8\ell} \qquad (1)$$

Where ν is the wood volume area^{-1}, d is a particle diameter, and ℓ is the plane transect length (Brown and Roussopoulos 1974). To avoid measuring the diameter of each piece, it is often more convenient to separate wood into size classes and use average diameter for each class in formula 1. Using the latter approach, formula 1 reduces to

$$\nu = \frac{\eta \Pi^2 d_i^2}{8\ell}$$

where η is the number of intercepts of size class i encountered on the transect and $\overline{d}_i$ is the geometric mean diameter for size class i.

To convert volume to biomass requires an estimate of wood density. A major drawback of the planar intercept method is that certain wood dimensions (diameter, density, and angle of repose) must be known before biomass can be calculated. However, for large inventory problems, any extra effort applied in calibrating the planar intercept method can be made up in savings during the sampling stage.

Woody fuel dimensions have been measured as part of a fuel inventory in the Great Smoky Mountains National Park. The results for major forest covers are reported here for those who are undertaking a fuel inventory but are unable to gather the necessary data for using planar intercepts. Because the Great Smoky Mountains are biologically and environmentally diverse, the results are widely applicable to other areas in the southern Appalachian Mountains.

STUDY AREA

The Great Smoky Mountains is primarily underlain by slightly metamorphosed Precambrian shales, sandstones, and conglomerates of the Ocoee Series (King et al. 1968). Elevations within the extremely dissected landscape range between 257 m to 2,025 m. Climates range from humid mesothermal at low elevations to prehumid microthermal above 1,500 m (Shanks 1954). Mean annual precipitation increases with elevation, with 147 cm at 438 m in Gatlinburg and 227 cm at 1,890 m on Clingmans Dome (Shanks 1954). Temperature decreases with elevation; mean annual temperatures are 13.7°C at 429 m and 8.9°C at 1,890 m (Shanks 1546). The overall vegetation pattern was described along gradients of moisture and elevation by Whittaker (1956). Proceeding along a moisture gradient from xeric to mesic sites below 1,350 m, one finds pine, open oak, closed oak, hemlock, and cove hardwood forests. Above 1,200 m, heath balds mantle the most xeric exposed ridges and intergrade with spruce and fir on upper slopes. Northern hardwoods generally dominate on concave topography and burned-over sites above 1,350 m.

METHODS

Wood diameters were measured with a caliper to the nearest 0.25 mm on randomly chosen line transects in study stands. For the most part, the forest stands examined were in the Cherokee Orchard area and correspond closely to those described by Whittaker (1956). Geometric averages were calculated for each stand by size classes, which were 0 to 7 mm, 7 to 25 mm, and 25 to 76 mm. Results were pooled when stands had similar forest composition.

Wood was also collected on randomly chosen line transects for density determinations. After a period of air drying (1 to 4 weeks), volume was measured using water displacement or by measuring particle lengths and diameters to the nearest millimeter. All wood pieces were air dried, then weighed, and a random sample of 10 pieces per day was oven dried at 105°C to determine moisture contents. All densities were then adjusted so moisture-free values were obtained. Variables considered in the study which might influence wood density were species, fungal presence, bark coverage, hardness, forest type, size class, and elevation. Analysis of variance and regression models were tested using SAS76 procedure GLM (Barr et al. 1976).

RESULTS AND DISCUSSION

Forest Types

A brief description of each forest type was prepared from species lists which were recorded in the field. Cove forests occupy ravines, draws, and lower slopes and can be segregated in four types: (1) hemlock, (2) rhododendron, (3) deciduous, and (4) successional. Hemlock and rhododendron coves are both dominated by hemlock (*Tsuga canadensis*); the principal distinction is the presence of *Rhododendron maximum* in the latter. An assortment of hardwoods, which includes buckeye (*Aesculus octandra*), yellow poplar (*Liriodendron tulipifera*), birch (*Betula lenta*, *B. lutea*), magnolia (*Magnolia fraseri*), ash (*Fraxinus americana*), silverbell (*Halesia carolina*), basswood (*Tilia heterophylla*), holly (*Ilex opaca*) and beech (*Fagus grandifolia*) occur with hemlock in these forests. In the western portion of Great Smoky Mountains National Park (GRSM), white pine (*Pinus strobus*) can be a dominant element in some cove forests. Deciduous coves tend to occur in sheltered draws above 900 m and lack white pine, hemlock, rhododendron, and holly. Successional coves occupy mesic sites that were cleared and are dominated by yellow poplar, black locust (*Robinia pseudo-acacia*), and the other hardwoods which occur in other coves. Yellow poplar, however, probably makes up at least two-thirds of the basal area.

