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Definitions and Types of Old-growth Forests with Ontario Examples

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"In the short-term, individual groups and societies might profit from forest destruction. However, ***with old-growth forest vanishing at an unprecedented pace, mankind as a whole loses the ecosystem services provided by these forests****… [including their] spiritual and/or aesthetic nature, genetic resources, non-timber products, habitat for wildlife, the sequestration of carbon, the prevention of floods and erosion, to name only a few... Data on old-growth forests are generally scarce… NGOs involved in the protection of old growth or primary forests need fast and efficient survey methods and, given the land-use pressure on the remaining areas, they cannot afford to waste time."*

(*Old-Growth Forests*, Wirth et al. 2009)

Introduction

A currently held tenant of mainstream North American forestry is that logging should take place prior to a stand reaching the age of old-growth onset, and that not doing this is a waste of the forest resource. For example, the age of onset for eastern hemlock is roughly 140 yrs. (OMNR 2003), representing only the first 18% of its potential lifespan of more than 800 yrs. (USFS 2020). This management approach is used to keep a forest site continuously stocked with trees during the stages of most rapid growth, thus maximizing above-ground commercial wood production on that site. However, this ignores the ecological (particularly biodiversity and carbon storage), recreational, spiritual, educational, scientific, cultural and other non-consumptive values of old-growth forests (OGF), which are lost or significantly impaired under most past and present logging practices. As a result, the vast majority of these unique and valuable ecosystems have declined severely throughout the world including in Ontario's Temperate Forest Region (NCC & TD 2017).

OGFs have also been called over-mature stands, decadent stands, ancient forests, climax forests, first forests, older growth, old forests, primeval forests, pristine forests, and virgin forests. Since the first published scientific study of old-growth or virgin (historical term) forests in 1936 by Morey, the science of old-growth forest ecology has grown substantially. The number of publications in this field increased, "from 9 per decade between 1940 and 1960, to 46 per decade between 1970 and 1980, followed by a sudden jump to 2,089 per decade between 1995 and 2005" (Wirth et al. 2009). This trend indicates the increasing importance of OGFs to societies worldwide.

The OGF condition is not an end point, but a continuum defined by slow ecological change initiated when forest tree growth begins to slow down (e.g., between 120 and 150 yrs. for eastern white pine (OMNR 2003)). This change in growth happens when a tree starts to allocate more energy to maintaining its increasingly large size as opposed to using that energy to produce new growth. This point in time is known as the "age of onset". Thus, as a tree ages, energy allocation to maintenance increases and allocation to producing new growth decreases. Most tree species in Ontario's Temperate Forest Region spend a greater proportion of their life after the OGF age of onset when they are able to maximize their lifespan.

Old trees beyond the age of onset are the most important feature of an OGF. Snags (dead standing trees), logs, and integrity (no or little human disturbance) are also important primary characteristics. Some secondary and more variable features of OGFs are shown in Table 1. Ancient forests have all or many of the same features as OGFs except that there is no minimum tree age and they usually cover larger areas - they have also been called pristine and virgin forests.

Table 1. Features Associated with Old-growth Forests in Ontario
(bold = primary features; from Ontario Nature undated)

- **old trees**
- **dead wood - logs and snags**
- **integrity (absence of or a low level of human disturbance)**
- high tree density
- multiple vegetation layers: understory, shrubs/saplings, canopy, super-canopy
- high diversity in the herbaceous layer
- lichen and fungus abundance and diversity
- openings in the forest canopy
- undisturbed soil layers

Most OGF characteristics continue to develop for centuries in the absence of catastrophic and/or human disturbance. However, trees do eventually die from old age, pathogens, severe wind storms, and fires. As long as some of the older trees remain after a natural disturbance to produce seeds, other younger trees will colonize where older trees died. Some OGFs support rare, threatened and endangered plants, animals and other biodiversity (fungi, lichens, etc.). In most parts of the world, including Ontario's temperate forests, OGFs are very rare, yet in Ontario as in most of the world, there is no legislative mandate to protect them. Central to designing rigorous, efficient, and effective survey methods for OGF ecosystems is an understanding of their characteristics and the variations of these characteristics, which is the focus of this report.

