OLD-GROWTH FOREST SURVEY METHODS

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INTRODUCTION

We now know that significant tracts of old-growth forest remain unprotected from logging in Algonquin Park, including large tracts of pristine old-growth forest with trees 300 to 400 years old (Henry et al., 2018; Henry & Quinby, 2006, 2007, 2018). However we do not know how much old-growth forest remains or where it is found. The Algonquin old-growth forest project was launched in 2021 to identify remaining old-growth forests in the recreation/utilization zone of Algonquin Park (where logging is permitted), it is a partnership between Michael Henry (oldgrowth.ca) and the Wilderness Committee (wildernesscommittee.org).

Existing map data (forest inventory, known harvest, etc) is used to identify candidate old growth areas. Locations that are far from access roads and rail lines and/or are isolated by steep terrain or water bodies are less likely to have had historical logging of hemlock and hardwood trees, since these species could not be floated to mills. In some cases hemlock forests remain relatively intact even in managed landscapes due to the relatively low commercial value of the species.

This paper describes rapid survey methods for suspected old-growth forests in Algonquin Park, however the techniques could be applied in other old-growth forests. Data sheets are provided for use or modification.

METHODS

We use rapid survey techniques to collect useful data as quickly and cheaply as possible. Sampling is conducted along pre-planned transects and in plots, which are located on a grid pattern oriented to fit within old-growth forest stands (in this case FRI stands with high stand ages). Hemlock forest is also prioritized in transect placement as it is a species of particular concern. Variable radius plots (prism sweeps) are located at the end points of each transect, where tree and snag basal area is recorded by species and diameter class. One or more trees are selected for coring at each point based on age characteristics.

All movement within old-growth stands is treated as an informal transect: presence of stumps is noted, and additional data collection including tree coring may take place along these routes.

TRANSECTS: GENERAL HABITAT AND STUMP SURVEY (FOR HISTORICAL LOGGING)

Transects are divided into 150 m sections and along each section the following data are recorded:

- stumps within line of sight of the transect are counted and grouped by decay class categories (1-3 or 4-5), decay class is used to provide an estimated time since logging. photos may be taken.
- Trees with old-age characteristics along transects may be selected for aging by tree core. Cores are collected in paper or plastic straws and counted after field work is complete.
- Qualitative observations of old-growth characteristics are recorded.
- Qualitative observations of stand age class distribution and regeneration are recorded.
- invasive species, disease resistant trees, and other conservation features are noted, locations may be saved and reported to iNaturalist projects

(https://www.inaturalist.org/projects/invasive-species-in-ontario, https://www.inaturalist.org/projects/beech-bark-disease-resistance, etc.)

Coarse Woody Debris (logs)

Line intersect sampling for logs was originally developed for use in forestry to quantify fuel loading and logging slash in forests, however it has been adopted by some researchers as a very efficient technique to measure coarse woody debris for its functions of providing wildlife habitat, carbon sequestration, etc. Because the probability of a log intersecting the line is related to its length, only one measurement is needed to estimate volume of coarse woody debris per hectare - diameter at the point where the log intersects the line. For highest precision it is recommended to use 100m long transects (Woldendorp et al., 2002), however for our rapid survey purposes we elect to use numerous shorter transects and average the results.

For this survey we lay out 50m transects beginning at each plot center and following the transect bearing (30m transects were used in 2022). Wherever a log crosses the transect tape the log diameter is recorded at the intersect point (Van Wagner, 1982) and also at large end to allow the logs to be analyzed more accurately by size classes (Bate et al., 2009). The formula to calculate volume (from Van Wagner 1982), is:

$V= (k/L) *Sum(D^2)$

Where V is volume in m3/ha, k is a constant (1.234), L is the transect length (m), D is diameter at intersect point (cm).

Decay class is recorded for logs. Wood masses that intersect the line but are not logs are recorded but notes are made. The line intersect sampling method assumes that logs are cylindrical and lie horizontal to the ground. When the transect crosses over highly decayed stumps they may have very large diameter but are low to the ground. Including these significantly skews the data, so we have chosen to omit them from the total volume calculation. This may result in an underestimation of coarse woody debris; however highly decayed logs tend to be overestimated in volume (since the formula assumes they are round, while they actually are a collapsed oval), so the two may partially balance out. Line intercept is a very rapid survey technique that provides a reasonable estimate of coarse woody debris, but it has limitations. Some of the same limitations apply to plot-based sampling; accurate measurements of coarse woody debris are challenging.