Mixed oak forests intergrade with cove forests on the mesic end of a moisture gradient, and chestnut oak forest on the xeric end. These forests are dominated by mixtures of red (*Quercus rubra*), white

Q. alba), black (*Q. velutina*), and chestnut (*Q. prinus*) oaks. Yellow poplar, black locust, black gum (*Nyssa sylvatica*), red maple (*Acer rubrum*), hickory (*Carya tomentosa*, *C. glabra*), and dogwood (*Cornus florida*) are found within the mixed oak forests and can often make up over half the basal area. Chestnut oak forests are dominated by chestnut, black, and scarlet (*Q. coccinea*) oaks and have a lower canopy layer of black gum, red maple, sourwood (*Oxydendrum arboreum*), and sassafras (*Sassafras albidum*).

Yellow pines (*Pinus rigida*, *P. pungens*, *P. virginiana*, and *P. echinata*) dominate pine forests, with scarlet, chestnut, and blackjack (*Q. marilandica*) oaks on dry exposed upper slopes and ridges. Old fields are also dominated by pines, but *P. virginiana* is most important on these sites. The understory of old fields is composed of dogwood, black gum, red maple, and hemlock.

Beech-northern hardwood forests occur above 1,200 m and intergrade with deciduous coves at lower elevations. Beech, sugar maple (*Acer saccharum*), buckeye, yellow birch (*B. lutea*), and fire cherry (*Prunus pensylvaticum*) are the most common canopy trees of this forest. Spruce-fir forests are composed of red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*), although yellow birch, fire cherry, and mountain ash (*Sorbus americana*) are very common elements. When disturbed by logging and slash fires, spruce-fir forests are converted to northern hardwood dominance. Above 1,200 m, heath balds dominated by *Rhododendron catawbiensis*, *R. minus*), mountain laurel (*Kalmia latifolia*), and other ericades mantle the very exposed ridgetops.

Wood Diameters

Since wood diameters were considered on a community basis, one would expect differences between forest covers when the branch morphologies of dominant species exhibited marked differences. The initial diameter of woody shoots probably has a very large genetic dependence. In older shoots, factors such as age, productivity, and apical dominance are important. Therefore, one might also expect the youngest shoots (or smallest size class) to show the highest differences between species and hence forest communities.

As a general trend, xeric low elevation forests have smaller mean squared diameters ($\overline{d^2}$) in the 0 to 7 mm size class than mesic forest (Table 1). Exceptions are the hemlock cove forests, which display an abundance of very fine twigs. The high elevation spruce-fir communities have $\overline{d^2}$ in the 0 to 7 mm size class that are very similar to hemlock coves. Above 7 mm diameter there are few differences between forest covers. Averaging $\overline{d^2}$ for all stands, regardless of composition, yields a mean of 185 mm^2 for the 7 to 25 mm size class and 1,760 mm^2 for the 25 to 76 mm size class. Brown and Roussopoulos (1974) present dimensions of slash and naturally fallen woods from stands in the Rocky Mountains and the Lake States. As in this study, the 0 to 7 mm size class exhibited the largest difference. Spruce, Douglas fir, and grand fir had the smallest sizes, followed by pines and oaks. The range of larger

Table 1. Mean squared diameter ($\overline{d}^2$) and standard error of naturally fallen woody material on various forest floors in the Great Smoky Mountains. See text for description of forest types.