Definitions of Old-growth Forest

Latitude

In the impressive tome titled, *Old-growth Forests: Function, Fate and Value* (2009), Wirth et al. state that it is very difficult to define “a complex dynamic system that is a result of gradual transitions involving several processes”, and that these systems and processes vary substantially from northern to southern biomes. They emphasize that, since most of the work done on OGFs has been focused on temperate forests, our concepts and empirical descriptions reflect the nature of these mid-latitude forests. Less work has been done on defining OGFs in the Boreal Forest Region where biomass reduction by fire is common and in the tropics where deadwood (snags and logs) does not accumulate due to rapid decomposition. Thus, we know much less about OGFs at the latitudinal extremes. Most OGF definitions also include multiple criteria and can be grouped into one of three categories including structural definitions, successional definitions and biogeochemical definitions (Wirth et al. 2009).

Structural Definitions

Age distributions, size distributions and spatial patterns of both live and dead trees are the focus of structural definitions of OGFs. The main limitation of this approach is accurately estimating tree ages even when using an increment borer. Although rare, due to growth suppression, a tree could be 100 yrs. old when it reaches 4.5 ft in height (breast height), which is the location where tree cores are often obtained. In such a case, decades of growth would be missed by the increment borer. However, it is very time-consuming and difficult to identify and address this problem. Also, some tree species can develop adventitious roots (above the root collar) that are triggered when a sapling is bent over by a fallen object, potentially resulting in under-estimation of tree age.

Successional Definitions

Oliver & Larson (1996) state that successional definitions of OGF “describe stands composed entirely of trees which have developed in the absence of allogenic processes [external disturbances]”. The old-growth phase begins when the first cohort of pioneer species has disappeared and the forest stand becomes dominated by mid- to late-successional tree species. There are no tree age or deadwood criteria and some successional definitions include ecological processes that maintain the OGF condition such as absence of stand-replacing events, maintenance of small-scale gap creation, and nurse log regeneration.

Biogeochemical Definitions

The most difficult to apply and therefore, the least studied and/or reported are the biogeochemical definitions of OGF. Criteria for this definition include closed nutrient cycles, zero net accumulation of biomass, reduced tree net primary production, and increased understory vegetation. The primary limitation of this approach is the high cost of labour and instrumentation, and the large effort required to quantify these ecosystem metrics.

Integrity

Most definitions include a human disturbance or integrity component ranging from complete absence to significant historical logging. This criterion typically allows for more historical logging in regions with high human densities and low forest cover compared to regions with low human densities and high forest cover. Integrity is also often associated with OGF size and generally increases with the size of an individual OGF. The minimum size of protected OGFs in both Canada and the eastern U.S.A. is 2 ha (Larson et al. 1999, Quinby 2018), which is much too small to maintain natural ecological and evolutionary processes within a human-dominated landscape.

Old Forest

These are forests that meet the minimum OGF tree-age criteria (e.g., Quinby 2020) but do not meet the dead-wood criteria, and they may or may not meet the integrity criterion. The absence of dead wood in old forests may be due to a variety of factors. For example, an old forest may be recovering from a catastrophic natural or human disturbance and dead wood (snags and logs) has not yet accumulated to a significant level. Or an old forest could have been an OGF at one time but has been cleared of most or all dead wood by humans.

Ontario's Temperate Old-growth Forests

In temperate OGFs of Ontario, tree mortality is caused by wind, insects, disease, surface fire, etc., forming gaps that remain in the canopy for a while. This mortality results in the production of logs and snags (dead standing trees), which generally increases over time, often for centuries. And eventually, because of those gaps that free-up light and other resources, the OGF will enter a steady state where trees are continuously germinating, establishing, increasing in size, reproducing and dying, becoming at least a partially uneven-aged forest. However, some northern forest types such as those dominated by red and jack pine may be reset by fire before they enter a true steady state. But no matter what kind of disturbance regime an OGF is subject to, at minimum, all OGFs are characterized by old trees, snags, logs and minimal human disturbance.

