Coarse Woody Debris in Managed and Unmanaged Forests of Northern Michigan, 2006 Progress Report




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April 5, 2007

Report Number 2007-06

Cover Photograph: Clockwise from top left: 1) blowdown in old-growth stand 2) large diameter *Tsuga canadensis* snag in an old growth stand 3) managed northern hardwood stand, 4) canopy gap in 80+ year old aspen stand. All photos by Christopher R. Weber.

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INTRODUCTION

Forest management has increasingly focused on maintaining biodiversity and sustainability. A large contributor to biodiversity within Michigan forests is coarse woody debris (CWD) on the forest floor. Coarse woody debris influences forest soil nutrient cycling (Fisk et al. 2002, Laiho and Prescott 2004) and provides a suitable seed bed for hemlock regeneration (Ward and McCormick 1982, Goodman and Lancaster 1990, O'Hanlon-Manners and Kotanen 2004). Due to its influence on understory and overstory forest structure, CWD is an essential component of mammal, amphibian, arthropod, bird, and microbial habitats (Harmon 1986, Burris and Haney 2005, Crow et al. 2002). Large-diameter CWD and tip-up mounds created by natural disturbances are a crucial structural component for forest biodiversity and are largely missing from managed landscapes (Goodburn and Lorimer 1998, Tyrell et al. 1998, McGee et al. 1999, Crow et al. 2002).

Measuring levels of CWD is an important step in assessing the sustainability of forest management practices. Several methods of sampling CWD exist and the Michigan DNR utilizes a specific method as part of their forest compartment inventory process (Integrated Forest Monitoring, Assessment, and Prescription (IFMAP) stage two). However, the method used during stage two inventory has not been compared with other sampling methods to determine which provides the most accurate and efficient means of measuring CWD. Some methods have shown different accuracy levels based on stand type and stand age (Bate et al. 2004). This study has set out to elucidate the accuracy of four different methods of measuring CWD, meanwhile establishing a range of variation for CWD in aspen and northern hardwood forests of Michigan. The data collected during this study provides estimates for current levels of CWD found across different stand ages and management histories for these two stand types.

STUDY AREA

Our study sites in 2006 were located in the eastern Upper Peninsula of Michigan, including the counties of Mackinaw, Luce, Chippewa, Schoolcraft, Alger, Marquette, Dickinson, and Menominee (Figure 1). In May and June of 2006, we sampled 39 stands averaging 10.8 hectares. We sampled in three stand types, which included aspen (A), northern hardwood (M), and mesic northern forest element occurrences (EOs). Aspen and northern hardwood stands were exclusively on state forest land and selected randomly from Michigan Department of Natural Resources, Operations Inventory (OI) frozen stands GIS data layers (MDNR 1994, 1995). Aspen stands were selected from four different age classes: 20-25, 40-45, 60-65, and 80+ years. Aspen age was determined by the "year of origin" in OI records, which indicated when the stand was last harvested. Randomly selected northern hardwood stands were all uneven aged and had all been selectively thinned. Mesic northern forest EOs were selected from high ranking (A, B, or AB) occurrences recorded within the MNFI database and were located on state forest, state park, and federally owned lands. A ranking of A-B indicates that the stand should be of old growth quality, with natural processes intact and showing minimum signs of silvicultural management. Of the 39 total stands sampled, 15 were aspen, with four each in the 20, 40, and 60 year age classes, and three stands in the 80+ age class. Twelve stands were M type and 11 stands were within EOs. The sites involved in the methodology analysis were sampled with all four methods and included 25 of the 39 stands mentioned above. These 25 stands included ten aspen (three each in the 20, 40, and 60 classes, and one 80 yr old stand), nine M type stands, and six EOs. Sample sites were located predominantly on mid to coarse textured glacial till, lacustrine sand and gravel, or outwash sand and gravel.

METHODS

Sampling Methods

Our goal was to examine how best to gather CWD data in Michigan forests, isolating both the sampling technique used and how the sampling points were positioned within the stand.

Two sampling methods were employed, line-intercept (De Vries 1973) and strip plot (Husch et al. 1972). The line-intercept and strip plot methods can perform differently based on characteristics of the stand (Bate et al. 2004). Each method was employed in two different ways: 1) at randomly located points along a circuit transect that meandered through a stand based on a predetermined route (circuits) and 2) at randomly located points on transects run perpendicular to a base-line transect (randoms). Sampling points for both the circuits and randoms utilized systematic sampling with a random start. Using both the circuit and random sampling designs, we attempt to compare the current IFMAP stage 2 method (circuit line intercept), employed by state foresters, with what is considered to be the best

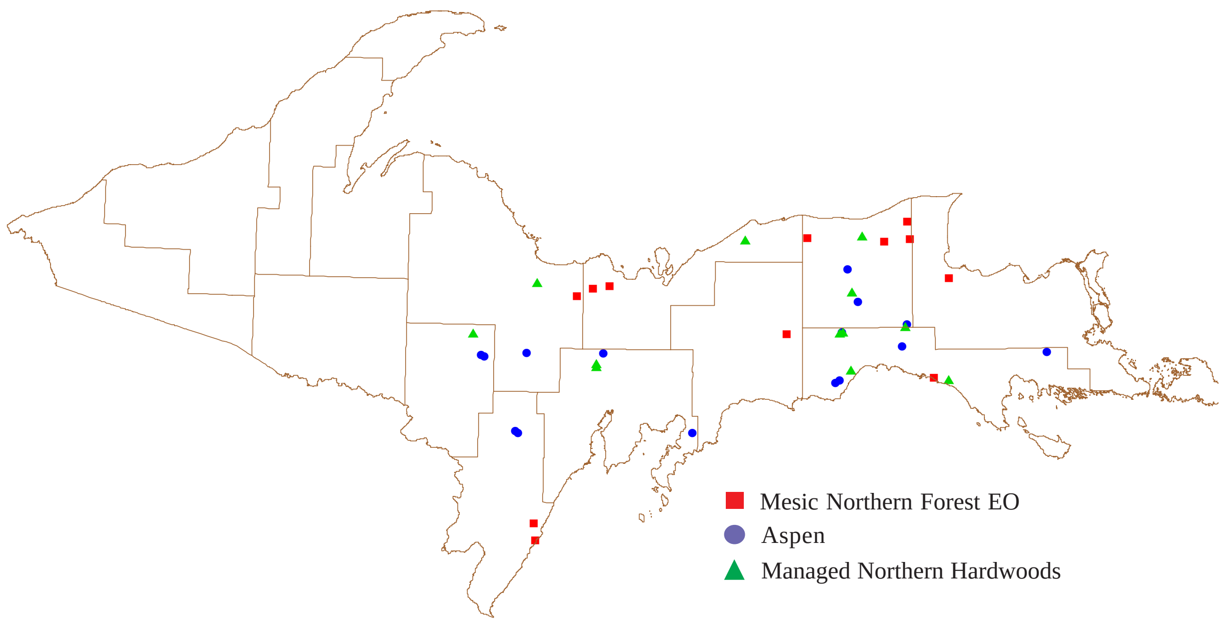

Figure 1. 2006 Sampling sites including aspen, northern hardwood, and mesic northern forest community element occurences in the eastern Upper Peninsula, Michigan.

method in terms of bias and statistical validity (randoms). The result were four distinct methods we applied in the field: 1) circuit line-intercept (CLI) (current IFMAP stage two method), 2) circuit strip plots (CSP), 3) random line-intercept (RLI), and 4) random strip plot (RSP) (Appendix I).