Forest Type	$\overline{d}^2$ (mm^2)	SE (mm^2)	N
0-7 mm diameter			
Successional cove	18.55	0.999	252
Mixed oak	15.56	2.074	187
Chestnut oak	13.56	1.425	263
Pine	12.88	1.154	839
Hemlock cove	5.82	--	--
Spruce-fir	6.58	0.750	140
7-25 mm diameter			
Successional cove	172	16.2	341
Mixed oak	175	39.6	90
Chestnut oak	189	23.7	206
Pine	187	26.7	293
Hemlock cove			
Spruce-fir	154	7.4	154
25-76 mm diameter			
Successional cove	1758	130	250
Chestnut oak	1735	137	129
Pine	1656	183	97
Hemlock cove			
Spruce-fir	1890	128	88

Table 2. Woody fuel dimensions for calculating volume per area in naturally fallen debris in Southern Appalachian forests.

Community Type	Geometric mean diameter $\bar{d}^2$ mm^2	Mean secant[A]
0-7 mm diameter		
Spruce-fir - hemlock	6.20	1.15
Pine	12.88	1.15
Oak, beech, and other hardwoods	15.76	1.15
7-25 mm diameter		
All forests	185.	1.13
25-76 mm diameter		
All forests	1760.	1.13

[A] Data taken from tables 3 and 4 of Brown and Roussopoulos (1974). Multiplying wood volume by the mean secant removes nonhorizontal angle bias of woody particles.

wood particles presented by Brown and Roussopoulos encompasses the means presented here for the 7 to 25 mm and the 25 to 76 mm diameter size classes. In calculating wood volume, the values presented in Table 2 are probably the most useful since communities with similar mean diameters are grouped.

Wood Density

The frequency distributions of wood density approximated normal curves (Fig. 1), and analysis of variance was conducted without transformation. Although each community had a slightly different mean density, statistically significant differences were obscured by high variances. There were no statistically significant differences in wood density associated with forest types (Tables 4, A1, and A2), size classes, fungi presence, or species (Tables A3 and A4). Regression analysis indicates elevation does not account for a significant portion of wood density variation. There was, however, a significant increase in density as bark coverage increased ($F_{1,4} = 5.828$). The least squares-derived equation for this relationship was $Y = 0.37 + 0.011$ (% bark coverage). Some differences might be expected in bark coverage density relationships for genera since some species (Betula lutea, Prunus pensylvanica) retain bark in an extremely rotted condition. When regression models using bark coverage for each genus were calculated, no significant differences were found. Therefore, it seems appropriate to use the all-species model.