Ontario Nature (undated) describe OGFs in Ontario as diverse ecosystems, with young and old trees, decay and new growth, canopy gaps, uprooted trees, large logs, pits and mounds, snags, and a diversity of plant and animal species with minimal to no human disturbance (Table 1). The first three characteristics, old trees, dead wood (snags and logs), and integrity, are essential to the basic character of old growth and they are reasonable to assess in the field. The remaining seven features (Table 1) are much more variable and difficult to assess and describe. Most of these old-growth characteristics continue to develop for centuries in the absence of catastrophic disturbance.

Multi-component definitions of OGFs in Ontario that include the basic criteria of old trees, logs, snags and cut stumps (integrity) are very rare and do not include those developed by OMNR (2003). Of these basic criteria, the current Ontario definitions provide only the age of onset (minimum old-growth tree age) for a variety of forest types and tree species; they do not include criteria for old tree tree density, snags, logs and integrity. In addition, the stand duration assigned to each OGF type (e.g., most are only a few hundred yrs.) by the current definitions conflicts with scientific understanding of temperate OGF development that is known to last for up to several centuries (Bormann and Likens 1979, Frelich and Lorimer 1991, Ziegler 2002, Luyssaert et al. 2008).

The only OGF definitions we know of for Ontario that include both live tree (density and age) and deadwood criteria (snags and logs) were developed in the early 1990s (Quinby 1993) for red and eastern white pine forests in central Ontario (Table 2) and are based on structural characteristics. The criteria for these definitions include live tree density and age, associate species, canopy type, snags (density and size), logs (density and size), and integrity. Minimum values for these criteria were determined for five old-growth forest community types including white pine-deciduous, white pine-mixed, white pine-conifer, white pine-red pine, and red pine-conifer.

Six years later in 1999, Larson et al. published a technical report describing ecological features of 35 "significant woodlands" in southern Ontario (south of the Canadian Shield), which represented some of the finest examples of OGFs in the region. These are the only field data we are aware of that are based on assessment of the primary features of OGFs in this region and eight of the structural metrics they sampled can be used to develop region-specific minimum standards for OGFs (Table 3).

The eight metrics included forest size, three live tree variables (size, density, biomass), three log variables (density, size, volume), and integrity (stump density) (Table 3). Larson et al. (1999) did not sample for density of OGF trees, tree age, or snag variables of any kind. All of the values of these OGF metrics are not discussed here, however, a few of the potential minimum standards are worth highlighting including forest size, log density and size, and integrity (stump density).

Table 2. Minimum Standards for Pristine[1] Old-Growth Red and Eastern White Pine Forests in the Temagami Region of Ontario (from Quinby 1993)

	White Pine-Deciduous	White Pine-Mixed	White Pine-Conifer	White Pine-Red Pine	Red Pine-Conifer
Old Live Trees Density	>10 trees/ha >140 years old	>10 trees/ha >140 years old	>10 trees/ha >140 years old	>15 trees/ha >140 years old	>9 trees/ha >140 years old
Associates >1 m2/ha basal area)	sugar maple, red maple, yellow birch, white cedar	white birch, red pine, white cedar, balsam fir, red maple	red pine, white cedar, black spruce, white birch	white birch, balsam fir, white cedar, white spruce	white pine, black spruce, white cedar, white birch
Canopy	white pine emergent above deciduous	multilayered canopy	multilayered canopy	multilayered canopy	mainly a single layered canopy
Snags	all species >70/ha, >10 cm DBH and 2 m tall	all species >30/ha, >10 cm DBH and 2 m tall	all species >60/ha, >10 cm DBH and 2 m tall	all species >50/ha, >10 cm DBH and 2 m tall	all species >30/ha, >10 cm DBH and 2 m tall
Logs	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long

NOTE: 1 - pristine = 0 stumps

Table 3. Key Characteristics of 35 Old-growth Forest Sites in Southern Ontario (from Larson et al. 1999)

	Mean	Minimum	Maximum	Potential Standard
Forest Size (ha)	22.1	1.6	162.4	at least 2
Mean Tree dbh (>10 cm dbh)	34.3	26.6	43.3	at least 27
Trees 50+ cm dbh (% in 314 m^2)	19.3	2.1	39.6	at least 2
OGF Trees (no./ha)[a]	not sampled	not sampled	not sampled	n/a
Tree Age (yrs)	not sampled	not sampled	not sampled	n/a
Tree Basal Area (m^2/ha)	36.0	20.9	65.2	at least 21
Snag Density (no./ha; >10 cm dbh)	not sampled	not sampled	not sampled	n/a
Mean Log Density (no./ha; >10 cm diameter)	38.4	3.2	92.8	at least 3 (min L=10 m)
Mean Log Size (cm diameter)	31.7	19.5	51.5	at least 20
Mean Log Volume (m^3/ha)[b]	30	12	320	at least 12
Mean Stump Density (no./ha; >10 cm diameter)	19	0	64	less than 65

