The History and Tree Stratum of an Old-Growth Forest of Haut-Saint-Laurent Region, Quebec

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ABSTRACT: An old-growth forest of presettlement origin was recently discovered at the northern limit of the Eastern Deciduous Forest (sensu Braun 1950) of North America, in an area that is extensively affected by logging, land clearing, and agriculture. In a study of the disturbance history, forest composition, and dynamics of this old-growth forest, we found that (1) the preservation of the forest can be attributed to the initial settler's lack of interest in exploiting it and to a strong sense of conservation by his descendants; (2) an American elm–black ash (*Ulmus americana* L.–*Fraxinus nigra* Marsh.) community occupies more hydric sites (approximately 15% of the forest) and a sugar maple - American beech (*Acer saccharum* Marsh.–*Fagus grandifolia* Ehrh.) community occurs on mesic sites; (3) larger canopy trees range in age from 150 to 300 years; (4) despite the absence of any major perturbation in the mesic portion of the site, the composition is not in equilibrium and beech is apparently increasing in abundance over the presently dominating maple; (5) the average tree growth has been very slow compared to that of trees in adjacent disturbed forests. Ecological information obtained from old-growth forests can contribute to decision making in management of natural areas.

INTRODUCTION

The Haut-Saint-Laurent region of Quebec lies near the upper limit of the Eastern Deciduous Forest (sensu Braun 1950) region of North America. The extensive clay plain that covers most of the area has been deforested and devoted to agricultural use for more than 150 years. The forested areas, which cover less than 10% of the region, occupy nonarable lands characterized by rocky outcrops, sandy soils, and morainal deposits. A detailed ecological study of the territory was initiated in 1984 by a multidisciplinary research group (Bouchard et al. 1985). Results indicate that these forests are on the average 40 to 80 years old, achieving a maximum age of approximately 120 years. Typically part of farm parcels, these forests have been intensively exploited for lumber, potash making, and firewood, or they were simply cleared for stock grazing and later allowed to regenerate. Not expected was the discovery of an 11-ha beech-maple wood showing relatively few signs of anthropogenic disturbance. A preliminary investigation from a 40-m x 40-m quadrat revealed that some of the trees were over 250 years of age (Brisson et al. 1988a). The scientific value of this forest was immediately recognized, and a more detailed analysis of its tree composition, structure, history, and dynamics was initiated. This paper reports the results of the study.

This forest, hereafter referred to as Muir's Wood (not to be confused with Muir Woods, California), may be the northernmost forest of presettlement origin in the Eastern Deciduous Forest region of North America.

THE STUDY AREA

Muir's Wood is located in the center of the Haut-Saint-Laurent region, some 70 km southwest of Montreal (Figure 1). It constitutes the distal part of a farm lot and is bordered by a road on the south, a cultivated field on the north, and extensively exploited forests on the east and west.

Surficial deposits of the region are inherited from the last glacial and postglacial era. The area is characterized by extensive lowlands covered with Champlain Sea clays deposited between 12,000 and 10,000 years ago. These lowlands are interrupted by moraines, glacial depressions, and zones of marine alteration.

Until the very beginning of the nineteenth century, the area bordering Châteauguay River was in a natural state, its only residents being a few nomadic Native American bands (Sellar 1888). The few early colonists limited their summer activity to their own lots and surveyed the rest of the territory in winter in search of timber for exportation. Especially desirable species were white pine (*Pinus strobus* L.), white ash (*Fraxinus americana* L.) and bur oak (*Quercus macrocarpa* Michx.). This stage of colonization was brief: the area was deserted between 1812 and 1820, during the war between the United States and Britain (Sellar 1888). After the war, a mas-