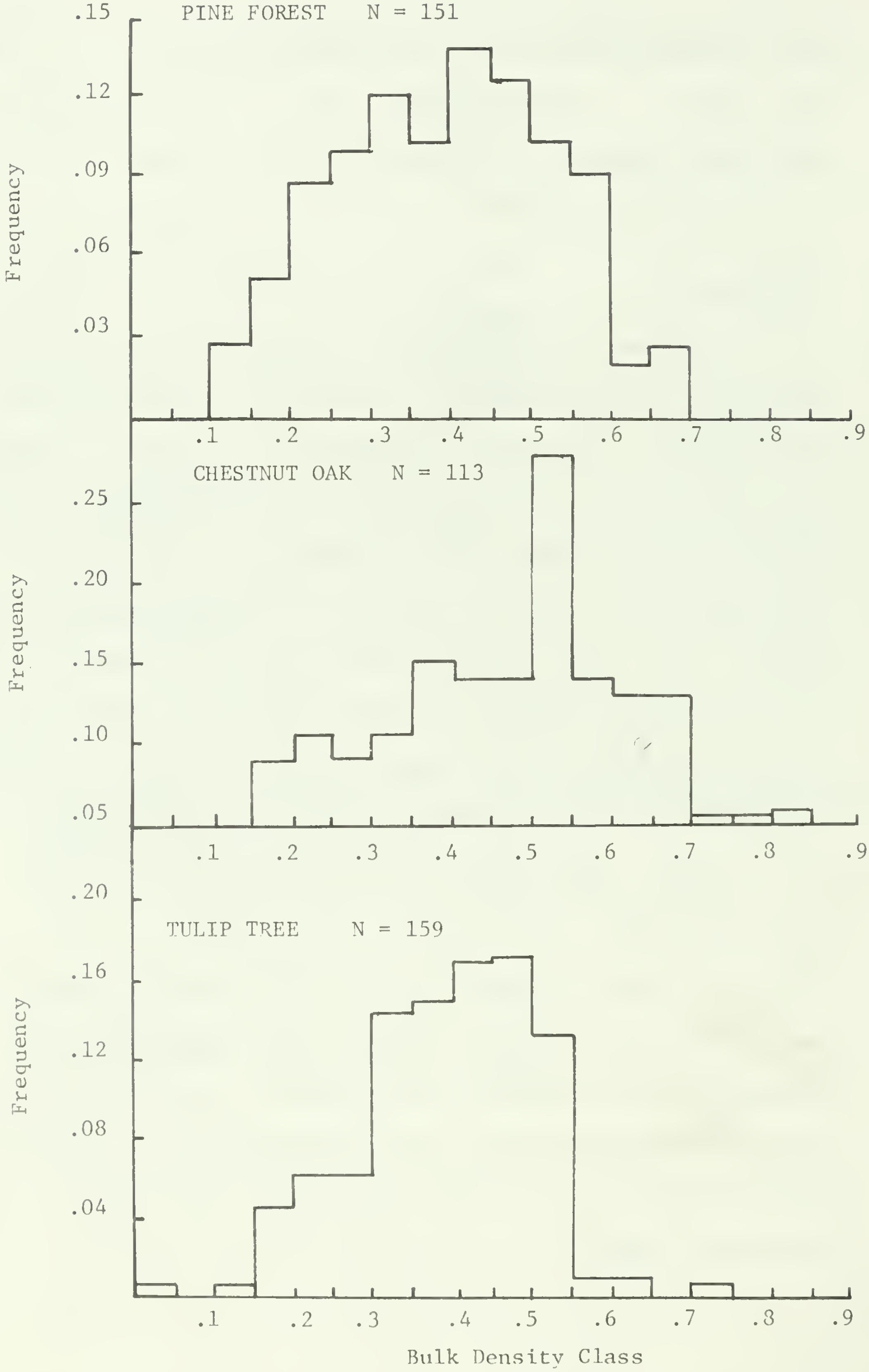

Figure 1. Frequency distribution of wood density by community.

Substantial differences in wood density between forest types and elevation are also expected since initial densities of fresh wood differ for most species and decay rates are probably lower at higher elevations. A calculation of what the effects of these factors might be under ideal conditions partially explains why the differences are not observed. Several assumptions must first be made:

(1) Annual input of wood is constant from year to year.

(2) Decay is primarily a process of weight loss due to microbial respiration rather than volume losses.

(3) This weight loss can be approximated by an exponential decay function.

(4) When wood reaches a certain minimum density (approximately .25 gm cm^{-3}), it crumbles and is incorporated into 02 horizon.

Density of wood at any given age can be calculated by the formula

$$D_t = D_0 e^{-tk}$$

where D_t is the wood density at age t, Do is the density of fresh wood, t is the age of the wood, and k is a decay constant. Since the input of fresh wood is constant from year to year, the mean density of all wood on the forest floor would be

$$\overline{D} = \frac{1}{t} \sum_{i=1} D_i$$

where $\overline{D}$ is the mean density of all forest floor wood, D_i is the density of wood after i years, and t is the time required for the wood to reach a density of .25 (the bulk density wood is assumed to be incorporated into 02). Combining these formulas, we get the equation

$$D = \frac{Do}{t} \sum_{i=1}^{t} e^{-ik}$$

which can then be used to examine theoretically what the effects of different initial densities and decay rates are.

Using an initial density of .7 gm cm^{-3}, a reasonable value for oak wood, we can examine the effect of changing the decay constant from k = .05, a low value, to k = .20, an extremely high value. Using the low decay constant, the wood takes 20 years to reach a density of .25 gm cm^{-3}, giving a mean density of .44 gm cm^{-3} for all dead wood in the stand. Increasing the decay constant to .20 results in the wood taking only slightly over 5 years to decay, but the mean density is still .44 gm cm^{-3}. Since the initial and final densities are the same and both stands are following an exponential curve, the mean densities are the same. There would simply be four times the wood accumulations in the stand with slow decay rates.