For the line-intercept methods, a measuring tape was used to make a straight transect one chain in length (66 ft). Pieces of CWD that qualified for measurement were those that intersected a planar transect that stretched from ground to sky along the tape transect. For strip plot methods, a 14 ft plot was centered on the transect line (7 ft on each side of the transect line). A piece of CWD qualified for measurement if 0.5 m of the log was located within the plot, and it was recorded whether the midpoint of the log was located within the plot. Logs or stumps measured were >1 m in length and >10 cm in diameter. In order to be counted, a piece of CWD needed to have at least two points of ground contact or at least 0.5 m ground contact anywhere along its length. Stumps taller than six feet were classified as snags. Pieces originating from the same fallen tree were counted separately if the two pieces were more than 1 ft (30 cm) apart. Branches or boles of the same tree that met the size criteria were considered individual pieces of CWD. Measurements for pieces tallied by line intercept methods included large end diameter (LED), ignoring the buttress of a log; small end diameter (SED); intersect diameter (diameter where the intercept line crosses the log); and total length (measured from the largest end to the point where the diameter reached 1 cm). Plot measurements included all of the above with the addition of diameter at both plot intercepts (if the piece crossed the plot boundaries) and total length in plot (note that length in plot and total length would be the same if entire piece was located within the plot boundaries).

Diameter was measured by holding a measuring tape above the log at a position perpendicular to the length. If logs were not round, as in the case of extensive decay, then the diameter was estimated from the widest portion visible. Logs lying at an angle of < 45 degrees to ground surface were considered as pieces of CWD, logs lying at angles > 45 degrees were considered snags. Every log sampled was given a decay class ranging from I (recent or least decomposed, leaves present, round in shape, bark intact, wood structure sound, current year twigs present) to V (very decayed, leaves absent, branches absent, bark detached or absent, wood not solid, and oval or collapsed in form) (Appendix 1) (Tyrell and Crow 1994).

Circuit sampling points were randomly placed at equidistant intervals along a pre-determined route drawn throughout the stand. The number of sampling points per stand depended on the size of the stand, but no more than 14 plots were allowed per stand.

Random sampling points were laid out along parallel transects equidistantly spaced at a random interval along a baseline transect. Sampling points were located random distances from the starting points of each transect. The same quantity of sampling points was utilized in both the random and circuit methods. In the field, random numbers were chosen that indicated how many chains to be walked to the next sampling point. If the stand was 16 chains wide, random numbers between 1 and 15 were chosen. [This was changed for the 2007 season; random points were calculated in the office and sampling locations were uploaded to a GPS as was done for the circuit sampling points.]

Snags (i.e., dead, standing trees over six feet) were measured two different ways, depending on the sample type. For plot samples, the DBH and approximate height were recorded for snags that had their center or pith located within the plot. For line-intercept sampling points, a 10 factor prism sweep was used to locate snags. Prism sweeps during line-intercept sampling also included recording the species of every living tree, which served as our measure of dominant overstory composition. Thus, prism sweeps provided two types of data, locating snags to obtain DBH and height as well as typing the stand based on overstory composition. Snag height was visually estimated in the field in feet and upon subsequent data entry were assigned height ranks at five meter increments (1-5).

Estimating Parameters

The calculations for density, total length, and volume were the same as those used in Bate et al. (2004).

Density was estimated for the CLI and RLI methods using equation 11 of De Vries (1973):

$$\text{Logs per hectare} = (5\pi \times 10^3 / L) \sum (1 / l_i)$$

where L is the length of the transect (20m), and *l* the length (m) of the *i*th log intersected. To estimate log density using the strip plot method, we took the sum of the number of logs having a midpoint in the plot and converted to logs per ha.

Total length of logs under CLI and RLI was calculated using equation 12 of De Vries (1973):

$$\text{Total length of logs} = n\pi \times 10^4 / 2L$$

where *n* is the number of logs intersected. For strip plots, total length was estimated by summing all portion of logs that fell within the plot, then converting to total length per ha.

Volume for CLI and RLI was estimated using equation 8 of De Vries (1973):

$$\text{Volume} = (\pi^2 / 8L) \sum d_i^2$$

where d is the diameter in cm of each log. Volume for CSP and RSP involved treating each log as a cylinder or frustum. The volumes of all the logs that fell into the plot were summed and then converted to m^3 per ha.

Statistical Analysis

We analyzed sampling data using a randomized complete block design (SAS 2006) with site as the random effect, and stand, sample type, and stand/type as fixed effects. Our response variables were density, length, and volume. This model tested whether any of the methods were significantly different from the method we considered to be the most likely to reflect the actual amount of CWD within a stand (RSP).

The RSP method was considered the best method for two reasons. First, the RSP method ensured that all areas of the stand had equal potential of being sampled. This contrasted with the circuit method which excluded certain areas of the stand from being sampled, based on the predetermined circuit route. Second, although the strip plot and line intercept methods differ in precision and efficiency depending on the abundance of CWD pieces, strip plots were found to be a better method when considering multiple variables in stands with logs of varying size and shape (Bate et al. 2004).

The model included unstructured parameterization to account for the lack of independence between variables (model chosen with lowest Bayesian Inference Criteria or BIC); The two circuit methods (CLI and CSP) do not have complete independence, since in most cases they were sampling some of the same pieces of CWD. Likewise, the two non-circuit methods (RLI and RSP) do not have complete independence. For the randomized complete block design, a square root transformation was used for density and volume to normalize the data. In order to compare sampling types within the different stand types, we used nonparametric bivariate correlation to see how each method correlated to RSP. For our stand type comparisons, using just one sampling method, we used one-way ANOVAs, with Tukey pairwise Post Hoc comparisons, and Levenne's test of homogeneity of variance (SPSS, 2005). A square root transformation was used on the length and volume variables due to a lack of normality and heteroskedasticity.

RESULTS

Stand Composition

Young aspen stands were composed almost exclusively of aspen clones, trembling aspen (*Populus tremuloides*) or bigtooth aspen (*Populus grandidentata*), regenerating from stump sprout and root suckers after past clear cuts. In the older aspen stands, other species such as red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), balsam fir (*Abies balsamea*), and paper birch (*Betula papyrifera*) were common (Figure 2a). Other species (each comprising ≤ 5%) sampled in aspen stands include: balsam poplar (*Populus balsamifera*), red maple (*Acer rubrum*), yellow birch (*Betula alleghaniensis*), American beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), green ash (*Fraxinus pensylvanica*), black ash (*Fraxinus nigra*), ironwood (*Ostrya virginiana*), white spruce (*Picea alba*), black spruce (*Picea mariana*), red pine (*Pinus resinosa*), white pine (*Pinus strobus*), northern white cedar (*Thuja occidentalis*), American basswood (*Tilia americana*), eastern hemlock (*Tsuga canadensis*), and American elm (*Ulmus americana*).