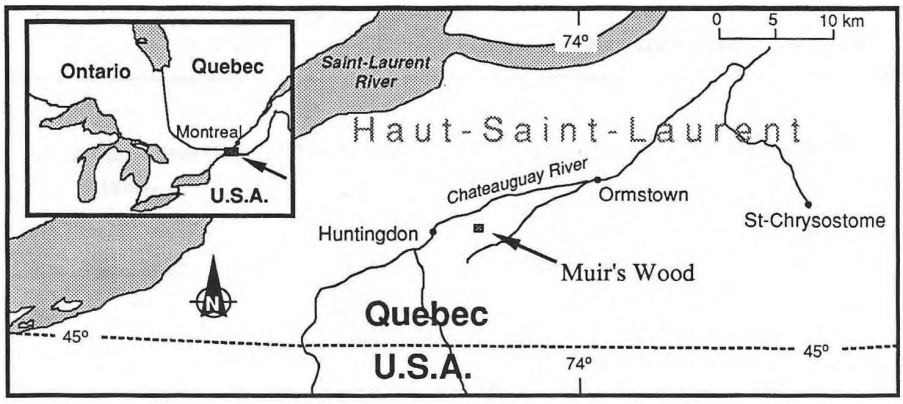

Figure 1. Location of Muir's Wood in Haut-Saint-Laurent Region.

sive influx of colonists began, which in only a decade or two made the Haut-Saint-Laurent one of the most cultivated regions of Quebec. Besides farming, forest exploitation was the major activity of the settlers. With the stock of timber diminishing rapidly, efforts were directed toward the lucrative fabrication of potash from wood ash. Trees of all sizes, especially sugar maple, black ash, and American elm, were cut, piled, and burned. This activity was later abandoned, after the discovery of an inexpensive process of fabrication from salts. Thereafter, the economic importance of forests in the region became secondary, as a source of fuelwood or, in the case of maple, to be tapped for sugar.

Today, forests are generally small in area and consist of second or third growth. Grandtner (1966) described the climax vegetation on mesic upland sites as a sugar maple and bitternut hickory (*Carya cordiformis* [Wang.] K. Koch.) association. Disturbed forests on the uplands are dominated by gray birch (*Betula populifolia* Marsh), trembling aspen (*Populus tremuloides* Michx.), and large-toothed aspen (*Populus grandidentata* Michx.).

TREE STRATUM OF MUIR'S WOOD

The small size of the study area enabled us to survey all of its trees. However, a 20-m-wide strip along the forest edges was ignored because of possible influence by surrounding disturbed areas. Each tree (dbh > 15 cm) was identified and mapped according to an x-y coordinate system. Exact diameter (dbh) was measured and whether the tree was living or dead was noted. Larger trees without heart rot were increment cored. Annual growth was measured using a movable stage and dial micrometer. For dead trees that could not be identified in the field, a piece of wood was collected for identification using the macroscopic morphology of the wood cells (Mullins and McKnight 1983).

Based on water regime, two different habitat types, each bearing a different forest composition, were recognized for the forest. Table 1 summarizes the tree composition of the mesic and hydric portions of Muir's Wood. To give a more representative picture of each type, a band of trees, of transitional composition, at the boundary between the mesic and hydric portions was excluded from Table 1.

Hydric Type

The hydric habitat type constitutes less than 15% of the forest. It occupies the southwestern corner and a few depressions scattered throughout the forest. In this type there is little slope but the surface is irregular. The water table is close to the surface and many puddles exist throughout the growing season. The hydric zone is mainly occupied by black ash and American elm, though most of the latter were recently killed by Dutch elm disease. If only living trees are considered, American elm is 10th out of 13 in density, and 12th in importance (Table 1). If recently dead elms are included in an estimate of the forest composition prior to the devastating effect of the disease, American elm's density and importance value jump to first place (numbers in parentheses in Table 1). The number of recently dead trees of other species, not included in this calculation, is negligible compared to the number of recently dead elms, so including the dead elm stems results in only a slight overestimate of elm abundance. Other important species in this habitat type are sugar maple, basswood (*Tilia americana* L)., and bitternut hickory (*Carya cordiformis* [Wang.] K. Koch.) (Table 1). The openings resulting from the death of the elms stimulated the emergence of a vigorous understory vegetation, mainly composed of herbs and shrubs such as *Rubus* sp., *Zanthoxylum americanum,* and *Circaea quadrisulcata*.

Only three trees were cored in the small hydric zone of the site, none of which was over 200 years of age (Table 1).