Trees and snags

Tree and snag data are collected using prism sweeps at the end points of each 150 m transect. Basal area prisms are traditionally used by forest managers to rapidly assess the total tree basal area (and by extrapolation volume of timber) in a forest. However when tree diameters are also measured a lot of information about a forest can be gathered in a short time, including tree density and diameter classes.

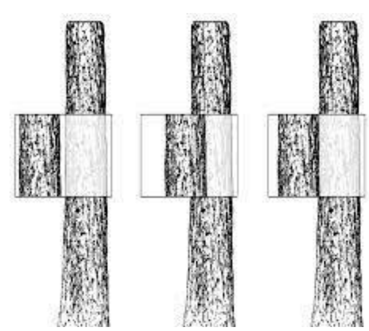

FIGURE 1. THE TREE ON THE LEFT IS OUT, THE CENTER IS IN, AND THE RIGHT IS BORDERLINE

The prism works by shifting the image of a tree to one side - if the tree in real life overlaps the shifted image the tree is counted as “in” – if there is no overlap the tree is out. If it falls exactly on the line it is borderline, and the most rapid way to resolve this is to include every second borderline tree.

Before beginning a prism sweep the center point is marked using flagging tape or a post and the prism is always held over that point, with the observer rotating around the point (the natural inclination is to stand in a fixed position and rotate the prism around yourself, which would introduce significant error). When working with volunteers we tend to attach the prism to a string anchored at the plot center to eliminate that source of error. One person uses the prism and records data, while a second person is directed to trees that are “in” the sweep, and calls out diameter at breast height, species, and whether the tree is alive or a dead snag. In the latter case decay class is also recorded. Only trees and snags >= 10 cm are recorded.

One (or more) tree(s) that are “in” the prism sweep are aged by tree core (see below). Qualitative observations of stand age class distribution and regeneration are also recorded.

Tree coring

Trees are selected for coring based on old age characteristics. These are summarized for hardwood trees by Pederson (2010) as: smooth bark; low stem taper; high stem sinuosity; crowns comprised of few, thick, twisting limbs; low crown volume; and a low ratio of leaf area to trunk volume. Smooth bark is commonly referred to as bark balding, which is common on the lower trunk of hardwoods when ridges or other bark texture are shed with old age (Figure 2). Deeply fissured, twisted or highly irregular bark can also be characteristic of very old trees (Piovesan & Biondi, 2021). Many of the attributes of old trees are captured in a drawing by Gosse (1840) showing the ‘celery stalk’ growth form common in very old hardwood trees (Figure 3).

FIGURE 2 BARK BALDING ON A BLACK GUM TREE

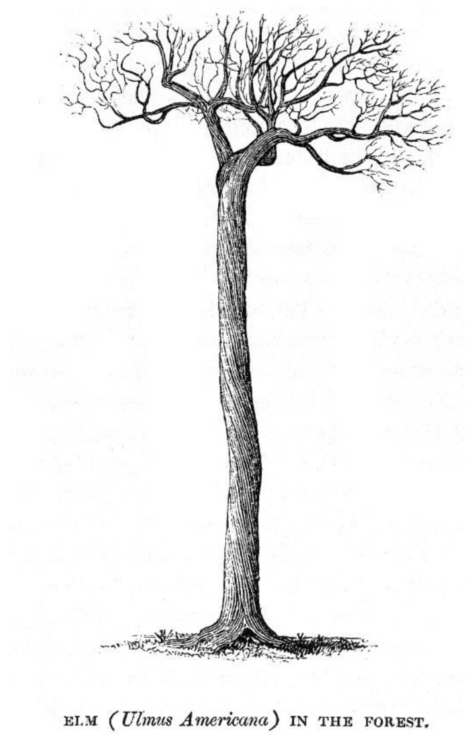

FIGURE 3 CELERY STALK GROWTH FORM OF AN OLD HARDWOOD TREE

Some of the same old age characteristics are shared by old conifer trees, especially low trunk taper and large, twisting upper limbs. Henry et al. (2018) found that very old eastern hemlock trees often had pronounced bark ridging in the upper 25% of the trunk, large twisty upper branches, trunk sinuosity, and low trunk taper (Fig. 4-8). DBH should not be used to select trees for coring unless other age-related characteristics are absent. The oldest trees are often very average size for the species (Pederson, 2010), and according to Piovesan & Biondi (2021) the oldest trees are never the largest ones across a wide range of species.