NOTES: a - an OGF tree has an age at least equal to the "age of onset" of the old-growth condition for the tree species; **b** - calculated as follows: [(3.14) (log radius in meters)^2 (mean log length (0.5 of maximum in the 20 m diameter plot) = 10 m) (mean log density = 38.4/ha)]

Although the mean size of these 35 OGFs was 22 ha, the smallest was slightly less than 2 ha. To those who are familiar with OGFs in central and northern Ontario, this mean and minimum seem very low. Even the largest of these forests at 162 ha is too small to function as a natural landscape, particularly in the context of multiple human disturbances that typify southern Ontario. These extremely small sizes of the best examples indicate just how rare OGFs are in this portion of Ontario. The potential minimum standard for log density and size of at least 3 logs of at least 20 cm diameter and 10 m long per ha also seems very low. The values for these log metrics are roughly one third of the values for these same metrics for pine OGFs in Temagami (Table 2). Finally, a maximum of 64 stumps/ha for OGFs in southern Ontario is very substantial and is also indicative of the very disturbed nature of this region.

Old-growth Forest Types

Influence of Site Productivity

Kershner (2004) described three types of old-growth forest that vary according to site conditions including big-tree old growth, medium-stature old growth, and dwarf old growth. Site conditions such as the availability of moisture, nutrients and light determine how quickly trees grow and they constrain the amount of biomass that a site can support. Landscape fragmentation also affects site productivity through its impacts on the distribution, structure and function of natural communities.

Big-Tree Old Growth

These are ancient forests of impressive, large-diameter trees that are typically found on the more productive sites. They fit the classic image that people have of ancient forests, the most famous of these in Ontario's Temperate Forest Region are the stands of towering white pines, such as the Lake Obabika White Pine OGF in Temagami, Ontario.

Medium-Stature Old Growth

These forests have unimpressive, average-size trunks whose non-descript appearance gives little hint of their ancient quality. They are hardest to recognize and are least appreciated. Because their age is rarely recognizable by visual clues, labor-intensive tree coring and intensive research is required to identify them. They are found on sites of medium productivity such as swamps, upper mountain slopes, alvars, sand barrens and savannahs. A good example is the upper dunes of Marcy's Woods, near Crystal Beach, Ontario.

Dwarf Old Growth

These ancient forests are comprised of small trees that are typically bonsai-like, twisted, and bizarre in growth form typically growing on lower productivity sites. They include the most ancient of all forests and grow in the most severe habitats such as cliffs, talus, mountain tops, sand dunes and barrens, and bogs. Cedars, hemlocks, birches, black gum, sassafras, holly, pitch pines, and certain oak species comprise most of them. The ancient cedar forests along the Niagara Escarpment in Ontario are good examples.

Influence of Human Activity

Old-growth Forest Fragments

OGF remnants result from landscape fragmentation, which is most severe in urban and suburban regions. For example, OGF fragments in highly-developed southern Ontario make up less than .1% of the landscape (NCC & TD 2017). Landscape fragmentation results in severe impacts to ecosystem integrity including facilitating non-native species invasions, and altering species richness and abundances, forest dynamics, trophic structure of communities, and evolutionary processes. In addition, forest fragmentation increases the negative effects of human activities such as hunting, fires, and logging (Laurance et al. 2002). A good example is the Jackson Creek OGF located in the City of Peterborough, Ontario, which is only 4.5 ha in size but provides huge recreational, educational, scientific and health benefits to a large urban population (Henry et al. 2016).

Secondary Old-growth Forests

These are not the original forests of a given region and consequently, their composition is significantly different from the forests they replaced. However, at minimum, secondary OGFs have some or all of the primary characteristics of an original OGF since they have been largely free of disturbance for 150 or more years (Kershner 2004). A good example of a significant secondary OGF is Connecticut's (USA) Cathedral Pines that is considered by many as the finest OGF in New England.