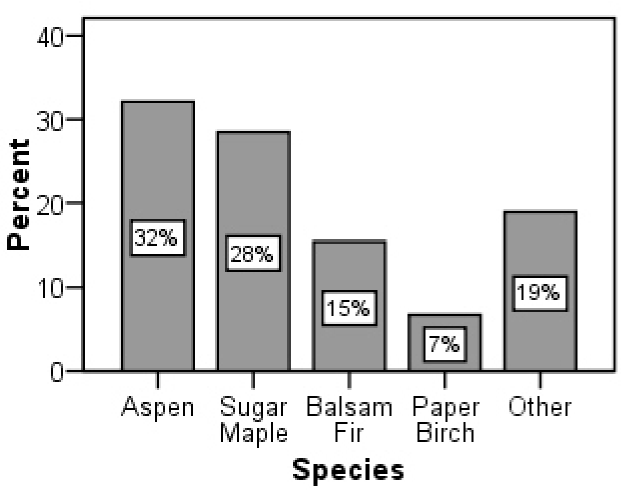

Figure 2a. Composition for dominant overstory species in aspen stands. Percentages based on frequency of tree species in basal area prism sweeps taken at CLI sampling points.

Northern hardwood stands were dominated by sugar maple with American beech, red maple, and hemlock common throughout (Figure 2b). Other species (each comprising ≤ 5%) sampled in northern hardwood stands include: balsam fir, yellow birch, paper birch, white ash, ironwood, white spruce, white pine, bigtooth aspen, trembling aspen, red oak, and American basswood.

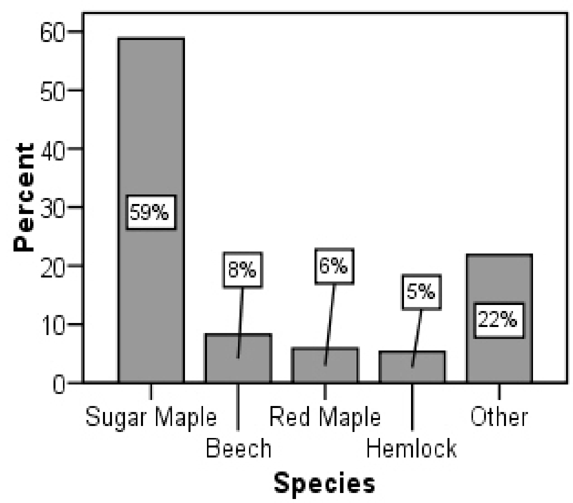

Figure 2b. Composition for dominant overstory species in northern hardwood stands. Percentages based on frequency of tree species in basal area prism sweeps taken at CLI sampling points.

EO stands were dominated by sugar maple as well, but with a greater presence of beech, yellow birch, hemlock, and northern white cedar (Figure 2c). Other species (each comprising ≤ 5%) sampled in EO stands include: white pine, northern white cedar, white spruce, black spruce, balsam fir, moosewood (*Acer pennsylvanicum*), paper birch, white ash, green ash, black ash, ironwood, and trembling aspen.

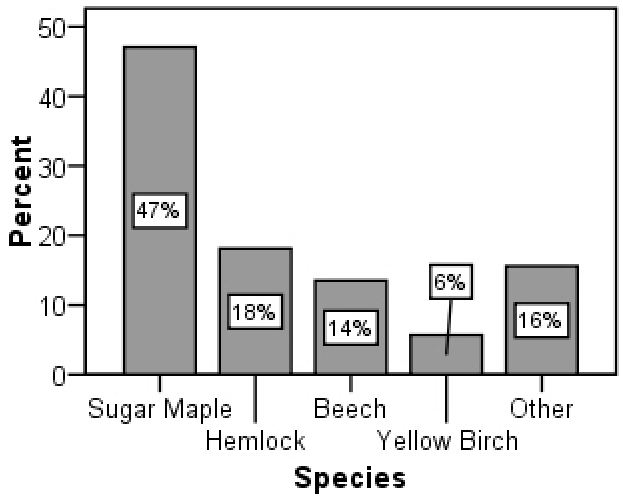

Figure 2c. Composition for dominant overstory species in mesic northern forest EO stands. Percentages based on frequency of tree species in basal area prism sweeps taken at CLI sampling points.

Method Comparisons

Downed Wood

As mentioned above, of the 39 stands sampled in 2006, 25 were sampled using all four methods (Table 1). Average stand size for all 39 plots was as follows: for aspen stands, 16 acres (average of 6 plots per stand); for hardwood stands, 26 acres (average of 7 plots per stand); and for EOs, 46 acres (average of 10 plots per stand). With the three stand types pooled (n = 25), the sampling methods did not differ significantly from each other in volume of CWD (Table 2). With density as the response variable, CLI did not differ from either RSP or RLI; however, CSP did differ significantly from CLI and RLI. With length as the response variable, CSP differed significantly from CLI and RLI; however, CLI did not differ from either of the random sample types, but was significantly different from CSP.

When comparing each sampling method to the RSP method, within each stand type, we found correlations to be largely insignificant, even negatively correlated for CLI in northern hardwood stands (Table 3). The random method types had the most significant correlations, as would be expected since the same area is sampled for both methods (same would apply for circuit samples).

Snags

The two methods for measuring snags produced different results. Data was used for just CSP and CLI methods, and included 38 stands (15 aspen, 12 hardwood, and 11 EO). Snags sampled by plot method produced mean numbers of snags per stand that were not significantly different for each stand type. Mean number of snags, when measured by the 66 ft x 14 ft plot were 2.07 ± 0.4, 2.5 ± 0.6, and 2.7 ± 0.7 for aspen, hardwood, and EO, respectively (Figure 3). Snags measured by basal area prism sweep (which was a component of the circuit transect sampling protocol) found

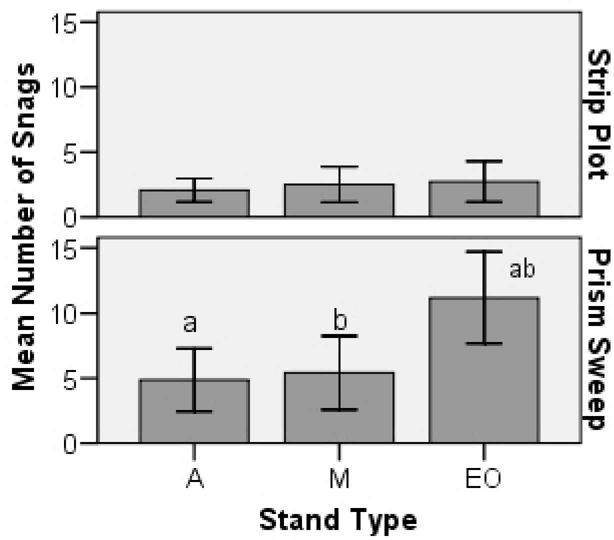

Figure 3. Snag density for individual stand type sampled by strip plot or basal area prism sweep. Statistical significance considered at $p \leq 0.05$. Letters indicate significantly different means. Error bars show 95% confidence intervals.

significantly different numbers of snags among the three stand types ($F = 6.676$, $df = 37$, $p = 0.003$). Mean number of snags measured by prism sweep were 4.8 ± 1.1, 5.4 ± 1.2, and 11.18 ± 1.6, for aspen, hardwood, and EO, respectively.