If this is repeated for a yellow poplar stand with an initial wood density of .4 gm cm^{-3}, no difference is seen between different decay rates, and the mean density is .32 gm cm^{-3}. Although the ratio of initial yellow poplar to oak densities was 0.4:0.7 or 0.57, the ratio of mean rotten densities is 0.73.

The densities of wood predicted with the theoretical model are quite similar to those actually observed for oak and yellow poplar forests. The fact that there is no statistical difference between the stands may be due to violations of the initial assumptions. Wood inputs vary considerably from year to year, so certain years should have more statistical weight in calculating mean densities. Volume is often lost from decaying logs; we observed many pieces of wood which lost up to one-third of their volume. Although decay rates may not follow an exponential curve, this will not affect the mean density a great deal. Finally, the factor which introduces the most variance into the calculations is the fact wood input densities are not constant, even for a given species. For example, many wood pieces are partially decayed before falling to the ground.

Although no statistical differences were detected by forest cover or size class, consistent differences were apparent. Separation by size and forest cover would be simple and fast, whereas recording the bark coverage of each piece would greatly increase sampling time and might eliminate any time savings gained using planar intercepts.

The most efficient sampling scheme is to use density values based on forest cover and size unless an extraordinary quantity of fresh or old wood is encountered. Situations where density values other than those presented in Table 3 should be used would include fires, blowdowns, beetle kills, or other cases of above normal mortality. In sites with recent disturbances, the large percentages of fresh wood would increase the mean density

Table 3. Wood density separated according to size class and forest cover.

Forest Cover	Wood density gm cm^{-3}		
	Mean	Standard error	N[A]
0-7 mm			
All hardwood except oak[B]	0.518	0.0215	9
Oak	0.559	0.0849	6
Pine	0.421	0.0924	4
7-25 mm			
All hardwood except oak[B]	0.402	0.0073	11
Oak	0.427	0.0262	6
Pine	0.395	0.0278	4
25-76 mm			
All hardwood except oak[B]	0.367	0.0130	12
Oak	0.444	0.0338	6
Pine	0.397	0.0320	4

[A] Each sample is based upon mean of a stand which had densities of 20 - 30 particles measured.

[B] These stands include all cove forest types.

value. For sites with older disturbances, where large quantities of rotten wood are present, a downward adjustment of mean density would be necessary.

A weighted average can be used to adjust the mean density on disturbed sites. By quantifying the proportions, W_i, and the density, D_i, of each decay class i, a weighted average $\overline{D}$ can be calculated:

$$D = \frac{W_i \ D_i}{\Sigma \ W_i}$$

Three decay states can be recognized easily in the field: (1) fresh, (2) rotten, and (3) very rotten. When density is below 0.20 grams centimeter^{-3}, crushing by hand is possible and the piece can be called very rotten. Fresh material can be recognized by either a knowledge of disturbance history or by observing degree of bleaching on exposed wood and the presence or absence of leaves. Standing dead wood densities of hemlock, Virginia pine, and oak are presented in Table 4. If the time of disturbance can be gauged accurately, the values in Table 4 can be substituted for D in calculating the weighted average D_i. Rotten wood can be defined simply as pieces which are not fresh or capable of being crushed by hand.

The calculation of a weighted average can be demonstrated using two examples. In the first case, 100 fresh, 50 rotten, and 5 very rotten wood pieces are counted in a pine forest. The caclulated mean density D_i is therefore

$$D_i = \frac{100\ (0.50) + 50\ (0.39) + 5\ (0.20)}{100 + 50 + 5} = 0.45$$

In the second example, the proportions are 5 fresh, 50 rotten, and 100 very rotten. The mean density of this stand would be

$$D_i = \frac{5\ (0.50) + 50\ (0.39) + 100\ (0.20)}{5 + 50 + 100} = 0.27$$

The frequency distribution of three forest types (Fig. 1) indicates fresh:rotten:very rotten ratio to be approximately 5:10:1.