Mesic Type

This habitat type, covering most of the site, is occupied by a beech-maple forest community. Drainage varies from moderate to good. Maximum slope reaches 10%, although it is less than 5% in general. Surficial deposits are of morainal origin. The soil is a brown stony loam with a pH ranging from 6.1 to 7.0 in the B horizon. Sugar maple strongly dominates the tree stratum and has an importance value of 56% (Table 1). Following in importance are American beech, basswood, ironwood (*Ostrya virginiana* [Mill.] K. Koch.) and hemlock (*Tsuga canadensis* [L.] Carr.). The understory is typical of a beech-maple forest: there is a low percentage of groundcover and acidophilic species such as *Polystichum acrostichoides* and *Maienthemum canadense* are present. American elms of the mesic zone were less affected by Dutch elm disease than those of the hydric zone (80% versus 96% mortality; $X^2 = 10.45$, $p < 0.01$). One possible explanation for this is that the lower density of elms in the mesic zone does not favor transmission of the disease by root grafts.

Age and Size Distribution of Trees

Coring confirmed the old-growth status of the forest suggested by the previous survey (Brisson *et al.* 1988a). Many trees are over

Table 1: Density, basal area, importance value, maximum age, and diameter of trees of Muir's Wood

Hydric Habitat Type (n=238 living trees)

	Density[a] (stems • ha^{-1})		Basal Area[a] (m^2 • ha^{-1})		Importance Value[a,b] (%)		Maximum DBH[c] (cm)	Maximum Age (years)
Acer rubrum	2.3		0.5		2.0	(1.1)	70.0	137 (n=1)[d]
Acer saccharum	54.0		3.1		19.2	(12.4)	(79.0)	185 (n=1)
Betula alleghaniensis	19.5		1.3		7.6	(4.8)	41.5	—
Carya cordiformis	31.0		1.9		11.4	(7.3)	44.0	—
Fagus grandifolia	12.6		0.7		4.4	(2.9)	41.5	—
Fraxinus americana	5.7		0.7		3.2	(1.9)	70.0	—
Fraxinus nigra	81.6		3.0		23.9	(16.0)	33.5	—
Juglans cinerea	1.1		0.1		0.6	(0.3)	36.0	—
Ostrya virginiana	6.9		0.2		1.9	(1.3)	23.0	—
Quercus macrocarpa	1.1		0.5		1.7	(0.9)	73.0	143 (n=1)
Tilia americana	39.1		3.8		18.6	(11.5)	73.5	—
Tsuga canadensis	14.9		0.6		4.4	(3.0)	32.0	—
Ulmus americana	3.4	(93.1)	0.1	(14.4)	1.1	(36.3)	(120.0)	—
TOTAL	273.6	(363.2)	16.5	(30.8)				

Mesic Habitat Type (n=1667 living trees)

	Density[a] (stems • ha^{-1})		Basal Area[a] (m^2 • ha^{-1})		Importance Value[a,b] (%)	Maximum DBH[c] (cm)		Maximum Age (years)
Acer saccharum	124.5		19.7		56.0	88.0		302 + (n=35)[d]
Betula alleghaniensis	2.5		0.1		0.6	43.0		—
Carya cordiformis	6.7		0.3		1.7	53.0		—
Fagus grandifolia	56.4		3.4		15.9	75.0		250 (n=15)
Fraxinus nigra	<1.0		<0.1		<0.1	20.5		—
Juglans cinerea	1.7		0.2		0.7	72.5		—
Ostrya virginiana	36.6		0.9		8.2	31.0		—
Tilia americana	22.3		3.0		9.2	80.0		—
Tsuga canadensis	22.5		1.4		6.4	74.0		307 (n=11)
Ulmus americana	3.2	(16.0)	(0.2)	(1.1)	0.9	1.1	(63.30)	—
Ulmus rubra	<1.0		<0.1		<0.1	27.0		—
TOTAL	277.4		29.4					

[a] Numbers in parentheses indicate that calculations include American elms (*Ulmus americana*) recently killed by Dutch elm disease. Otherwise, only living trees were considered.

[b] Importance Value = (relative density + relative basal area) / 2.

[c] A number in parentheses indicates that the tree was dead at time of measurement.

[d] Number of trees cored.