Mean snag DBH was different for both sampling methods as well (Figure 4). Plots found DBHs to be significantly different between aspen and EOs only ($F=4.17$, $df = 33$, $p = 0.025$), with means of 19.7 ± 1.7 cm, 23.2 ± 2.4 cm, and 32.2 ± 4.9 cm for aspen, hardwood, and EO, respectively.

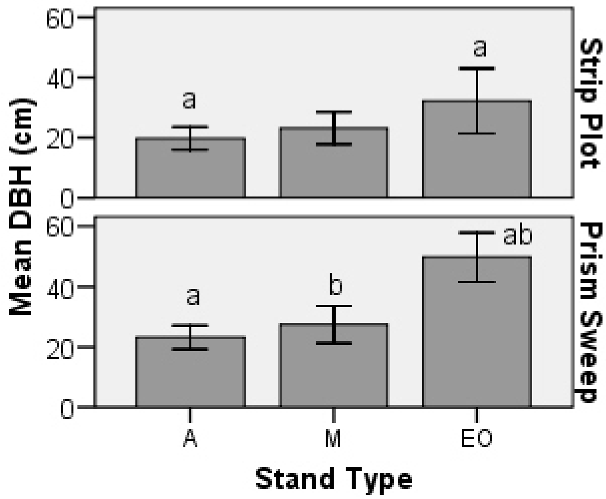

Figure 4. Mean snag DBH for individual stand type sampled by strip plot or basal area prism sweep. Statistical significance considered at p ≤ 0.05. Letters indicate significantly different means. Error bars show 95% confidence intervals.

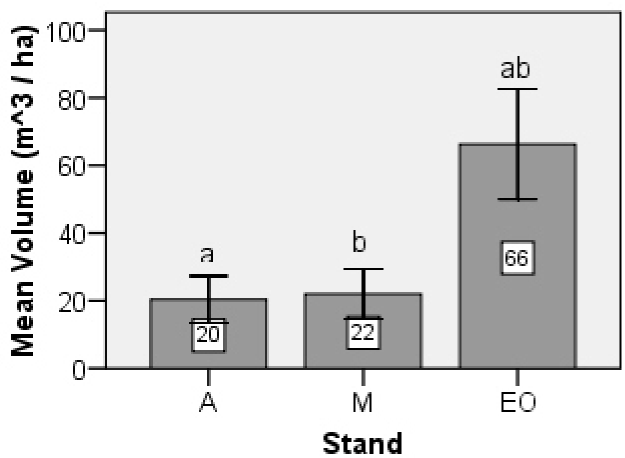

Figure 5. Mean CWD volume for three stand types, including data from CLI data only. Statistical significance considered at p ≤ 0.05. Letters indicate significantly different means. Error bars show 95% confidence intervals.

Basal area prism sweeps found DBHs of snags within EOs to be significantly larger than those occurring in both aspen and managed hardwood stands ($F = 27.079$, $df = 33$, $p < 0.001$), with means of 23.2 ± 1.8 cm, 27.5 ± 2.7 cm, and 49.7 ± 3.6 cm, for aspen, hardwood, and EO, respectively.

Stand Comparisons

In order to make comparisons between levels of CWD between stand types and gain an understanding of the range in levels of CWD within stand types, we used data from just one of the sampling methods. For this analysis, we used data collected via the CLI method from 39 stands which included 15 aspen stands, 12 hardwood stands, and 12 EOs. Selecting CLI method data is not meant to endorse circuit transects as the preferred sampling method, rather CLI data was used because it was employed for the highest number of stands. Volume for EOs was significantly higher than aspen and managed northern hardwoods stand types ($F = 21.45$, $df=37$, $p < 0.001$). Mean volume was 20 ± 5, 21 ± 4, and 74 ± 10 m^3 ha^{-1} for aspen, northern hardwoods, and EOs, respectively (Figure 5).

Likewise, total length of CWD was significantly different for EOs, compared to aspen and managed hardwood stand types ($F = 4.835$, $df = 37$, $p = 0.014$). Mean total lengths were 811 ± 150, 760 ± 83, and 1,254 75 m ha^{-1} for aspen northern hardwood, and EOs, respectively. Density of CWD did not differ significantly between stand types, with means of 141 ± 27, 162 ± 33, and 168 ± 22 logs ha^{-1} for aspen, northern hardwood, and EOs, respectively.

To examine levels between aspen age classes, data from 2005 and 2006 were combined, which provided a sample for analysis of seven stands for all but the 20 year age class. Again, comparisons between age classes for aspen used only the CLI data. Among the four age classes of aspen, the oldest age class (80+) had the highest volume, length, and density of CWD (table 4). The trend in aspen showed increasing levels for all three variables with increased age, and the oldest age class exhibited both the highest mean and greatest variability (i.e., largest confidence intervals) (Figure 6).

Table 1. Sampling data from 2006. FCS Key = Forest, Compartment, Stand number; Plots = the number of sampling plots per stand; Age is in years; Mean BA = Mean Basal Area per plot in ft^2 $acre^{-1}$.

Site	FCS Key	Plots	Stand Type	Age	Mean Basal Area	Acres	Hectares
1	45033027	7	Aspen	80	76	10.1	4.1
5	42104096	5	Aspen	80	88	18.5	7.5
10	42085061	4	Aspen	20	90	14.1	5.7
12	45202023	3	Aspen	20	83	3.1	1.2
17	45202003	6	Aspen	60	115	16.7	6.8
18	45182034	6	Aspen	20	92	13.3	5.4
19	33094024	6	Aspen	60	113	10.3	4.2
23	33070039	4	Aspen	40	78	7.9	3.2
27	42135064	10	Aspen	60	126	45.9	18.6
28	45158033	4	Aspen	20	88	7.8	3.1
29	45158033	6	Aspen	80	73	10.1	4.1
33	12027045	7	Aspen	60	124	20.4	8.2
37	32066004	8	Aspen	40	85	29.6	12.0
38	12027013	5	Aspen	40	85	40.3	16.3
39	33070020	7	Aspen	40	64	15.2	6.1
2	EO-01	7	EO		94	74.4	30.1
8	EO-12	9	EO		150	26.7	10.8
16	EO-71	9	EO		146	24.7	10.0
22	EO-08	11	EO		125	51.9	21.0
24	EO-44	6	EO		120	13.6	5.5
25	EO-25	13	EO		140	66.7	27.0
31	EO-30	12	EO		131	44.5	18.0
36	EO-11	13	EO		100	74.4	30.1
40	EO-76	7	EO		201	26.6	10.8
41	EO-20	5	EO		124	11.9	4.8
42	EO-43	6	EO		137	25.0	10.1
4	45102048	6	Hardwood		82	62.0	25.1
6	42135055	7	Hardwood		91	28.6	11.6
9	42027050	10	Hardwood		125	39.1	15.8
11	45177074	10	Hardwood		97	32.6	13.2
13	42112055	14	Hardwood		94	79.5	32.2
14	45182043	7	Hardwood		114	16.4	6.6
15	45182030	3	Hardwood		67	4.1	1.7
20	33096012	3	Hardwood		117	4.2	1.7
21	33096015	4	Hardwood		115	7.2	2.9
30	32275001	13	Hardwood		117	60.8	24.6
34	12020017	7	Hardwood		117	20.0	8.1
35	41137003	7	Hardwood		146	18.7	7.6