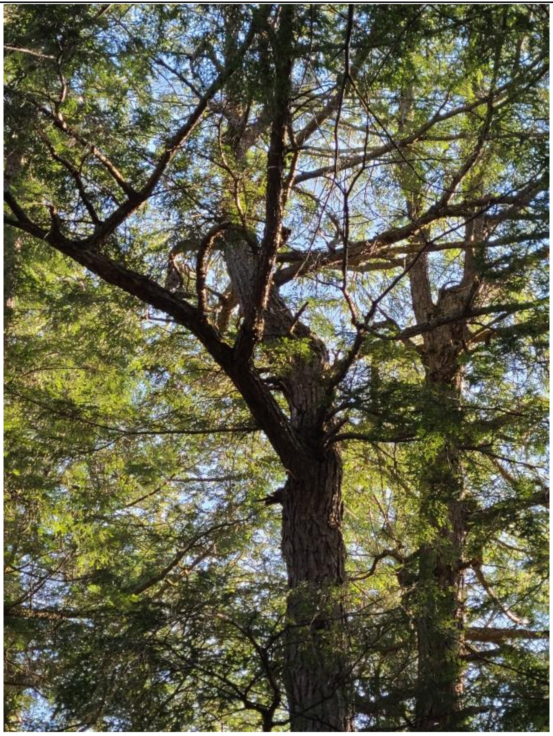

FIGURE 4 LOW TRUNK TAPER, THICK BRANCHING, BARK RIDGING, AND SINUOSITY IN THE CROWNS OF OLD HEMLOCK TREES

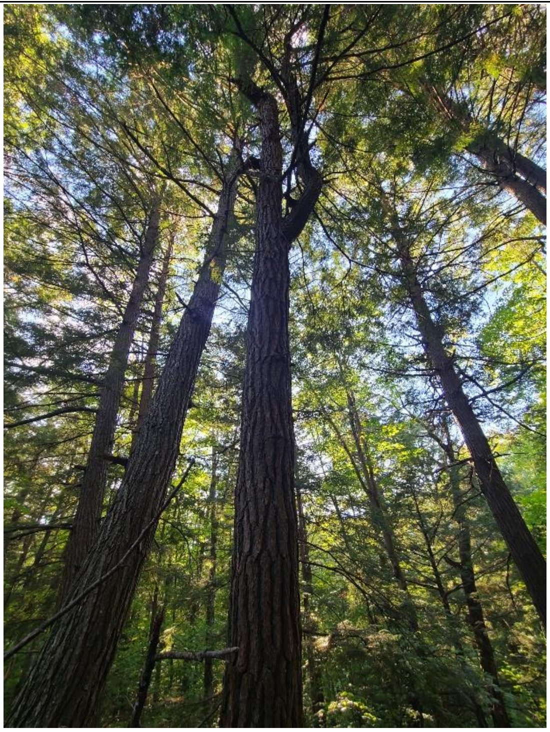

FIGURE 5 THICK BRANCHING AND HIGH BARK RIDGING ON A 425-YEAR-OLD HEMLOCK

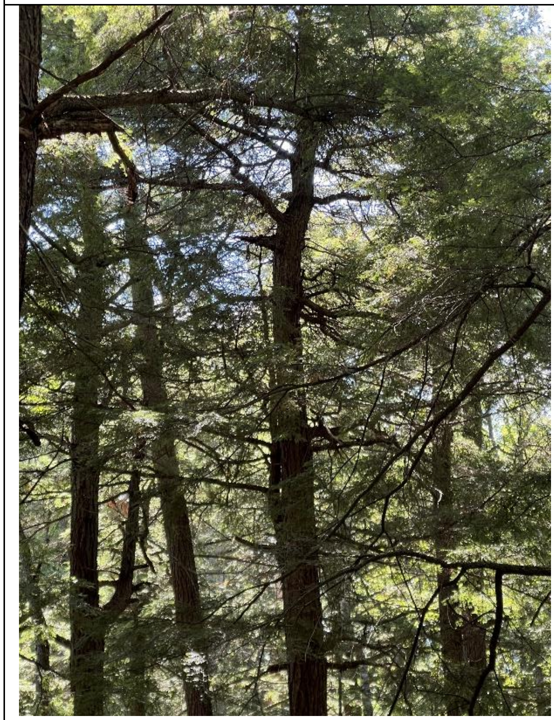

FIGURE 6 LOW TAPER, SINUOSITY ON A 427-YEAR-OLD HEMLOCK

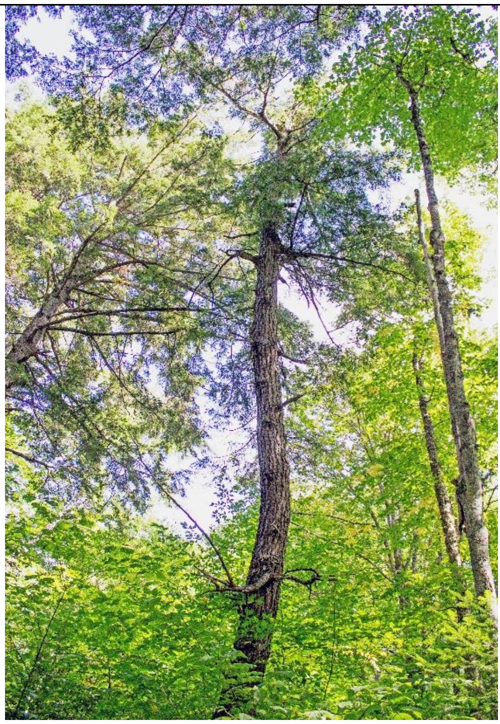

FIGURE 7 TRUNK SINUOSITY ON A 349-YEAR-OLD HEMLOCK

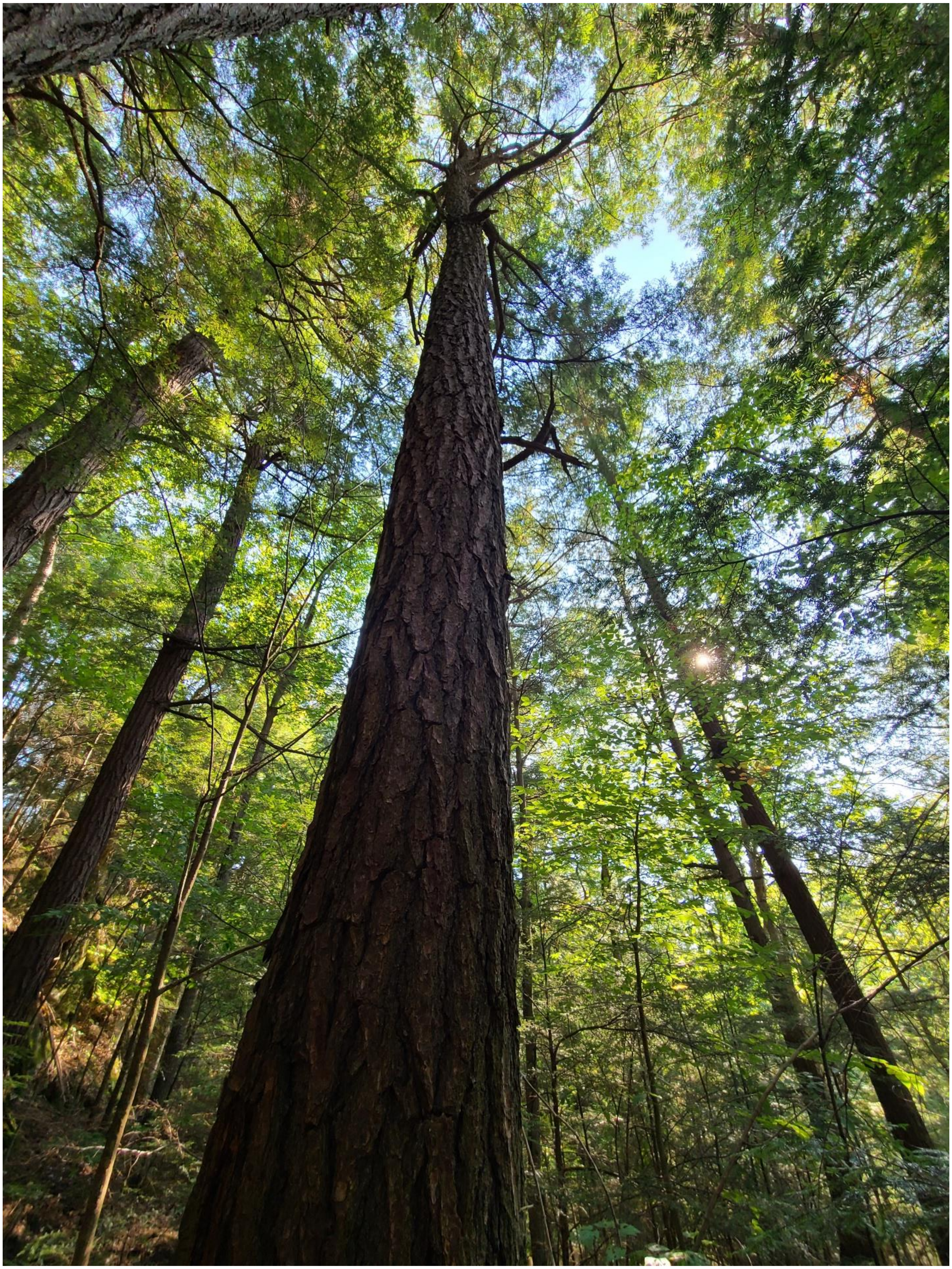

FIGURE 8 LOW TRUNK TAPER AND HIGH BARK RIDGING ON A 413-YEAR-OLD HEMLOCK

TREE CORING PROTOCOL

Extracting increment cores from trees can and should be a non-destructive sampling technique. The likelihood of harm to the tree is generally very low however the extent to which it may occur depends on the species sampled, the timing of sampling, and to a lesser extent the procedures that are followed (Dujesiefken & Rhaesa 1999, Grissino-Mayer 2003, Tsen et al. 2016).

The most important factor in limiting damage due to tree coring appears to be selection of tree species for sampling. Extracting cores from conifers usually has little or no detrimental effect on the tree, whereas hardwood trees may be more susceptible to damage and colonization by fungi, with significant interspecific variation in susceptibility to damage (Dujesiefken & Rhaesa 1999, Grissino-Mayer 2003, Van Mantgem & Stephenson 2004, Tsen et al. 2016). Grissino-Mayer (2003, table 4) summarizes known effects of coring on some North American hardwood tree species. As a generalization, oaks, ashes, hickory, cherry and red maple have shown less evidence of damage while beech, sugar maple and birches appear to be more susceptible to damage. However, this is based on a limited number of studies. It also should be noted that the long-term effect of any damage on tree mortality is unknown.

The timing of coring impacts the ability of the tree to effectively compartmentalize the wound and resist colonization by fungi. Hardwood trees are most susceptible when cored during dormancy, and the preferred season for coring is spring or summer (Dujesiefken & Rhaesa 1999, Tsen et al. 2016). Conversely, conifers are more susceptible to decay when cored in spring and summer, and preferred seasons are autumn or winter (Tsen et al., 2016).

There is little evidence that any treatment of core holes improves outcomes. Grissino-Mayer (2003) concludes that "the overwhelming majority of studies clearly indicate that plugging holes in conifers and hardwoods has little benefit, and may actually cause more harm than good." In a study of the effect of different treatments of boreholes, Dujesiefken et al. (1999) found only small differences between treated boreholes and untreated controls. Tsen et al. (2015) found that, while studies show little or no significant benefit to plugging core holes, antimicrobial preparations may reduce decay at least in the short term (but do not influence fungal diversity in wounds).

The benefits of regularly disinfecting corers does not appear to have been widely studied, but has likely benefits and few if any drawbacks other than the difficulty of effective sterilization in the field. Direct application of alcohol to the tree wound should be avoided as alcohol may dessicate and damage the cambial tissue of trees (Tsen et al., 2016). Our tree coring protocols are as follows:

1. Use visual characteristics to select old trees, and core a minimal number of trees per site.
2. When appropriate, select conifers for coring (e.g. to determine stand ages).
3. Extract cores from conifers in autumn or winter when possible.
4. Extract cores from hardwoods in spring or summer when possible.
5. Avoid trees with evidence of heart rot.
6. Be aware of invasive pathogens that may be present in a stand (e.g. oak wilt, beech bark disease), and plan sampling accordingly. This may require adjusting season of sampling or avoiding a species altogether.
7. Use a spray bottle containing 70% isopropyl alcohol to disinfect the corer between tree cores; wipe off any dirt and excess alcohol and allow to dry before coring the next tree.
8. Thoroughly clean interior (with a gun-cleaning kit) and exterior of tree corer at the end of each work day, including sterilization with 70% isopropyl alcohol.