250 years of age, and some even reach 300 years (Figure 2). The number of old trees is higher than suggested by Figure 2 because many of the larger trees, especially beech, had heart rot and could not be aged. Despite the age of the trees, their diameters are not exceptional. Most of the older trees range from 45 to 75 cm dbh (Figure 2), a size easily attained by trees half as old for the same species from other forests in this area (cf. Brisson et al. 1988a). The poor growth probably resulted from the trees growing under a relatively closed canopy for much of their early life. Most increment cores showed periods of extremely slow growth, sometimes as low as 1 or 2 mm a year for several decades. In contrast, tree growth in neighboring forests is faster, either because these trees established after a clear-cut and consequently grew in full sunlight, or because they benefited from partial cuts.

Large dead trees are scattered throughout the forest, as snags or fallen logs with intact or highly decomposed wood. This condition prevailed in old-growth forests before European settlement, but is unusual now, even in mature forests, for most owners cut dying or dead trees for fuelwood. Clearing dead trees removes the wood from further decomposition. The long-term effects of

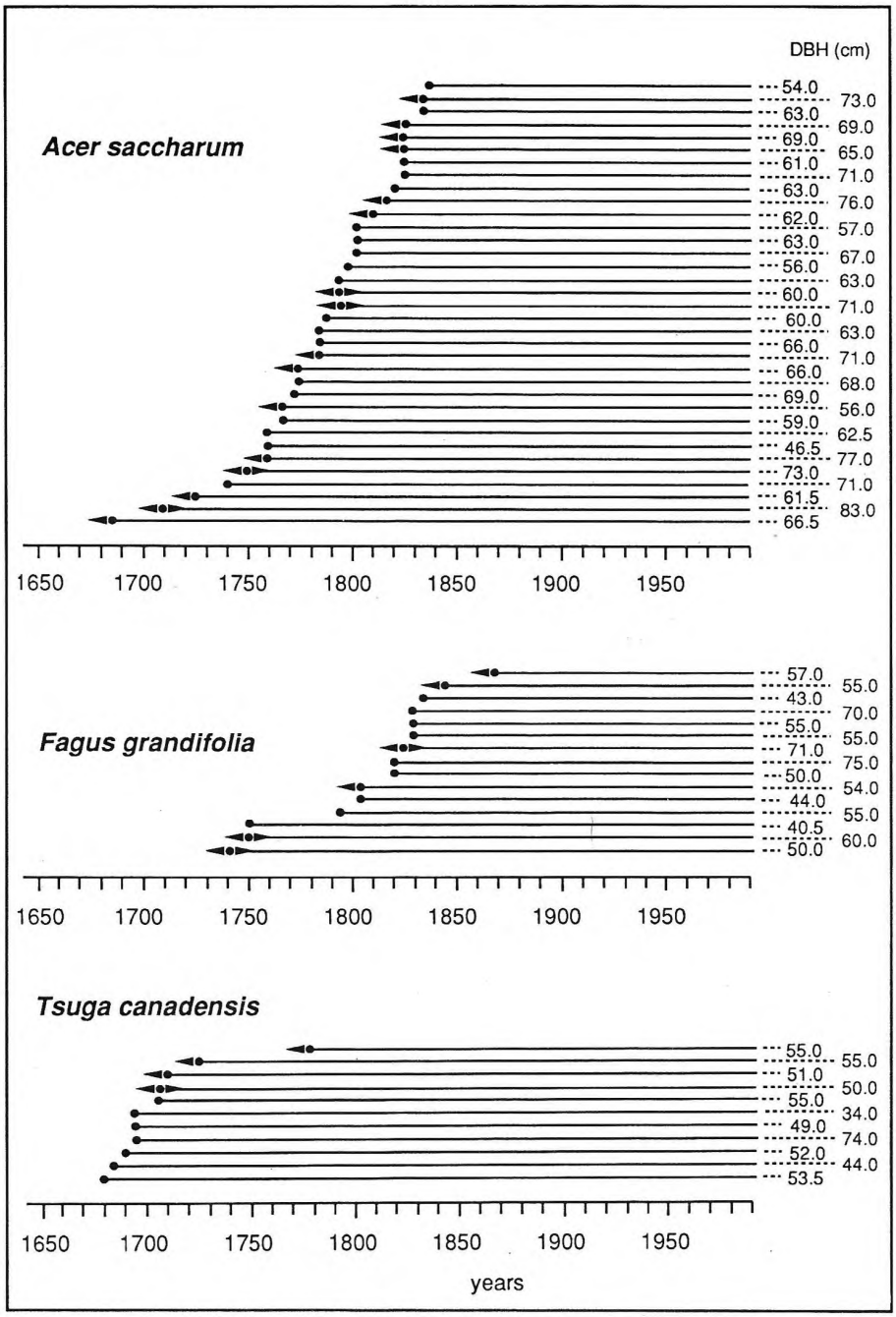

Figure 2. Year of birth and diameter of 61 trees that were cored. ●— : exact year of birth (+/- 10 years); ◄●► : approximate year (+/- 10 years); ◄●— : minimum year of birth (usually from trees with a rotten heart).

this removal are poorly known.

While tree age provides better information about the past history of a forest, tree size distribution may be a better indicator of the site's future (Enright 1982). Size distributions in Muir's Wood suggest that its tree composition is not near steady-state despite its age. The diameter classes of maple trees show a flat distribution (Figure 3). A stable distribution for this species would more resemble