Table 2. Results of complete random block design analysis. Statistical significance considered at p ≤ 0.05. Estimates are least squares means (SAS) with all stand types pooled

Type	Est.	Error	DF	t value	p value
Volume					
CSP CLI	-0.123	0.419	66	-0.29	0.7703
CSP RSP	-0.050	0.419	66	-0.12	0.9058
CSP RLI	0.093	0.419	66	0.22	0.8247
CLI RSP	0.073	0.419	66	0.17	0.8621
CLI RLI	0.216	0.419	66	0.52	0.6079
RSP RLI	0.143	0.419	66	0.34	0.7341
Density					
CSP CLI	1.960	0.883	66	2.22	0.0299
CSP RSP	1.602	0.883	66	1.81	0.0742
CSP RLI	3.133	0.883	66	3.55	0.0007
CLI RSP	-0.358	0.883	66	-0.41	0.6862
CLI RLI	1.172	0.883	66	1.33	0.1889
RSP RLI	1.531	0.883	66	1.73	0.0877
Length					
CSP CLI	214.910	99.423	66	2.16	0.0343
CSP RSP	150.710	99.423	66	1.52	0.1343
CSP RLI	273.880	99.423	66	2.75	0.0076
CLI RSP	-64.199	99.423	66	-0.65	0.5207
CLI RLI	58.968	99.423	66	0.59	0.5551
RSP RLI	123.170	99.423	66	1.24	0.2198

Table 3. Spearman's rho coefficients for correlations between sample types and random strip plot (RSP). Significance at the 0.05 level indicated by (*).

	Stand	CSP	CLI	RLI
Density	Aspen	0.634*	0.255	0.833*
	Hardwood	0.628	0.000	0.583
	EO	0.257	0.429	0.371
Length	Aspen	0.515	0.345	0.626
	Hardwood	0.717*	0.527	0.740*
	EO	0.086	0.600	0.543
Volume	Aspen	0.527	0.503	0.697*
	Hardwood	0.417	-0.233	0.667*
	EO	0.429	0.886*	0.886*

Table 4. **Estimated means and mean standard error for three variables of the four age classes of Aspen.**

	Density (logs ha^{-1})		Length (m ha^{-1})		Volume (m^3 ha^{-1})	
Age Class	Mean	SE	Mean	SE	Mean	SE
20	90.06	22.51	412.11	101.73	7.22	2.46
40	88.38	32.21	502.76	124.76	9.92	2.66
60	140.24	43.84	860.52	222.17	17.13	4.31
80+	276.04	53.03	1349.34	236.06	35.37	10.21

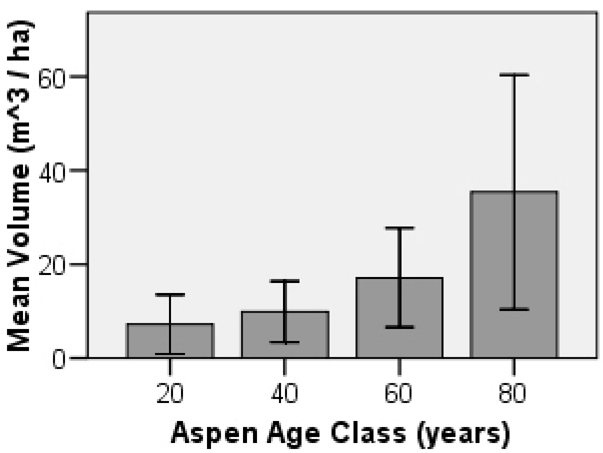

Figure 6. Mean volume estimates for four age classes of Aspen. Error bars show 95% confidence intervals.

DISCUSSION

Based on our random complete block analysis, for estimates of volume, the four methods do not differ significantly from one another. For density and length, the circuit transect seems to differ the least from the random plot technique. However, within each stand type, circuit samples are not strongly correlated with random samples. This would suggest that our samples may not adequately account for the natural variation within a stand. Snags and CWD are not uniformly distributed, and usually exist as patches or clumps (Bate et al. 1999). Previous studies have addressed this issue by varying transect length (Bate et al. 2004) and found that different lengths of the line intercept transect worked better depending on the amount and density of CWD within a stand. Our sampling kept the transect length constant at 66 feet, and so cannot consider this variable. With sample sizes of 10 stands or less in all three stand types, we concluded that our sample size at this point in the study is still too low to make meaningful comparisons among methods.

Results of sampling within different aged aspen stands indicated a connection between age of aspen and the amount of CWD. The lowest amount of CWD was in the youngest age group (20 yrs). These results confirm that slash residue from final harvest in aspen has limited residency time in these stands. Aspen stores large amounts of nutrients in perennial tissue (Pastor and Bockheim 1982), which influences the rapid decay of material deposited. A substantial buildup of CWD does not appear until the later age classes, after mature aspen clones have started to naturally senesce. Important aspects of CWD in aspen stands, such as grouse drumming logs, would not develop until an aspen stand has reached the 60 to 80 year age classes.

Coarse woody debris is considered an important characteristic of unmaganged, old-growth forests (Tyrrell and Crow 1994, Goodburn and Lorimer 1998, Hale et al. 1999, Siitonen et al. 2000, Crow et al. 2002). Increased CWD in old growth forests can be both a function of increased diameter of trees and of forest composition. The amount of CWD in northern Wisconsin and Michigan forests was found to increase linearly with both the age of the stand and the percentage of hemlock in the stand (Tyrrell and Crow 1994).

Hemlock is known to have a slower rate of decay and so would remain on the forest floor longer than hardwood species (Harmon et al. 1986). In our study, the managed northern hardwoods and aspen stands were missing the large, 50 to 70 cm DBH size (200-300 year old) trees that are frequent in the EOs. In addition, 18% of the trees recorded by basal area sweeps in EOs were large diameter hemlock, compared to just 5% in managed northern hardwood stands. As a long-lived (500 years) conifer that also possesses a much longer residency time as CWD than hardwoods species, differences in hemlock abundance between managed and unmanaged stands greatly influences both present and future forest structure and utilization by wildlife.