Stages of Forest Development

Prior to the age of onset for any forest type, three stages of forest development typically occur following a major disturbance (natural or human-caused). Figure 1 shows these three stages including: (1) stand initiation stage representing tree establishment, (2) stem exclusion stage representing young forest, and (3) canopy transition stage representing mature forest. The final stage of forest development is the OGF phase (Figure 1).

It is important to note that the "time since disturbance" horizontal axis in Figure 1 is not properly scaled to represent the time period for each development stage. For example, both Spies (2004) and Wirth et al. (2009) have described OGF types that develop over centuries to millennia following the age of onset (initiation of the OGF phase). Thus, the OGF phase can last for an order of magnitude longer than any of the first three stages.

Wirth et al. (2009) analyzed 118 studies that reported on OGF ages, which ranged from 50 years (mangrove forest) to 1,150 years (montane fir-hemlock forest) with a median age of approximately 300 years for all forests combined and for temperate forests separately. The median age for boreal OGFs was 224 years and the median age for tropical OGFs was 400 years. Based on these results, we propose five categories of forest development with associated ages as shown on Table 4. Each phase of OGF development can be assessed for and described during field surveys; category cut-off values will vary by tree species since age of onset may differ significantly among tree species.

Figure 1. Stages of Forest Development (from Bartels 2016)

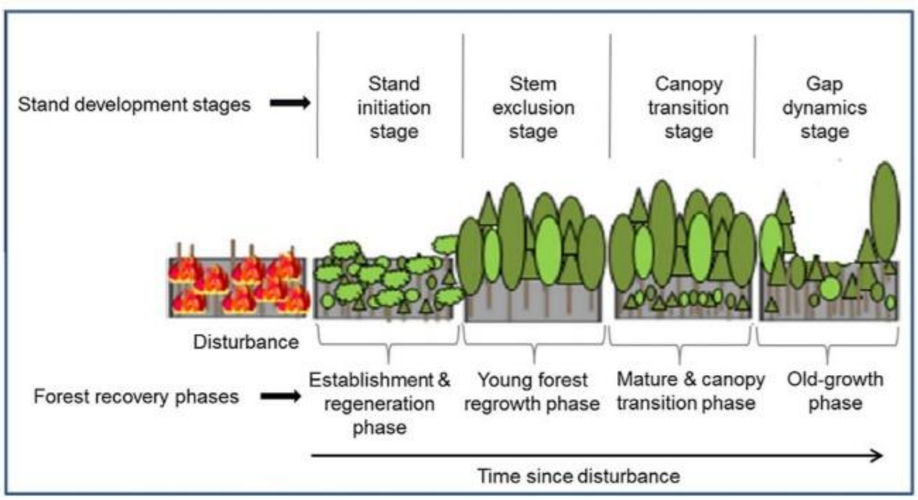

Table 4. Proposed Phases of Forest Development

- Regeneration Phase - 0 years to (age of onset/3)
- Young Forest - (age of onset/3) to ((age of onset/3)*2)
- Mature Forest - ((age of onset/3)*2) to age of onset
- Early Old-growth Forest - (age of onset) to 299 years
- Ancient Old-growth Forest - 300+ years

Using eastern white pine OGF with an age of onset of 120 years as an example, the *regeneration phase* would be from 0 to 39 years, the *young forest* would be from 40 to 79 years, the *mature forest* would be from 80 to 120 years, *early OGF* would be from 120 to 299 years and *ancient OGF* would be 300+ years.

AFER's Mission and Guiding Principles

AFER is a non-profit scientific organization with a mission to carry out research and education that lead to the identification, description and protection of ancient (pristine) forested landscapes, including old-growth forests. The earth-stewardship principles that guide our work include the following.

- Many forest ecosystem types are now endangered. We consider these ecosystems and other ancient forests to be non-renewable resources, which is not consistent with the practice of mining or logging them.
- We consider biodiversity conservation needs at local, provincial, federal and international scales.
- We support the Government of Canada's commitment to increase protected areas to 30% of the Canadian land base.
- We support the *New York Declaration on Forests* to end natural forest loss by 2030.