a steeply descending curve, with many stems in the smaller size classes and progressively less in the larger ones (Lorimer and Frelich 1984). In Muir's Wood, maple dominates the larger size classes, but the smaller trees, after some future mortality, will not be able to sustain the same density. Data on regeneration collected in a 40-m X 40-m quadrat show that the number of maple saplings (1 cm < dbh < 10 cm) is low (38 stems / ha) considering the large number of seedling trees (Brisson et al. 1988a). Observed maple germination was high, but most seedlings died before the end of the growing season. In nearby maple forests, the density of saplings ranges from 194 to 1970 stems / ha (Brisson et al. 1988a).

Unlike maple, the number of beech trees increases with decreasing size, suggesting at least stability if not an increase in its future importance (Figure 3). Beech saplings from both seed and root sucker origin are abundant (1244 stems / ha in the 1988 quadrat). We recently used an approach based on patch dynamic and transition probabilities to estimate the direction of composition changes (Horn 1975). Here again, the results suggest that maple is strongly decreasing to the benefit of beech (Brisson et al. unpubl. data).

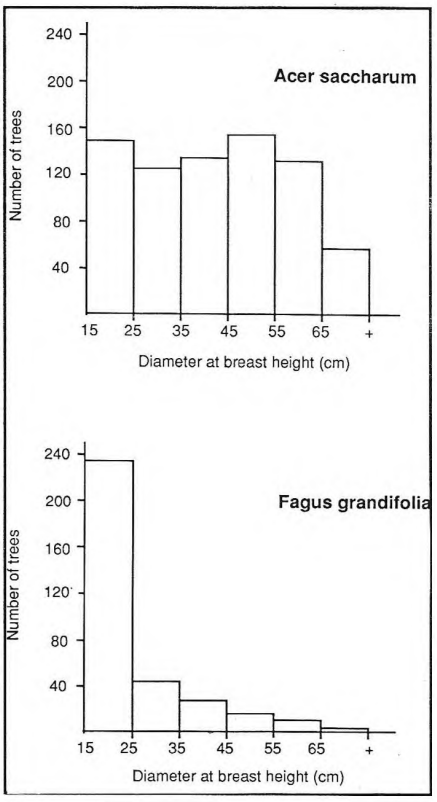

Figure 3. Diameter distribution of maple and beech trees.

HISTORY OF MUIR'S WOOD

Conflicting evidence prevents us from determining whether or not the present forest originated from a major perturbation. On the one hand, the oldest hemlocks seem to arise as a cohort dating from the end of the seventeenth century (Figure 2), suggesting sudden recruitment following a major opening in the canopy. On the other hand, the early growth of these trees was extremely slow, not corresponding to that of young stems growing in full sunlight. If the forest originated from a major perturbation, it was not due to European settlement since the first settlers only came to the region more than a century later.