An important outcome of the analysis of three different variables of CWD was the clear sensitivity of the measure of volume to varying management regimes. When measuring merely the number of logs (density) or the total length of logs on the ground, the disparity between actively managed ecosystems and old growth ecosystems was surprisingly absent. Analysis of size classes within each stand type indicated that it was not the fact that EOs contained more logs, but rather, EOs contained more logs of large diameter. Density of CWD is the variable typically monitored in wildlife habitat programs (Bate et al. 2004). However, with our sampling methods, the variable of density did not distinguish a significant difference in CWD between old-growth and managed forests. Research suggests that it is the volume of CWD, obtained by large diameter boles of fallen mature trees that harbor the greatest benefit to wildlife (Goodburn and Lorimer 1998). Therefore, our results suggest using the volume of CWD within a stand to accurately assess quality of habitat and stand ecological integrity.

In our study, snags were considered separate from logs on the ground; and volume of snags was not calculated as part of the overall CWD volume. Another study of CWD (Hale et al. 1999) found that snag volume provided significant information for accurately determining old-growth condition, even though snag volume was a relatively small portion of total CWD volume. Further analysis of our data for total CWD volume could include the volume of each snag recorded. In our study, snag height was visually estimated and was initially entered and analyzed based on height categories (1 to 4). If including snags in the total volume of CWD for a stand was determined to provide a better understanding of overall stand volume, future sampling could use more accurate methods to assess snag height. Tall snags could be measured using a clinometer and small snags using a measuring tape.

PLANS FOR 2007

For the 2007 field season, we plan to double our sample size in aspen and northern hardwoods. Our sampling will mostly be located in the northern Lower Peninsula. We also plan on adding to our EO data, but in order to adequately sample old-growth, unmanaged stands, we will be sampling in the Western UP.

Further analysis of the data will be important in order to determine how each of our stand types compared to those in previous studies for abundance and size class of CWD. Upon preliminary analysis, our stands appear to have higher abundance of CWD. However, our data is based on different transect lengths than that of Bate et al. (2004). In that study, line intercept method performed best in stands that had a higher density of CWD (i.e., ~11 logs per 100m transect). As the abundance of CWD in our study appears to be elevated, it may be informative to include a comparison of all methods to RLI as well as RSP.

ACKNOWLEDGEMENTS

This project was funded by Michigan Department of Natural Resources, Wildlife Division. The field crew for 2006 included Brittany Woiderski and Michael “Cletus” Beulow. Special thanks to Helen Enander for GIS support; Dan Hayes, PhD. (MSU), Melissa Mata (MSU), and Sarah Mayhew (MDNR) for statistical support. Additional assistance came from Jennifer Kleitch (MDNR) and the following MNFI staff: Kraig Korroch, Brad Slaughter, Jeff Lee, Josh Cohen, Adrienne Bozic, Becky Schillo, Dave Cuthrell, Phyllis Higman, Connie Brinson, Sue Ridge and Ryan O’Connor.

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APPENDIX A. CWD FIELD METHODS

Circuit Line Intercept (CLI) will be laid out to efficiently cover all areas of the target stand with a minimum of backtracking. A starting point that is clearly identifiable on an aerial photo is selected, and a route through the stand is selected along which transects and plots are established (Figure 1). The number of transects within the stand will depend on stand size. Transects will be one chain (66 feet) in length and separated by a distance of at least one-half chain (33 feet). The number and length of cwd intersecting transects will be recorded. Plots will be determined using a 10 BAF prism at the beginning of each transect. The number, height, diameter, and species of snags in the plot will be recorded.

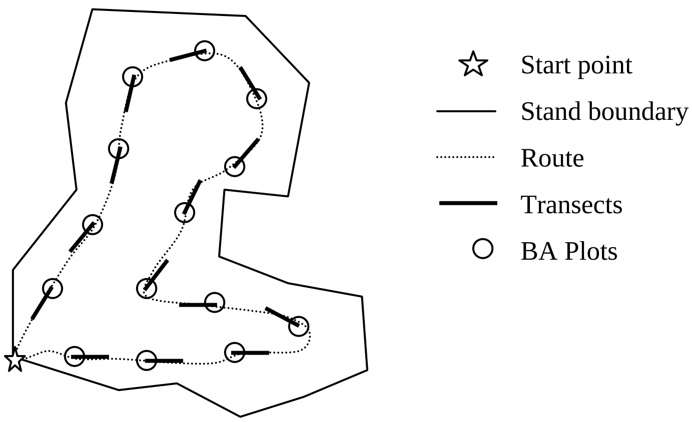

Figure 1. Example of circuit transect layout within a stand

Circuit Strip Plots (CSP) will be laid out in the same manner as circuit transects, with the same starting point, and along the same route. Transects will be used as the basis for the central length of strip plots (one chain in length, separated by one-half chain), and strip width will be 14 feet (7' on each side of the transect, Figure 2). The number and length of cwd, as well as snags within the plot within plots will be recorded.

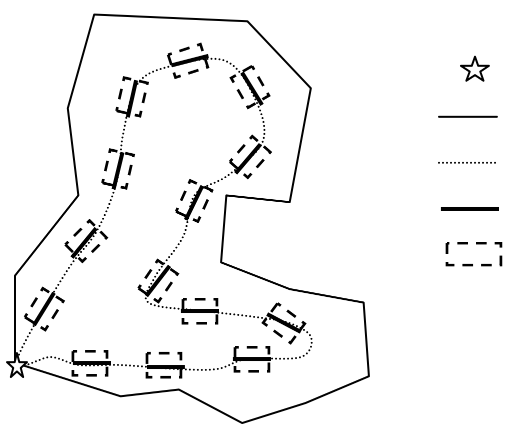

Figure 2. Example of circuit strip plot layout within a stand.

Random Line Intercept (RLI) will be laid out along parallel routes through the stand. A baseline along a known feature will be selected and starting points for routes will be established at a set distance apart. A randomly selected distance will be traversed from the start along the route to locate the first transect.

Additional transects will be established a random distance greater than or equal to one-half chain (33’) from the end of the previous transect (Figure 3). The number of transects within the stand will be equal to the number of circuit transects established within the stand (dependent on stand size). Transects will be one chain (66 feet) in length. The number and length of cwd intersecting transects will be recorded. Plots will be determined using a 10 BAF prism at the beginning of each transect. The number, height, diameter, and species of snags in the plot will be recorded

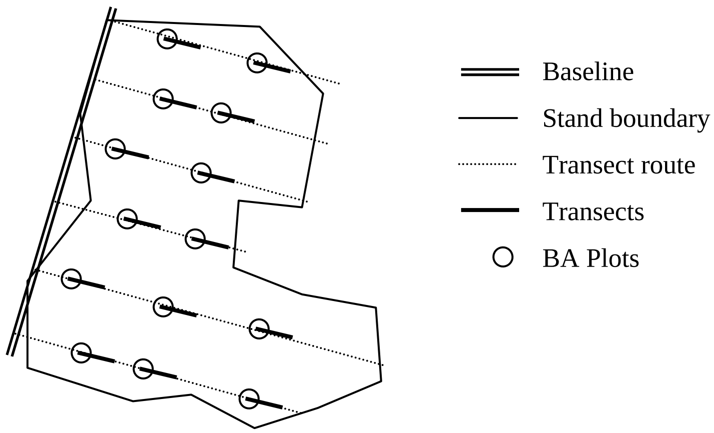

Figure 3. Example of random transect layout within a stand.