References

Bartels, S. F. et al. 2016. Trends in post-disturbance recovery rates of Canada's forests following wildfire and harvest. ***Forest Ecology and Management*** 361:194–207.

Bormann, F. H. and G. E. Likens. 1979. ***Pattern and Process in a Forested Ecosystem: Disturbance, Development and the Steady State Based on the Hubbard Brook Ecosystem Study***. Springer, New York, NY.

Frelich, L. E. and C. G. Lorimer. 1991. Natural Disturbance Regimes in Hemlock-Hardwood Forests of the Upper Great Lakes Region. ***Ecological Monographs*** 61:145-164.

Henry, M. et al. 2016. The Jackson Creek Old-growth Forest: Core Area of the Jackson Creek Significant Woodland in Peterborough, Ontario. ***Research Report No. 33***, Ancient Forest Exploration & Research. Powassan, Ontario.

Kershner, B. 2004. Old Growth Forest Survey of Eastern Niagara Peninsula Phase 2, Final Report. A Project of the Bert Miller Nature Club, Final Report to the Trillium Foundation. ***Native Tree Society Special Publication Series Report #13***, Native tree Society (http://www.nativetreesociety.org/); (http://www.ents-bbs.org/viewtopic.php?f=297&t=3806).

Larson et al. 1999. ***The Woodland Heritage of Southern Ontario***. Report prepared for the Federation of Ontario Naturalists (current: Ontario Nature), Don Mills, Ontario.

Laurance, W. F. et al. 2002. Ecosystem Decay of Amazonian Forest Fragments: a 22-Year Investigation. ***Conservation Biology*** 16:605–618.

Luyssaert, S. et al. 2008. Old-growth forests as global carbon sinks. ***Nature*** 455:213–215.

Morey, H. F. 1936. Age-Size Relationships of Hearts Content, A Virgin Forest in Northwestern Pennsylvania. ***Ecology*** 17: 251-257.

Nature Conservancy of Canada (NCC) and TD Bank Group. 2017***. Putting a Value on the Ecosystem Services Provided by Forests in Canada: Case Studies on Natural Capital and Conservation***. Nature Conservancy of Canada, Toronto, Ontario. (http://www.natureconservancy.ca/assets/documents/nat/Natural-Capital_2017_draft.pdf)

Oliver, C. D. and B. C. Larson. 1996. ***Forest Stand Dynamics***. John Wiley, New York, NY.

OMNR (Ontario Ministry of Natural Resources). 2003. ***Old-growth Forest Definitions for Ontario***. Ontario Ministry of Natural Resources, Queen's Printer for Ontario, Toronto, Ontario.

Ontario Nature. Undated. ***Introducing Old Growth, the Ultimate Forest: Southern Ontario Woodlands***. Ontario Nature. Toronto, Ontario.

Quinby, P. 1993. Definitions of Old-Growth Eastern White and Red Pine Forests for the Temagami Region of Ontario. ***Forest Landscape Baselines No. 3***, Ancient Forest Exploration & Research. Powassan, Ontario.

Quinby, P. 2018. Status Update for Endangered Old-growth Eastern White Pine and Red Pine Forests. ***Research Report No. 37***, Ancient Forest Exploration & Research. Powassan, Ontario.

Quinby. P. 2020. Minimum Diameters for Old-growth Trees in Ontario's Northern Temperate Forests. ***Forest Landscape Baselines No. 36***, Ancient Forest Exploration & Research. Powassan, Ontario.

Spies, T. A. 2004. Ecological Concepts and Diversity of Old-Growth Forests. ***Journal of Forestry*** April/May:14-20.

USFS (United States Forest Service). 2020. ***Tsuga canadensis, Index of Species Information, Fire Effects Information System***. (https://www.fs.fed.us/database/feis/plants/tree/tsucan/all.html).

Wirth, C. et al. (eds.). 2009. ***Old-Growth Forests: Function, Fate and Value***. Springer-Verlag, Berlin, Germany.

Ziegler, S. S. 2002. Disturbance regimes of hemlock-dominated old-growth forests in northern New York, U.S.A. ***Canadian Journal of Forest Research*** 32:2106–2115.

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