During the first phase of colonization (1800–1812), most of the large pines covering the sand flats and the bur oaks abundant along the rivers fell under the axes of the loggers. Morainic ridges dominated by sugar maple and beech were not harvested, although scattered pines that are sometimes found in this type of habitat may have been cut. Tree-ring analysis revealed no unusual growth release or decrease during this period in Muir's Wood (Figure 4).

Archibald Muir, the first to settle on the lot where Muir's Wood is located, arrived in 1827, after the war. At this time, logging was a major activity for the settlers. If Muir's Wood was spared during this period of heavy deforestation, it is because the

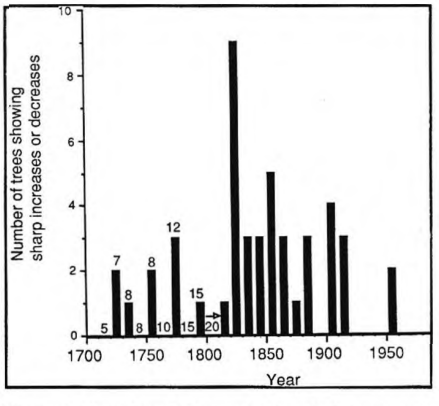

Figure 4. Number of sharp changes in tree growth revealing periods of more intensive perturbation. Mathematical criteria developed by Lorimer (1980) were used to objectively determine these chages. A number over a stack indicates the total number of trees measured for the period. From 1800 on, 20 trees were used.

Muirs were "excellent farmers, desiring good soils, caring nothing about lumbering or potash-making" (Sellar 1888, p. 474). They concentrated their activity on the flat clay plain that borders Muir's Wood to the north. A lack of interest in potash-making was certainly exceptional since barrels of potash were the major source of ready money for most settlers. In fact, Sellar (1888) states that without this specialized industry, the colonization of the Haut-Saint-Laurent region would never have known such success.

The present ages of the trees also indicate that the wood escaped fires that burned in the Huntingdon area in 1825 (Sellar 1888).

Muir's Wood may have been affected, though not severely, during the critical period 1820–1830. A higher number of sharp changes in tree growth was recorded for this period (Figure 4). Simultaneous changes in growth in several trees throughout a forest often indicate a disturbance (Lorimer 1980) but reveal nothing about its nature. It is not known if these changes are related to some minor partial cuttings, fire, or some other factor.

Several generations of the Muir family have owned this site, down to the present owner, Mrs. Annie Muir. During this period, light selective cuttings were certainly performed. A few stumps have been noted, but most of them were at the north edge of the forest, near the field. In addition to the dirt road that crosses the forest from north to south, remains of an old path have been found in the western part. Finally, it is probable that the sugar maples were tapped for sugar or syrup. However, the large proportion of trees over 200 years of age and the number of dead or decomposing mature trees indicate that a major selective cut never occurred. Moreover, besides the period between 1820 and 1830, no other periods showed a significant number of changes in tree growth (Figure 4).

Beginning in 1943, Huntley Muir and his sister Annie farmed the property. Their conservative approach toward farming methods and their way of living was notorious in the region. They conserved and used the tools, appliances, and furniture of their ancestors. This conservative attitude applied also to their forests, where they would go sometimes to get wood for their own needs, recovering dead or diseased trees. To this end, it seems more likely that they used the small woodlot next to their house rather than the area of this study. Huntley Muir died in 1977. Mrs. Muir has no direct descendants, and her farmhouse is presently vacant. For many years now the field has been leased to a farmer in the area. As for the forest, a salvage cut of the dead elms was attempted in the hydric zone in the mid-1980s by a neighbor. However, most trunks were left on the spot, probably because of the advanced deterioration of the wood. This intervention had only a minor impact since these trees were soon destined to fall.

In 1987, the forest was proposed for an ecological reserve, a status that would provide maximum legal protection, only allowing research or education activities with the permission of the Ministère de l'Environnement du Québec (1983). Despite the positive response of the ministère, the low investment involved, and the urgency of the situation, no concrete action was taken. In 1990, the lot was sold and the maples were tapped for syrup. This intervention provoked public protestation and made its acquisition and protection more urgent (Riendeau 1990).