Random Strip Plots (RSP) will be laid out along parallel routes through the stand. A baseline along a known feature will be selected and starting points for routes will be established at a set distance apart. A randomly selected distance will be traversed from the start along the route to locate the first transect. Additional transects will be established a random distance greater than or equal to one-half chain (33’) from the end of the previous transect (Figure 3). The number of strip plots within the stand will be equal to the number of circuit plots established within the stand (dependent on stand size). Strip plots will be one chain (66 feet) in length. The number and length of cwd intersecting transects will be recorded.

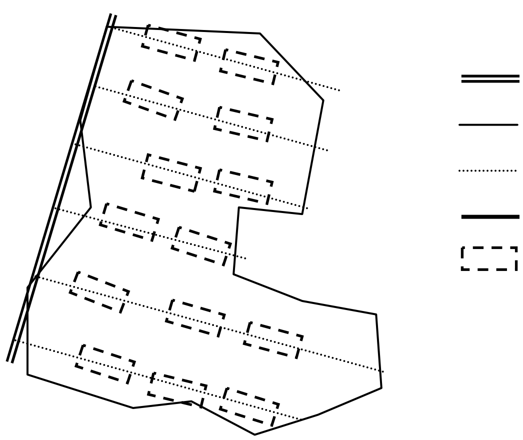

Figure 4. Example of random strip plot layout within a stand.

CWD Measurements:

Dead and down material measurements will include the number, size, and decay class of coarse woody debris pieces that meet minimum size requirements.

Methods:

1) Gather field sheets and maps: Make sure that you have a complete set of field sheets ant the appropriate maps for the stand. The map will show the number of transects/plots within the stand. Prepare one data sheet for each transect/plot, making sure to note the forest, compartment, and stand number, and the id for the transect/plot.
2) Necessary equipment: With transect maps and field forms prepared, inventory personnel go to field with: pencils, data forms, prisms (BAF 10), dbh tape, measuring tapes, flagging, compass, and GPS.
3) Starting point
   Circuit Transects and Strip Plots: Use map and GPS to find the starting "reference" point of first transect.
   Random Transects: Use map to find the beginning of the baseline and start of the transect route. use the start point coordinates listed on the top of page one to navigate with GPS.
4) Locate sampling sites:
   If the GPS unit is detecting your location with an acceptable amount of error, you can locate the sampling sites using the GPS unit. The start points of all transects/plots should be uploaded in the unit and labeled as they are on the map. The direction of the transects can be determined using the directions indicated on the map (random transects and circuit transects/plots) or using the GO TO function on the GPS unit to determine the direction of the next sample (circuit transects/plots only). If the GPS unit is not working, follow the directions on the map to locate your starting point and pace to the next starting point using the distance and direction indicated on the map.
5) BA Plots for Snags (*Transects only*): Establish plot center at the beginning of each transect (do not conduct BA plots at strip plot locations). Determine a starting direction (direction of travel). Systematically work in a clockwise direction using a 10 Basal Area Factor (BAF) prism to determine the number of "in" snags (Figure 4). Tally the number and species of snags "in" the plot. Have a partner measure the diameter of each snag at breast height (dbh) using a dbh tape and estimate the height of the snag in 5m increments. Record all information on the data sheets.

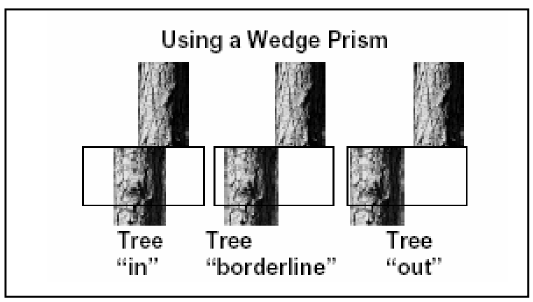

Figure 5. Illustration of how to use a Basal Area (BA) prism to determine the number of snags to tally.

6) CWD Along Transects: Have one partner hold the end of the measuring tape and, in the direction indicated on the map or GPS, measure one chain (66', 20m), making sure the transect is as straight as possible. Using the "GO, NO-GO" gauge, tally qualifying down woody pieces that intersect a planar transect that stretches from ground to sky (e.g. if a qualifying piece crosses the transect above ground, that piece must be tallied). For each intersected qualifying piece measure diameter at the transect intersection, small and large ends, piece length, and assign decay class (Figures 5 and 6).

7) CWD and Snags Within Strip Plots: Complete strip plots immediately after completing circuit transects (do not collect plot data at random locations). Using the pre-measured poles as a guide for determining the plot width, work systematically from one end of the plot to the other, tallying snags within the plot. Using the "GO, NO-GO" gauge within the plot, tally qualifying down woody pieces and measure the total length, length within the plot (may be the same if there are no intersections with plot edge), diameters at plot intersections (if present), large and small end diameters (indicate if outside the plot), and assign a decay class to all qualifying down woody pieces that have at least 0.5m (~20") of length within the plot (Figure 6). Record whether the point of mid-length of a tallied log falls within the plot.

Qualifications for tallying a "piece" as CWD:

1) CWD includes logs on the ground or stumps. Logs/downed trees should have at least 2 points of ground contact or at least 1.5' of ground contact anywhere along it's length.
2) Logs must be at least 4" (10cm) in diameter. Transects: 4" anywhere along its length. Plots: 4" anywhere along its length within the plot. *(Note: we started this project using 7" as a guide but later changed to 4".)*
3) Stumps must be at least 4" (10cm) in diameter at the base (excluding buttress) and at least 18" tall but no taller than 6 feet ("stumps" taller than 6 feet would meet our definition of a snag.)
4) Broken lengths originating from the same fallen tree: count as same piece only if individual portions are less than 1' apart and meet requirements above for a qualifying piece.

Rules for making measurements:
All measurements are to the nearest 1cm.

Diameter: Measure the diameter by holding a tape above the log, at a position perpendicular to the length. If pieces are not round in cross-section because of missing chunks of wood or "settling" due to decay, measure the diameter in two directions representing the largest and smallest diameters and take an average. If the log is splintered or decomposing at the point where a diameter measurement is needed, measure the diameter at the point where it best represents the log volume. Diameter at small end: record the diameter of the small end to the nearest centimeter at either the actual end of the piece if the end is >3cm, or at the point where the piece tapers down to 3cm. This will serve as the end of the log for length measurements. Diameter at large end: Record the diameter to the nearest centimeter, ignoring buttressed areas (USDA 2004).