Other rapid survey protocols

The New York Natural Heritage Program has an Old-Growth Rapid Evaluation (OGRE) protocol that includes use of a basal area prism and a grid pattern (New York Natural Heritage Program, n.d.). We've added a quantitative Coarse woody debris assessment but otherwise use similar protocols. Ancient Forest Exploration & Research use line intercept for coarse woody debris sampling, but use a circular fixed area plot instead of a variable radius prism plot (AFER, n.d.) The use of a fixed area plot has advantages, particularly in capturing smaller trees that are missed by the prism, but fixed area plots risks missing large diameter trees outside the plot boundaries that would be picked up in a variable radius plot. There are advantages to both but the prism sweep is a faster way to collect data and may perform better in old-growth forests, therefore we prefer it for rapid surveys. The Mersey Tobeatic Research Institute had an app-based survey protocol that used prism sweeps and line intersect for logs, however it appears it is no longer available.

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Name / date: Transect #

Site Name: Transect start plot: (Lat: Long:)

Transect end plot: (Lat: Long:)

Stump survey

# of stumps seen from transect path Class 1-3 ______Class 4-5 ________Notes:

Conifer / hardwood

FOREST CHARACTERISTICS

- ☐ Presence of beech or hemlock
- ☐ Presence of large trees, >50 cm diameter (common / uncommon / rare)
- ☐ Presence of apparently old trees, 140+ years (common / uncommon / rare)
- ☐ Logs >30 cm (common / uncommon / rare)
- ☐ snags >30 cm (common / uncommon / rare)
- ☐ Pit and mound topography (common / uncommon / rare)
- ☐ Cut stumps – pine >80 years, decay class 4-5 (common / uncommon / rare)
- ☐ Cut Stumps – hardwood / other conifer - decay class 1-3 (common / uncommon / rare)
- ☐ Cut stumps – hardwood / other conifer - decay class 4-5 (common / uncommon / rare)
- ☐ Other major human disturbance (describe)
- ☐ Invasive tree species
- ☐ Invasive understory species
- ☐ EAB (dead / dying ash)
- ☐ BBD - circle all that apply (beech trees: Dead / Dying / Scale / Fungus / Resistant trees)
- ☐ Trees checked for HWA #:
- ☐ Diversity of tree size classes. Describe:
- ☐ Heavy browse of tree regeneration. Describe, tree species etc:

Regeneration of common tree species

Tree species	Excellent	Good	Poor	V. poor	Tree species	Excellent	Good	Poor	V. poor

Description/ other notes (e.g. understory composition, disease/insect damage, signs of wildlife, wetlands, non-forested habitats, relationship to surrounding areas, general impressions):

[Rare: one or two occur Uncommon: up to 10%, or 3-5 in sight Common: >10% or > 5 in sight]

Survey Equipment: DBH tape / Wedge prism / 30 m tape (for logs)/ Small caliper or ruler / Increment borer / Straws / Tape / Alcohol spray bottle / Camera / Clipboard and data sheets / Notebook / Pencil / GPS / Compass (for transects and emergency) / Clinometer or Rangefinder (if measuring height) /

Name / Date: Site name:

Tree # [Core ID: Counted age: Adjusted age:]

Species		Lat	(decimal degrees)
DBH		Long	(decimal degrees)
Photos		Height	(if practical)
(Plot #)		1st branch	(height from ground, if practical)
(Tree #)		Notes on core	

Tree Characteristics (circle all underlined characteristics that apply).

- ☐ Sinuous trunk
  # Deflections:
  Slight / Moderate / extreme
- ☐ Leaning
  Slight / Moderate / extreme
- ☐ low taper on trunk
  low / very low / fat column
- ☐ Spiral grain
  Slight / Moderate / extreme
- ☐ Deep ridges, flaky bark
  Slight / Moderate / extreme
  Notes:
- ☐ Bark balding
  Slight / Moderate / extreme
  Height on tree:
- ☐ Unusual bark colour / texture
  Describe:
- ☐ Ridges run very high on trunk
- ☐ Branches few / large / twisting
  Notes:
- ☐ Flat top (~no active leader)

Forest Characteristics (within 20 m of tree, if outside plot)

- ☐ Large trees (>50 cm DBH)
- ☐ Invasive tree species
- ☐ Logs / snags >30 cm
- ☐ Old trees
- ☐ Pit and mound topography
- ☐ Cut stumps

Notes:

Tree # [Core ID: Counted age: Adjusted age:]

