

Standard Operating Procedure #9:

Coarse Woody Materials

Version 2.1 (1/26/2024)

Prepared by

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Revision History Log

Date	Previous version	New version	Authors
2012	1.0	2.0	Suzanne Sanders and Jessica Grochowski
References to other SOPs were changed to reflect new numbering.			
2024	2.0	2.1	Suzanne Sanders and Jessica Kirschbaum
Revised to: • make monitoring questions more in-line with those of the main monitoring protocol; also to remove question dealing with change between sampling events, due to measurement difficulties on decaying material and extreme variability in values; • reflect the fact that we now use tablets, rather than paper datasheets; • improve wording and flow of text; • correct the calculation for transect volume in the example calculation, located at the bottom of page 11 of the previous version; • correct formula numbering.			

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9.0 Introduction

This standard operating procedure (SOP) provides guidance for monitoring coarse woody materials (CWM) within the nine Great Lakes Network national parks. This indicator of forest health will be monitored within the context of the Forest Vegetation Monitoring program (Sanders and Kirschbaum 2024). Field methods are detailed in SOP6, while analysis techniques are presented in SOP 11. Here, we focus on calculations behind the CWM estimations.

The NPS-GLKN coarse woody materials sampling is designed to answer the following specific questions:

- What is the CWM volume (m^3/ha) and biomass (kg/ha) in specific habitats or forest types or across the entire park?
- What is the density (pieces/ha) of CWM in specific habitat or forest types or parkwide? We will calculate this for key size and decay classes.

In addition to the questions above, we will use data collected on standing dead trees to determine densities of snags in key size classes.

Data from CWM sampling can be combined with that of community structure, succession, and other indices of forest growth and allow us to develop holistic forest health inferences.

9.1 Field Methods

As part of the Forest Vegetation Monitoring Protocol, the Great Lakes Network uses the Hybrid plot design (Johnson et al. 2006). This plot design was developed to meet the needs of the Great Lakes Network by combining assets of other long-term monitoring protocols used in the region. Our measurement methods and criteria mirror that of the U.S. Forest Service Forest Inventory and Analysis (FIA) program. For example, criteria for discerning between CWM decay classes will be identical between the two programs. This will enable comparisons of CWM data collected within the Network parks with that from forested areas surrounding the parks.

The Hybrid plot is composed of three parallel, 50-meter-long, horizontal distance transects, each oriented east-west (Figure 1). Data on CWM is collected along each of these transects using the line intercept method (Brown 1974, de Vries 1986, Woodall and Williams 2005). For all pieces, the parameters recorded are transect intercept diameter, small-end diameter, large-end diameter, length, species, and decay class (Table 1). For decay classes 1–4, the minimum qualifying size is ≥ 0.90 m long and ≥ 7.5 cm diameter. For pieces in decay class 5, the length must be ≥ 1.5 m and the diameter at the line intercept must be ≥ 12.7 cm (only pieces that still have some shape and log form are tallied; humps of decomposed wood that are becoming part of the duff layer are not tallied). Refer to SOP 6: Field Methods and Data Collection, for specific tally rules on data collection.

