Selected Nova Scotia old-growth forests: Age, ecology, structure, scoring[1]

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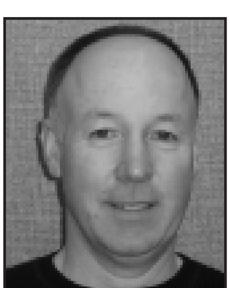
A study of four old-growth stands in Nova Scotia was conducted to document the ecological characteristics of these currently rare Acadian forest ecosystems. Stands were selected to represent the two dominant climax forest types, hemlock–red spruce–eastern white pine, and sugar maple–yellow birch–beech. Data include measurements of age structure, species composition, diameter distribution, basal area, height, coarse woody debris, snags, vertical structure, and canopy condition. All stands were determined to be uneven-aged. Old-growth reference ages calculated for the stands ranged from 164 to 214 years. All stands displayed broad diameter distributions that had peak basal area representation in the 40- to 50-cm diameter classes. Volumes of dead wood ranged from 111 to 148 m^3/ha in the softwood stands and from 63 to 83 m^3/ha in the hardwood stands. Dead wood consisted of approximately one-third snags and two thirds downed coarse woody debris. Measurements from the stands were used to evaluate Nova Scotia's recently developed Old Forest Scoring System. Six stand attributes were rated for a maximum score of 100: stand age, primal value, number of large-diameter trees, length of large-diameter dead wood, canopy structure, and understorey structure. Based on the age attribute, three of the four stands were classed as Mature Old Growth and one was very close, indicating that all are in the shifting mosaic stage of late forest succession. The scores for all stands were relatively high, ranging from 75 to 85, as would be expected from some of the best old-growth stands in the province.

Key words: old growth, climax, primal, late succession, uneven-aged, scoring, coarse woody debris, age structure, diameter, Acadian forest, northern hardwood, red spruce, eastern hemlock, white pine, sugar maple, yellow birch, American beech

Nous avons mené une étude sur quatre peuplements anciens de la Nouvelle-Écosse afin de relever les caractéristiques écologiques de ces rares écosystèmes forestiers acadiens. Les peuplements choisis représentent les deux forêts climaciques dominantes: la forêt de pruches du Canada, d'épinettes rouges et de pins blancs et la forêt d'érables à sucre, de bouleaux jaunes et de hêtres à grandes feuilles. Les données recueillies portent notamment sur la structure d'âges, la composition spécifique, la distribution des diamètres, la surface terrière, la hauteur, les débris ligneux grossiers, les chicots, la structure verticale et l'état du couvert forestier. Nous avons déterminé que tous les peuplements sont inéquiennes. Les « âges de référence » calculés pour ces peuplements varient entre 164 et 214 ans. Tous les peuplements ont une vaste distribution des diamètres dont la surface terrière maximale se situe dans la classe de diamètres de 40 à 50 cm. Le volume de bois mort varie entre 111 et 148 m^3/ha dans les peuplements de résineux et entre 63 et 83 m^3/ha dans les peuplements de feuillus. Le bois mort est constitué de chicots (environ un tiers) et de débris ligneux grossiers au sol (deux tiers). Nous avons utilisé les mesures des caractéristiques des peuplements pour évaluer le système de pointage des forêts anciennes récemment élaboré par la Nouvelle-Écosse. Six caractéristiques ont été évaluées, pour un pointage maximal, soit 100 : l'âge du peuplement, la virginité, le nombre d'arbres de grand diamètre, la longueur du bois mort de grand diamètre, la structure du couvert et celle du sous-étage. En vertu de leur âge, nous avons désigné trois des quatre peuplements comme forêt ancienne avancée, et le quatrième avait presque l'âge requis, ce qui montre que ces peuplements sont tous au stade de mosaïque évolutive de fin de succession. Les pointages de tous les peuplements sont relativement élevés et se situent entre 75 et 85. Il s'agit là d'un résultat prévisible puisqu'il s'agit de quelques-uns des meilleurs peuplements anciens de la province.

Mots clés : vieilles forêts, climax, primal, fin de succession, inéquienne, dénombrement, débris ligneux grossiers, répartition des âges, feuillus nordiques, épinette rouge, pruche de l'Est, pin blanc, érable à sucre, bouleau jaune, hêtre à grandes feuilles



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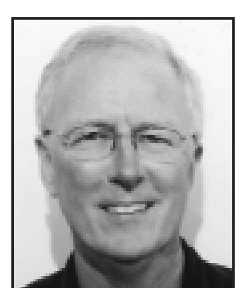

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Introduction

This report presents a detailed description of four old-growth Acadian forests in the late stage of natural succession. Thomas Spies (1997), summarizing the work of various writ-

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ers, describes a general model of forest succession as a four-stage process: establishment, thinning, transition, and shifting mosaic. The first two stages currently dominate Nova Scotia's heavily managed Acadian forest landscape, where 91% of the forest consists of even-aged stands less than 100 years old (Nova Scotia Department of Natural Resources 2000a). When succession continues beyond the thinning phase, stands enter a transition period, in which the original overstorey begins to slowly break up, promoting understorey development and recruitment of new cohorts to the overstorey. In Nova Scotia, Lynds and Leduc (1995) define this stage as Immature Old Growth, which usually begins at 100 to 150 years for most climax species in the province. The transition period progresses into the shifting mosaic phase, in which stands persist in a dynamic, uneven-aged condition marked by mature canopy processes of gap formation and recruitment from a developed multi-layered understorey. Lynds and Leduc (1995) term this stage Mature Old Growth, which, depending on species, usually begins at 150 to 200 years. Although there is much debate on exactly when in the successional process old growth begins, or how much human disturbance is permitted to influence development (i.e., need for primal conditions), the shifting mosaic state is generally regarded as a true old-growth condition (Bormann and Likens 1979, Oliver and Larson 1990, Spies 1997).