Species		Lat	(decimal degrees)
DBH		Long	(decimal degrees)
Photos		Height	(if practical)
(Plot #)		1st branch	(height from ground)
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- ☐ Deep ridges, flaky bark
  Slight / Moderate / extreme
  Notes:
- ☐ Bark balding
  Slight / Moderate / extreme
  Height on tree:
- ☐ Unusual bark colour / texture
  Describe:
- ☐ Ridges run very high on trunk
- ☐ Branches few / large / twisting
  Notes:
- ☐ Flat top (~no active leader)

Forest Characteristics (within 20 m of tree, if outside plot)

- ☐ Large trees (>50 cm DBH)
- ☐ Invasive tree species
- ☐ Logs / snags >30 cm
- ☐ Old trees
- ☐ Pit and mound topography
- ☐ Cut stumps

Notes:

Name / date: Plot #

Site Name: Plot location Lat: Long:

SPECIES	DBH >10	SNAG? DECAY / NOTES	SPECIES	DBH >10	SNAG? DECAY / NOTES
1.			16.		
2.			17.		
3.			18.		
4.			19.		
5.			20.		
6.			21.		
7.			22.		
8.			23.		
9.			24.		
10.			25.		
11.			26.		
12.			27.		
13.			28.		
14.			29.		
15.			30.		

Notes on Regeneration / Age Classes:

Name / date: Plot #

Site Name: Plot location Lat: Long:

SPECIES	DBH >10	SNAG? DECAY / NOTES	SPECIES	DBH >10	SNAG? DECAY / NOTES
1.			16.		
2.			17.		
3.			18.		
4.			19.		
5.			20.		
6.			21.		
7.			22.		
8.			23.		
9.			24.		
10.			25.		
11.			26.		
12.			27.		
13.			28.		
14.			29.		
15.			30.		

Notes on Regeneration / Age Classes:

Coarse Woody Debris Transect Algonquin Old-Growth Forest Survey

Name / date: Site Name:

Plot #

Conifer/Hardwood	D_{cross}	D_{large}	Decay
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			

Plot #

Conifer/Hardwood	D_{cross}	D_{large}	Decay
1.			
2.			
3.			
4.			
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6.			
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12.			
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14.			
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Plot #

Conifer/Hardwood	D_{cross}	D_{large}	Decay
1.			
2.			
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Plot #

Conifer/Hardwood	D_{cross}	D_{large}	Decay
1.			
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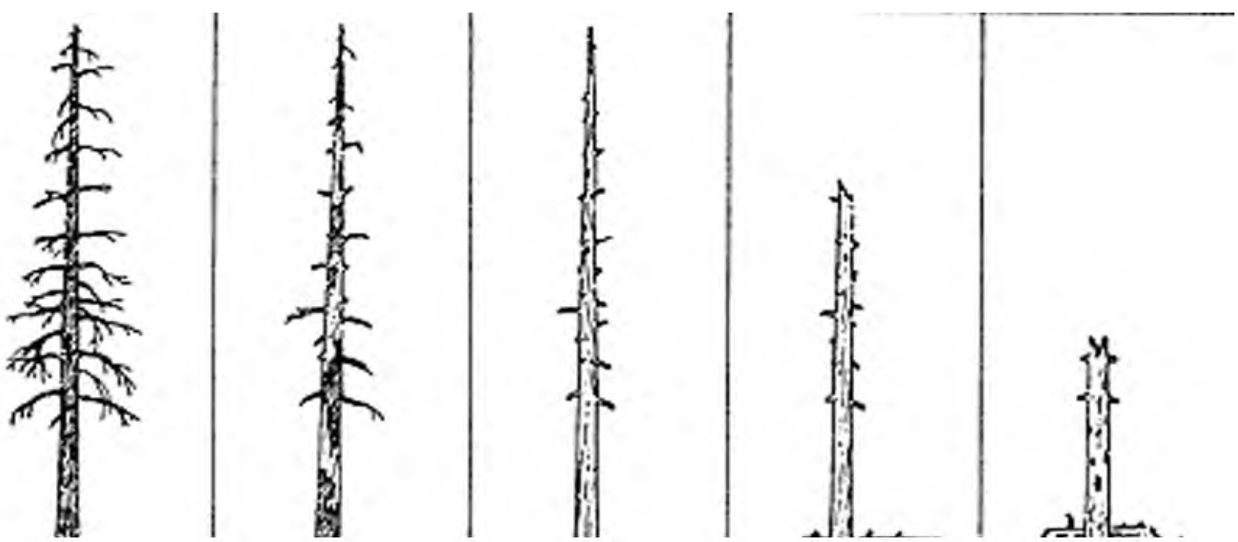
Decay Classes