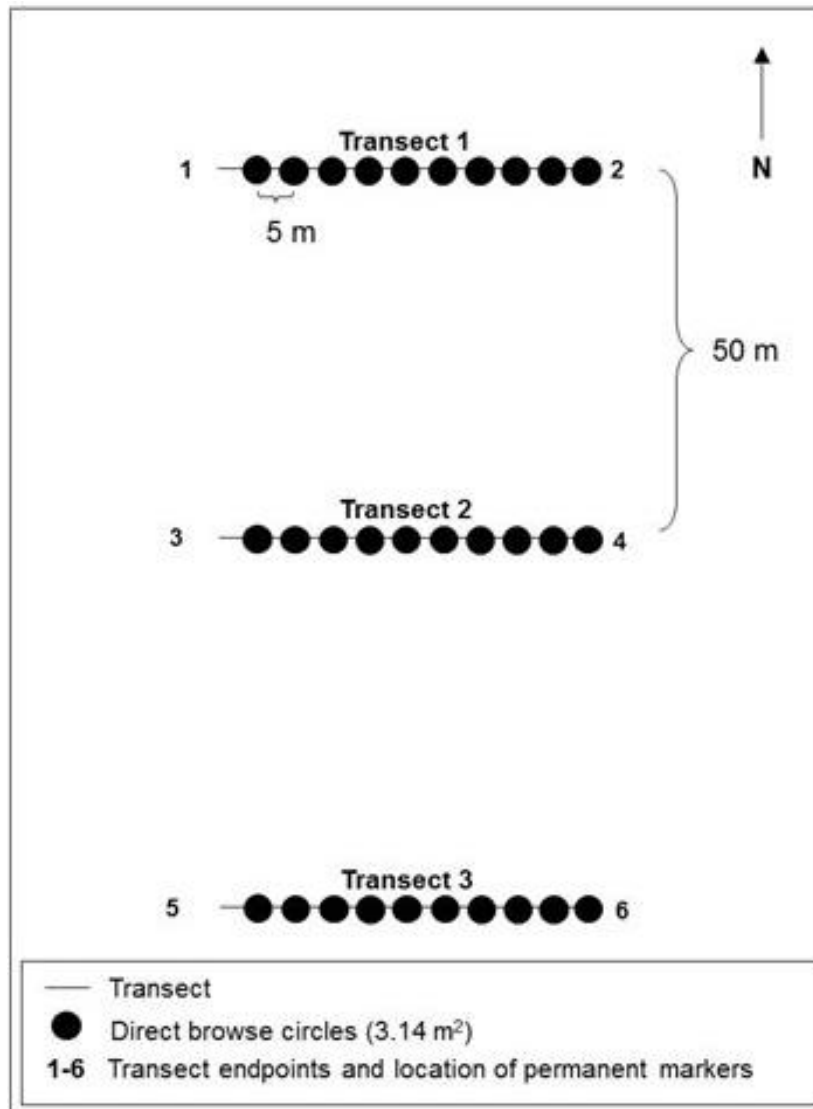


Figure 1. The Hybrid plot, showing the three parallel transects along which data on coarse woody materials will be collected.

Table 1. Distinguishing characteristics of the five decay classes. From Woodall and Williams (2005).

Decay class	Structural integrity	Texture of rotten portions	Color of wood	Invading roots	Branches and twigs
1	sound, freshly fallen, intact logs; all bark intact; hard when kicked	intact, no rot; conks of stem decay absent	original color	absent	if branches are present, fine twigs are still attached and have tight bark
2	sound; some bark missing; hard when kicked	mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	original color	absent	if branches are present, many fine twigs are gone and remaining fine twigs have peeling bark

Decay class	Structural integrity	Texture of rotten portions	Color of wood	Invading roots	Branches and twigs
3	heartwood sound; most of the bark is missing; piece supports its own weight; still hard when kicked	hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	reddish brown or original color	sapwood only	branch stubs will not pull out, and most of the branches < 1" missing
4	heartwood rotten; piece does not support its own weight, but maintains its shape; sounds hollow when kicked and you can remove wood from outside with boot	soft, small blocky pieces; a metal pin can be pushed into heartwood	reddish or light brown	throughout	branch stubs pull out
5	none, piece no longer maintains its shape, it spreads out on the ground; easy to kick apart	soft; powdery when dry	red-brown to dark brown	throughout	branch stubs and pitch pockets have usually rotted down

9.2 Estimation Methods

Volume estimation for CWM based on a single transect of horizontal distance length L (in meters) is calculated by:

(Eq. 9.1)

$$\bar{y} = \frac{f\pi}{2L} \sum_{i=1}^n (y_i/l_i)$$

where $\bar{y}$ is the volume in m^3/ha , $f = 10,000 \text{ m}^2/\text{ha}$, y_i is the volume of piece i (m^3), and l_i is the length of piece i (m) (Woodall and Williams 2005).