DISCUSSION

Old-growth forests are generally defined on the basis of age of the dominant trees and, frequently, on their relative freedom from human or natural disturbances (Whitney 1987; Barnes 1989). There is no doubt that Muir's Wood meets most age criteria for old growth. In fact, some of its trees were already relatively old (approximately 130 years) when the first European settled on the property. Degree of disturbance can be assessed differently, depending on how one measures "relative freedom from disturbance." Though the small hydric portion of the site has been severely altered by the death of the elms, the mesic portion has never been seriously logged or affected by natural disturbances. That a forest of such natural quality exists in an area with a history of so much deforestation is very fortunate.

Old-growth forests are more likely to resemble the conceptual climax community than are younger stands. The American reader may not find it remarkable that a beech-maple forest community inhabits the mesic portion of Muir's Wood; this type of association is believed to represent the endpoint of succession of a large part of the Eastern Deciduous Forest of North America (Braun 1950). However, in the Haut-Saint-Laurent region, the hypothesized climax forest community for mesic sites is a maple formation where beech is occasional or absent (Dansereau 1959; Grandtner 1966). Moreover, an increasing abundance of beech in some maple forests of southern Quebec has been attributed to abusive exploitation, such as repeated selective cuttings (Bouliane 1962; Grandtner 1966). Ironically, submature mesic forests of Haut-Saint-Laurent, all of them with a history of severe human disturbance, conform more in structure and composition to the maple-climax type than does Muir's Wood. It must be pointed out that these submature forests were the models for the hypothesized climax, since the forests of Haut-Saint-Laurent had been cut long before the first ecological studies in the region. This choice was perfectly logical, since the dominating maple typically reaches a stable size structure in these forests, precluding future changes in composition. Although it is a small piece of evidence, the composition of Muir's Wood suggests that beech may have been a more important component of mature hardwood forests of southern Quebec. Information on forest composition before European settlement would give us a better idea of the successional status of the different tree species. Reconstruction of the presettlement forest from survey data, a common practice in the United States, is not possible in Quebec since the survey method under the French regime did not include recording of trees. However, a recent study using information on wood sales recorded in notary deeds to reconstruct the presettlement forest composition of the Haut-Saint-Laurent region concluded that beech was more abundant then than it is now (Bouchard et al. 1989).

Even more surprising is the transient nature of the composition of Muir's Wood. One of the characteristics of old-growth forests is their generally steady-state condition (Whitney 1987). However, the size structure of maple in Muir's Wood gives the impression of a mid-successional species that is decreasing in population size. In contrast, the beech population is apparently increasing. The relative lack of disturbance in this forest suggests that the change from maple to beech is a natural successional trend. A similar trend has been suggested elsewhere (Nicholson et al. 1979; Forcier 1975). Further studies would be required to explain the deficiency in maple recruitment, since this species is known to grow well under its own canopy.

The better understanding of late successional dynamics that can be gained from studying old-growth forests like Muir's Wood certainly is not only of theoretical value; it has applications to natural areas protection, where efforts are directed toward the preservation and management of vegetation in the most natural state possible. For example, park managers of Parc-du-Mont-Saint-Bruno (southern Quebec) were concerned about an apparent increase in beech in some locations of the park (Brisson et al. 1988b). They considered controlling the beech population by cutting some individuals to prevent the "degradation" of the maple forest. The dynamics in Muir's Wood suggest that this view should be reconsidered, and that the observed trend in the park may be perfectly natural, precluding the need for intervention. This illustrates only one aspect of the scientific value of old-growth forests.

Whitney (1987) stressed the importance of preserving old-growth forests for educational, scientific, and aesthetic purposes. The location of Muir's Wood at the northern limit of the Eastern Deciduous Forest, and within one of the most deforested portions of Quebec, make it even more valuable. Its small surface area, although characteristic of the remaining old-growth forests of eastern North America, makes the long-term maintenance of its integrity questionable (Parker 1989). A concerted effort to systematically identify and subsequently protect other old-growth forests in the inhabited portion of Quebec certainly is justified. We hope that the discussions generated by the singularity of Muir's Wood will stimulate such interest.

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