Log decomposition

	Class 1	Class 2	Class 3	Class 4	Class 5
Texture	intact, hard	intact, hard to partly soft	hard, lage pieces	small, soft, blocky pieces	soft and powdery
Portion on ground	elevated on support	elevated, but sagging slightly	sagging, near ground or broken	all of log on ground, sinking	log on ground, partly sunken
Branch system	current yeartwigs present	larger twigs present, branch system entire	large branches present, longer than log diameter	branch stubs present, shorter than log diameter	absent
Bark	intact	intact or partially missing	trace	absent	absent
Shape	round	round	round	round to oval	oval

Snag decay classes



Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Recently dead	Loose bark, fine branching absent	Bark and branches mostly absent	Broken top, wood softening, little or no branching	Wood decayed, soft, blocky.or punky, broken top

HOW TO PHOTOGRAPH OLD TREES FOR IDENTIFICATION

Photos should show the bark, also the trunk and branch shape from below and a distance. Provide these **four photos**:

- Bark, showing lower ~3m of trunk
- Bark on the other side of tree
- Trunk from below. Stand back 2-3 m from the base of the tree and photograph straight up trunk from below (include major branching).
- Growth form of the tree. Walk upslope, or in the direction where the forest understory is most open, until you can capture the growth form of the entire tree in a photo. Two photos at 90 degrees if possible

OLD TREE FEATURES EXPLAINED

<u>Bark</u>: The bark of hardwoods of many species follows a fairly consistent pattern with age. Young trees are fairly smooth-barked, developing ridges or plates as they age. Usually sometime after middle age the ridges, plates etc. actually start to fall away, and the bark begins to smooth out again. This is called balding, it has a fairly distinctive appearance and tends to indicate old age (>250 years). On the other hand many conifers have increasingly ridged bark throughout their lives, and extreme ridging is an indicator of old age. Sometimes conifer bark takes on a red hue with age. On the older conifers the bark ridging remains pronounced very high on the trunk.

<u>Trunk</u>: One of the best ways to recognize old trees, both hardwood and conifer, is to look at the amount of taper in the trunk. Middle aged trees may be quite large near ground level but taper to a much narrower growing tip. The reason is fairly self-evident: the base of the bole has been growing for entire life of the tree, whereas it might take 80-100 years for the tree to achieve most of its height growth. Therefore on a 100 year-old tree the trunk has had very little time to gain diameter near the top. On a 300 year-old tree, however, there is much less difference between the top of the tree and the base. In fact the upper trunk gains diameter a little faster than the lower trunk, so old trees can have little or no taper in the trunk. Trunks of old trees are also often sinuous, with strange twists and curves, and may have spiral grain.

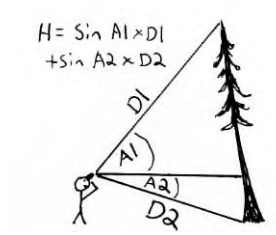
<u>Branching</u>: Much like the upper trunk, the branches of old trees may have been growing for centuries, and can be very large. In that time they may have endured ice storms, wind storms and other catastrophes that have broken tips and reshaped them in mysterious ways. In general, dendrochronologist Neil Pederson describes the result as “crowns comprised of few, thick, twisting limbs.”

Beech and hemlock are notable because they are very shade tolerant, and tend to decline with human disturbance.

<u>NOTES</u>:
DBH = Diameter at Breast Height (1.4 m) = Circumference/3.14.

If possible record height using a clinometer and measuring tape, or preferably an accurate laser rangefinder. Also record height to first branch (straight shot up with rangefinder, remember to add height to eye level).

Tree Height = Sin(Angle1)*Distance1 + Sin(Angle 2)*Distance2



RESOURCES

http://www.oldgrowth.ca/2019/10/17/recognizing-old-trees/

http://www.ldeo.columbia.edu/~adk/pubs/CharacteristicsOldTreesNAJ_2010pederson.pdf

https://www.researchgate.net/publication/233678309_An_Improved_Tree_Height_Measurement_Technique_Tested_on_Mature_Southern_Pines

Class 2 hardwood. Solid wood, bark loose

Class 3 hardwood. Largely intact but wood soft

Class 4 conifer. Decayed but ~intact

Class 5 conifer

Class 5 hardwood

Class 5 stump and yellow birch

Class 5 historic pine stump