The volume of individual pieces of CWM (V) is calculated following Smalian's formula (Husch et al. 1972):

(Eq. 9.2)

$$V_m = \frac{(\pi / 8)(D_S^2 + D_L^2)l}{10,000}$$

where D_S is the small end diameter (cm), D_L is the large-end diameter (cm), l is the length of the piece (m), and subscripted m denotes that the units are cubic meters.

For pieces in decay class 5, the only diameter used in calculations is at the transect intercept, and the volume of the individual piece (V) is estimated using Huber's formula (Husch et al. 1972):

(Eq. 9.3)

$$V_m = \frac{(\pi / 4)(D_T^2)l}{10,000}$$

where D_T is the transect diameter (cm) and subscripted m denotes that the units are cubic meters. Refer to Appendix A for an example of the CWM volume calculation.

While volume of CWM per unit area is important for many applications, estimates of CWM biomass are critical to carbon and fuel monitoring efforts. Because the biomass of any individual CWM piece is partially dependent on its species and stage of decay, CWM biomass estimates of individual pieces must incorporate these values. Hence, biomass of an individual piece is calculated by:

(Eq. 9.4)

$$B_{kg} = V \times 1,000 \text{ kg/m}^3 \times AD$$

where B is the biomass of the piece (in kg), V is the volume of the piece (in m^3), and AD is the absolute density for a given species-decay class combination (Table 2) (Harmon et al. 2008).

Biomass estimation for CWM based on a single transect of horizontal distance length L (m) is calculated by:

(Eq. 9.5)

$$\bar{y} = \frac{f\pi}{2L} \sum_{i=1}^n (y_i/l_i)$$

where $\bar{y}$ is the biomass in kg/ha, $f = 10,000 \text{ m}^2/\text{ha}$, y_i is the biomass piece i (kg), and l_i is the length of piece i (m) (Woodall and Williams 2005).

In addition to volume and biomass, we are also interested in the density of CWM pieces. Estimation of the number of CWM pieces per hectare based on a single transect of length L is calculated by:

(Eq. 9.6)

$$\bar{y} = \frac{f\pi}{2L} \sum_{i=1}^n (1 / l_i)$$

where $\bar{y}$ is the number of pieces per hectare, $f = 10,000 \text{ m}^2/\text{ha}$, and l_i is the length of piece i (m). An example of this calculation is shown in Appendix A.

Table 2. Species and absolute density values for trees in Great Lakes Network parks. Values are from Harmon et al. (2008).

Species	Decay class				
	1	2	3	4	5
<i>Abies balsamea</i>	0.360	0.360	0.290	0.170	0.100
<i>Acer</i> spp.	0.536	0.377	0.281	0.177	0.135