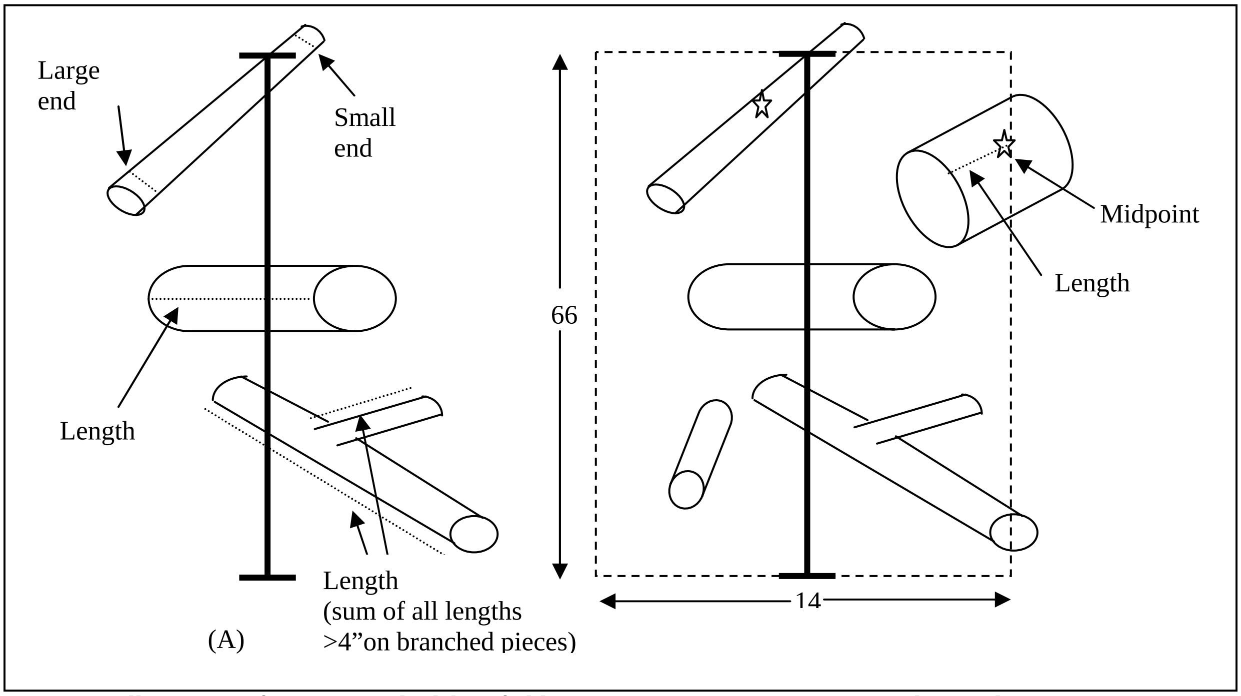

Figure 6. Illustration of coarse woody debris field measurements at transects (A) and strip plots (B). Logs shown in each illustration should be tallied and have measurements and decay class recorded.

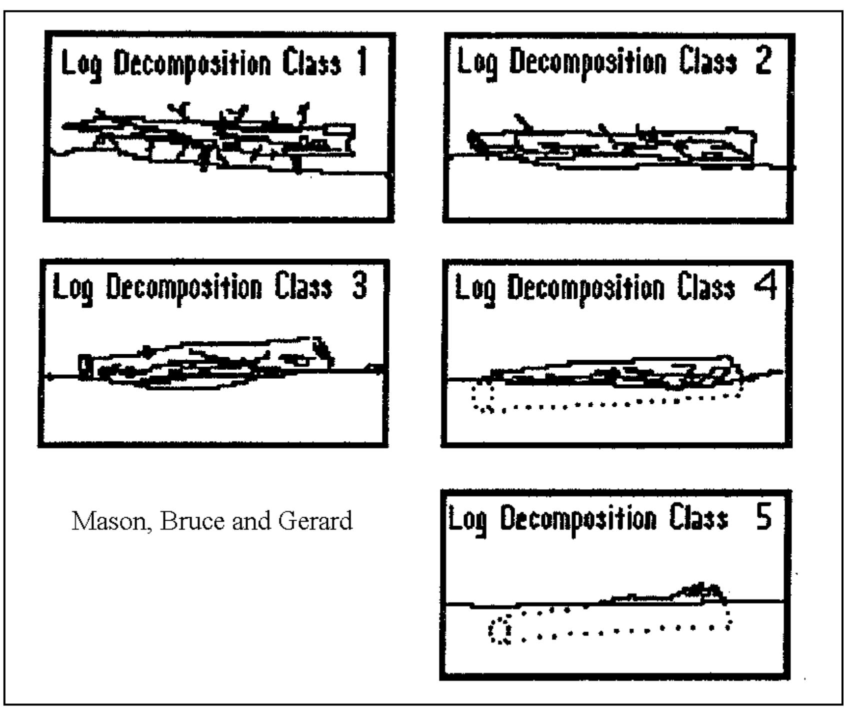

Figure 7. Illustration of log decomposition classes.

USDA Forest Service. 2004. 2.0 Phase 3 Field Guide – Down Woody Materials.

Circuit Line Intercept

Forest and Compartment ______________________________ Name _____

Stand ________________ Date _____

Azimuth ________________

Transect # ____ of ____

Snags "in" BA sweep			
Snag #	Species	DBH	Height

Circuit Line Intercept					
Piece #	Intersect Diam 1	Total Length	Lg End Diam	Small End Diam	Decomp

Appendix B: Field Forms

Random Strip Plot

Forest and Compartment ____________________________ Name ____________________

Stand ______________ Date ____________________

Azimuth ______________

____ of

Plot # ____

Snags within plots				Snags within plots			
Snag #	Species	DBH	Height	Snag #	Species	DBH	Height

Random Strip Plot								
Piece #	Intersect Diam 1	Intersect Diam 2	Total Length	Length in Plot	Lg End Diam	Small End Diam	Midpt in Plot?	Decomp

Appendix B: Field Forms

Random Line Intercept

Forest and Compartment ______________________ Name ________
Stand ______________
Date _____
Bearing ______________
Distance ______________
Transect # ____ of ____

Snags "in" BA sweep			
Snag #	Species	DBH	Height

Random Line Intercept					
Piece #	Intersect Diam 1	Total Length	Lg End Diam	Small End Diam	Decomp

Circuit Strip Plot

Forest and Compartment ______________________________ Name ____________________

Stand ______________ Date ____________________

Azimuth ______________

Plot # ____ of ____

Snags within plots				Snags within plots			
Snag #	Species	DBH	Height	Snag #	Species	DBH	Height

Circuit Strip Plot								
Piece #	Intersect Diam 1	Intersect Diam 2	Total Length	Length in Plot	Lg End Diam	Small End Diam	Midpt in Plot?	Decomp