SUMMARY AND CONCLUSIONS

Wood diameters show the largest differences between forest covers for the 0 to 7 mm size class. Three groups are proposed for volume calculations within this size class: (1) spruce-fir-hemlock, (2) pine, and (3) hardwoods. Since little statistical or theoretical basis exists for separating the larger size classes, use of an overall geometric mean is suggested.

The only statistically valid differences in wood density are associated with bark cover. However, estimating each particle's density with bark coverage would be very slow. A simpler method of adjusting stand wood densities would be to observe the proportions of fresh, rotten, and dead wood. When the proportions expected in a "normal" stand (5:10:1) are not found, then a weighted average can be calculated. Use of a weighted average for biomass calculations will probably be most useful in stands with higher-than-average mortality (beetle kill, fire, windthrow, ice damage, etc.).

Table 4. Bulk density of wood after various types of decay in forests below 3000 feet elevation within Great Smoky Mountains National Park.

Species	Bulk densities, gm cm^{-3}			
	Fresh	11 months*	19 months**	31 months**
Acer rubrum	.56	.56	.51	.48
Carya spp.	.60	.59	.62	.53
Cornus florida	.61	.60	.60	.59
Kalmia latifolia	.59	--	.62	.54
Liriodendron tulipifera	.43	--	--	--
Nyssa sylvatica	--	--	.55	.48
Oxydendrum arboreum	--	--	.60	.44
Pinus spp.	.53	.50	--	.49
Quercus spp.	.71	.58	.54	.53
Rhododendron maximus	.52	--	.53	.42
Tsuga canadensis	.51	--	.48	.44

*Exposed to decay on forest floor

**Exposed to decay as standing dead trees

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APPENDIX

TABLE A1. Mean bulk density of wood 0 - 7 mm diameter for various stands in Great Smoky Mountains National Park

Forest Cover	Elevation	Mean	SE	N
Rhododendron Cove	1770'	.434	.7700	4
Rhododendron Cove	2300'	-	-	0
Rhododendron Cove	3200'	.646	-	1
Rhdodendron Cove	4070'	.519	.0417	2
Hemlock Cove	1690'	.577	.0184	5
Hemlock Cove	2760'	.455	.0220	2
Hemlock Cove	3600'	.512	.0585	3
Deciduous Cove	3150'	.540	.0421	5
Deciduous Cove	3670'	-	-	0
Mixed Oak	2920'	.754	.1790	3
Mixed Oak	1380'	.810	.2833	2
Mixed Oak	2000'	.282	-	1
Chestnut Oak	1870'	.549	.0455	4
Chestnut Oak	2630'	.366	.0404	2
Chestnut Oak	3600'	.593	.0346	12
Pine	1180'	.351	.0284	3
Pine	2130'	.192	.1866	2
Pine	3700'	.564	.0634	3
Pine	4100'	.578	-	1
Successional Cove	1180'	-	-	0
Successional Cove	2020'	-	-	0
Successional Cove	3000'	.498	.0396	6
Successional Cove	3000'	.478	.0540	2
Beech/Northern Hardwoods	5050'	.570	.2440	2
Heath Bald	4100'	-	-	0

A - Each sample consisted of 5 individual twigs

TABLE A2. Mean bulk density of downed wood 7 - 25 mm diameter for various stands in Great Smoky Mountains National Park

Forest Cover	Elevation	Mean	SE	N
Rhododendron Cove	1770'	.406	.0267	20
Rhododendron Cove	2300'	.381	.0252	30
Rhododendron Cove	3200'	.396	.0314	22
Rhododendron Cove	4070'	.417	.0274	22
Hemlock Cove	1690'	.428	.0308	24
Hemlock Cove	2760'	.455	.0220	30
Hemlock Cove	3600'	.396	.0227	33
Deciduous Cove	3150'	.400	.0196	32
Deciduous Cove	3670'	.375	.0296	22
Mixed Oak	2920'	.436	.0263	32
Mixed Oak	1380'	.458	.0374	19
Mixed Oak	2000'	.301	.0312	23
Chestnut Oak	1870'	.428	.0409	15
Chestnut Oak	2630'	.458	.0257	29
Chestnut Oak	3600'	.479	.0471	11
Pine	1180'	.359	.0225	20
Pine	3130'	.345	.0296	22
Pine	3700'	.407	.0255	21
Pine	4100'	.468	.0221	33
Successional Cove	1180'	.382	.0219	31
Successional Cove	2020'	.381	.0174	35
Successional Cove	3000'	.417	.0285	22
Successional Cove	3000'	.450	.0191	19
Beech/Northern Hardwoods	5050'	.504	.0231	20
Heath Balds	4100'	.444	.0213	24