Species	Decay class				
	1	2	3	4	5
<i>Acer negundo</i>	0.536	0.377	0.281	0.177	0.135
<i>Acer nigrum</i>	0.536	0.377	0.281	0.177	0.135
<i>Acer pensylvanicum</i>	0.536	0.377	0.281	0.177	0.135
<i>Acer rubrum</i>	0.436	0.260	0.198	0.177	0.135
<i>Acer saccharinum</i>	0.536	0.377	0.281	0.177	0.135
<i>Acer saccharum</i>	0.679	0.452	0.324	0.182	0.150
<i>Acer spicatum</i>	0.536	0.377	0.281	0.177	0.135
<i>Aesculus</i> spp.	0.533	0.422	0.325	0.212	0.158
<i>Aesculus flava</i>	0.533	0.422	0.325	0.212	0.158
<i>Aesculus glabra</i>	0.533	0.422	0.325	0.212	0.158
<i>Ailanthus altissima</i>	0.533	0.422	0.325	0.212	0.158
<i>Amelanchier</i> spp.	0.533	0.422	0.325	0.212	0.158
<i>Amelanchier arborea</i>	0.533	0.422	0.325	0.212	0.158
<i>Amelanchier humilis</i>	0.533	0.422	0.325	0.212	0.158
<i>Amelanchier interior</i>	0.533	0.422	0.325	0.212	0.158
<i>Amelanchier laevis</i>	0.533	0.422	0.325	0.212	0.158
<i>Asimina triloba</i>	0.533	0.422	0.325	0.212	0.158
<i>Betula</i> spp.	0.580	0.403	0.265	0.170	0.110
<i>Betula alleghaniensis</i>	0.580	0.403	0.190	0.170	0.110
<i>Betula lenta</i>	0.635	0.420	0.283	0.170	0.110
<i>Betula nigra</i>	0.580	0.403	0.265	0.170	0.110
<i>Betula papyrifera</i>	0.469	0.403	0.352	0.170	0.110
<i>Carpinus caroliniana</i>	0.533	0.422	0.325	0.212	0.158
<i>Carya</i> spp.	0.633	0.417	0.195	0.173	0.151
<i>Carya cordiformis</i>	0.610	0.367	0.249	0.173	0.151
<i>Carya glabra</i>	0.599	0.409	0.238	0.173	0.151
<i>Carya laciniosa</i>	0.599	0.409	0.238	0.173	0.151
<i>Carya ovata</i>	0.551	0.479	0.308	0.173	0.151
<i>Carya tomentosa</i>	0.601	0.372	0.238	0.173	0.151
<i>Castanea dentata</i>	0.360	0.348	0.255	0.212	0.158
<i>Celtis occidentalis</i>	0.533	0.422	0.325	0.212	0.158
<i>Cercis canadensis</i>	0.533	0.422	0.325	0.212	0.158
<i>Cornus</i> spp.	0.533	0.422	0.325	0.212	0.158
<i>Cornus florida</i>	0.533	0.422	0.325	0.212	0.158
<i>Crataegus</i> spp.	0.533	0.422	0.325	0.212	0.158
<i>Fagus grandifolia</i>	0.570	0.300	0.167	0.240	0.160
<i>Fraxinus</i> spp.	0.475	0.317	0.298	0.212	0.100
<i>Fraxinus americana</i>	0.475	0.317	0.298	0.212	0.100
<i>Fraxinus nigra</i>	0.475	0.317	0.298	0.212	0.100
<i>Fraxinus pennsylvanica</i>	0.475	0.317	0.298	0.212	0.100
<i>Fraxinus quadrangulata</i>	0.475	0.317	0.298	0.212	0.100
<i>Gleditsia triacanthos</i>	0.533	0.422	0.325	0.212	0.158
<i>Ilex opaca</i>	0.533	0.422	0.325	0.212	0.158
<i>Juglans</i> spp.	0.533	0.422	0.325	0.212	0.158
<i>Juglans cinerea</i>	0.533	0.422	0.325	0.212	0.158
<i>Juglans nigra</i>	0.533	0.422	0.325	0.212	0.158
<i>Larix laricina</i>	0.381	0.318	0.257	0.162	0.143
<i>Liriodendron tulipifera</i>	0.352	0.275	0.203	0.141	0.158