TABLE A3. Mean bulk density of wood 26 - 75 mm diameter in various stands in Great Smoky Mountains National Park

Forest Cover	Elevation	Mean	SE	N
Rhododendron Cove	1770'	.358	.0382	15
Rhododendron Cove	2300'	.366	.0292	10
Rhododendron Cove	3200'	.382	.0371	17
Rhododendron Cove	4070'	.307	.0376	15
Hemlock Cove	1690'	.423	.0348	11
Hemlock Cove	2760'	.353	.0254	8
Hemlock Cove	3600'	.382	.0368	12
Deciduous Cove	3150'	.306	.0222	24
Deciduous Cove	3670'	.394	.0336	17
Mixed Oak	2920'	.421	.0315	13
Mixed Oak	1380'	.430	.0339	17
Mixed Oak	2000'	.327	.0366	14
Chestnut Oak	1870'	.459	.0306	16
Chestnut Oak	2630'	.584	.0774	6
Chestnut Oak	3600'	.442	.0373	16
Pine	1180'	.331	.0248	14
Pine	2130'	.365	.0448	12
Pine	3700'	.415	.0383	17
Pine	4100'	.478	.0304	6
Successional Cove	2020'	.389	.0415	9
Successional Cove	1180'	.321	.0329	14
Successional Cove	3000'	.356	.0353	11
Successional Cove	3000'	.457	.0296	4
Beech/Northern Hardwoods	5050'	.436	.0278	17
Heath Bald	4100'	.386	.0279	16

TABLE A4. Mean bulk density of 7 - 25 mm wood for various genera in Great Smoky Mountains National Park

	Bulk Density, g cm^{-3}		
Genus	Mean	N	Standard Error
Acer	0.472	28	.0290
Betula	0.397	32	.0257
Fagus	0.462	20	.0258
Hardwood Misc.	0.365	109	.0117
Halesia	0.426	30	.0216
Liriodendron	0.409	90	.0106
Pinus	0.406	81	.0142
Quercus	0.394	87	.0162
Rhododendron	0.453	33	.0218
Tsuga	0.451	63	.0148
*Castanea**	0.439	9	.0321

*For *Castanea*, the densities of 7 - 25 mm and 25 - 76 mm wood were pooled to calculate the mean.

TABLE A5. Mean bulk density (g. cm^{-3}) of downed 25 - 75 mm wood for various genera in Great Smoky Mountains National Park

Genus	Bulk Density Mean	N	Standard Error
Acer	0.443	10	.0411
Betula	0.378	12	.0450
Fagus	0.409	20	.0258
Hardwood Misc.	0.348	58	.0178
Halesia	0.357	15	.0321
Liriodendron	0.334	23	.0252
Pinus	0.381	47	.0200
Quercus	0.412	56	.0207
Rhododendron	0.400	32	.0246
Tsuga	0.387	24	.0207
*Castanea**	0.439	9	.0321

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*For *Castanea*, the densities of 7 - 25 mm and 25 - 76 mm wood were pooled to calculate the mean.

Table A6. Mean bulk density of downed wood for major forest covers in Great Smoky Mountains National Park.

Forest Cover	Bulk Density, g cm^{-3}		
	0 - 7 mm	7 - 25 mm	25 - 76 mm
Rhododendron Cove	0.489	0.398	0.353
Hemlock Cove	0.533	0.411	0.389
Deciduous Cove	0.540	0.390	0.342
Successional Cove	0.493	0.401	0.361
Mixed Oak	0.694	0.517	0.395
Chestnut Oak	0.558	0.454	0.471
Pine	0.412	0.404	0.386
Beech/Northern Hardwoods	0.570	0.504	0.436
Heath Bald	--	0.444	0.386