Species	Decay class				
	1	2	3	4	5
<i>Maclura pomifera</i>	0.533	0.422	0.325	0.212	0.158
<i>Malus</i> spp.	0.533	0.422	0.325	0.212	0.158
<i>Morus alba</i>	0.533	0.422	0.325	0.212	0.158
<i>Morus rubra</i>	0.533	0.422	0.325	0.212	0.158
<i>Nyssa sylvatica</i>	0.533	0.422	0.325	0.212	0.158
<i>Ostrya virginiana</i>	0.533	0.422	0.325	0.212	0.158
<i>Picea</i> spp.	0.393	0.312	0.280	0.155	0.129
<i>Picea glauca</i>	0.393	0.312	0.280	0.155	0.129
<i>Picea mariana</i>	0.393	0.312	0.280	0.155	0.129
<i>Pinus banksiana</i>	0.368	0.324	0.273	0.169	0.171
<i>Pinus resinosa</i>	0.340	0.324	0.270	0.150	0.110
<i>Pinus strobus</i>	0.368	0.324	0.273	0.169	0.171
<i>Pinus</i> sp.	0.368	0.324	0.273	0.169	0.171
<i>Pinus sylvestris</i>	0.368	0.324	0.273	0.169	0.171
<i>Platanus occidentalis</i>	0.533	0.422	0.325	0.212	0.158
<i>Populus</i> spp.	0.370	0.422	0.300	0.160	0.110
<i>Populus balsamifera</i>	0.353	0.422	0.299	0.160	0.110
<i>Populus deltoides</i>	0.353	0.422	0.299	0.160	0.110
<i>Populus grandidentata</i>	0.336	0.422	0.298	0.160	0.110
<i>Populus tremuloides</i>	0.353	0.422	0.299	0.160	0.110
<i>Prunus</i> spp.	0.489	0.418	0.281	0.212	0.158
<i>Prunus pensylvanica</i>	0.401	0.337	0.216	0.212	0.158
<i>Prunus serotina</i>	0.577	0.499	0.346	0.212	0.158
<i>Prunus virginiana</i>	0.577	0.499	0.346	0.212	0.158
<i>Quercus</i> sp.	0.565	0.462	0.318	0.196	0.248
<i>Quercus alba</i>	0.567	0.383	0.335	0.168	0.248
<i>Quercus bicolor</i>	0.611	0.450	0.382	0.241	0.248
<i>Quercus macrocarpa</i>	0.611	0.450	0.382	0.241	0.248
<i>Quercus rubra</i>	0.545	0.303	0.387	0.234	0.248
<i>Quercus velutina</i>	0.611	0.363	0.453	0.241	0.248
<i>Robinia pseudoacacia</i>	0.725	0.560	0.325	0.212	0.158
<i>Salix</i> sp.	0.533	0.422	0.325	0.212	0.158
<i>Sassafras albidum</i>	0.432	0.388	0.338	0.212	0.158
<i>Sorbus americana</i>	0.533	0.422	0.325	0.212	0.158
<i>Sorbus decora</i>	0.533	0.422	0.325	0.212	0.158
<i>Thuja occidentalis</i>	0.329	0.259	0.315	0.143	0.143
<i>Tilia americana</i>	0.406	0.333	0.256	0.212	0.158
<i>Tsuga canadensis</i>	0.398	0.322	0.325	0.178	0.140
<i>Ulmus</i> sp.	0.533	0.422	0.325	0.212	0.158
<i>Ulmus americana</i>	0.533	0.422	0.325	0.212	0.158
<i>Ulmus pumila</i>	0.533	0.422	0.325	0.212	0.158
<i>Ulmus rubra</i>	0.533	0.422	0.325	0.212	0.158
Unknown hardwood	0.533	0.422	0.325	0.212	0.158
Unknown softwood	0.375	0.323	0.279	0.164	0.142
Unknown	0.454	0.372	0.302	0.188	0.150

9.3 Data Summaries and Analyses

Summarized data will be presented in figures and tables following sampling in each park. This may be presented parkwide, or by habitat/forest type.

To test for change between successive sampling events, we will likely use liner mixed models (see SOP 11: Data Summary and Analysis). Prior to all analyses, assumptions (e.g., normality and sphericity) will be tested and modifications made if needed.

Results of the CWM inventory may be compared qualitatively with those describing plant community structure. This will allow inferences to be drawn relating fuel loads, community structure, successional states, and forest health.

9.4 Acknowledgements

The Great Lakes Network is grateful to Christopher Woodall of the U.S. Forest Service for providing reviews and comments on this SOP.

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