By any of these descriptions, 500 hundred years of post-European settlement activity have left little primal old-growth forest in Nova Scotia. Recognizing the critical role of old-forest habitat in sustaining biodiversity, Nova Scotia introduced an Interim Old Forest Policy for Crown land in 1999, with the goal of protecting and restoring old-growth forest on a minimum of 8% of public land (Nova Scotia Department of Natural Resources 1999). The following study was designed to address the need for improved knowledge of old-growth conditions and ecological processes. The primary purpose was to gain a scientific understanding of the ecology, age structure, tree composition, and long-term stand dynamics within the two dominant climax Acadian forest types, namely hemlock–red spruce–eastern white pine and sugar maple–yellow birch–beech. An additional objective was to use the measurements of these high-quality old-growth stands to gauge the functionality of Nova Scotia's recently developed Old Forest Scoring System, which was introduced with the Interim Old Forest Policy (Nova Scotia Department of Natural Resources 1999).

A variety of scoring approaches for old-growth evaluation have been described and used across North America (e.g., Mehl 1992, Kneeshaw and Burton 1998, Wells *et al.* 1998). By scoring old forests, consistent, quantitative evaluations can be obtained, permitting non-subjective comparisons between forests, and providing unbiased and transferable inventories. Scoring also provides a valuable educational tool for highlighting characteristics of old-forest ecosystems and provides a common language for discussion. Scoring, and the resulting inventories, may also provide valuable guidance for designing silvicultural systems that promote the development of old-growth conditions. Scoring has limitations, one of the most important being the subjectivity involved in the selection and weighting of indicator attributes. This results in a simplified description of complex ecosystems that fails to recognize some of the unique values of individual forests. However, despite the limitations, the benefits of an old forest scoring system in a conservation program are numerous.

Methods

Stand selection

Four stands were selected for the study, each an example of high-quality, mature, old growth in the shifting mosaic stage of forest development (Lynds and Leduc 1995, Spies 1997). The sites were selected from documented mature, old-growth forests listed in the Nova Scotia Museum and Nova Scotia Protected Areas Program files (Lynds and Leduc 1995). The Nova Scotia Department of Environment (Lynds, *personal communication*) and Parks Canada (Bridgeland, *personal communication*) were consulted to help narrow the selection. The Nova Scotia Department of Natural Resources inventory, old-forest databases, and aerial photography were used to verify information and focus the study area. Three of the stands, Grand Anse, North River, and Panuke Lake, were included in Selva's (1998, 1999) lichen studies of old-growth stands in eastern North America, and were verified by lichen analysis as old-growth forests with long histories of ecological continuity. The Sporting Lake Island site, although not included in Selva's studies, is a documented, mature, old-growth stand (Lynds and Leduc 1995) protected as an Ecological Reserve under the Special Places Act. It was selected as one of the few old-growth hemlock–spruce–pine ecosystems in Nova Scotia that contain a significant representation of eastern white pine. Two stands were selected from each of the two dominant climatic climax forest types in Nova Scotia. Tolerant softwood (eastern hemlock (*Tsuga canadensis* (L.) Carrière), red spruce (*Picea rubens* Sarg.), and eastern white pine (*Pinus strobus* L.)), and tolerant hardwood (sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula alleghaniensis* Britt.), and American beech (*Fagus grandifolia* Ehrh.)) communities are identified in the Nova Scotia Ecological Land Classification (Nova Scotia Department of Natural Resources 2000b) as the potential climax forests on 24% and 23% of the forest land, respectively, and tolerant mixedwood composed of these species is identified as the potential climax on 11% of the forest land (Fig. 1).

Data collection

ArcInfo® (Esri, Environmental Systems Research Institute, Inc., Redlands, CA) was used to randomly generate coordinates for eight sample point locations within each stand. A March II® (Corvallis Microtechnology, Inc., Corvallis, OR) handheld GPS receiver was used in the field to locate the sample points. Depending upon the time available, four to seven sample points were established in each stand. Polyareal horizontal point sampling using either a 2 or 3 BAF prism was used to measure the composition of standing live and dead trees taller than breast height (1.3 m) (Husch *et al.* 1982). Species and diameter at breast height (dbh) (mm) were recorded for all live trees sampled. These measurements were used to estimate basal area (m^2/ha), tree density (number/ha), quadratic mean diameter at breast height (cm), and species composition proportional to basal area (Husch *et al.* 1982). For dead standing trees (snags ≤ 45° lean) height was also measured, and visual estimates were recorded for top diameter (cm), as well as the height (m) to diameters of 20, 30, 40, and 50 cm. Smalian's formula was used to calculate snag volumes, with the cross-sectional area of the base assumed to be the same as that measured at breast height (Husch *et al.* 1982). Line intersect sampling was used at each plot to sample coarse woody debris (CWD) (> 45° lean, > 10 cm diameter) along a systematically established 150-m line tran-

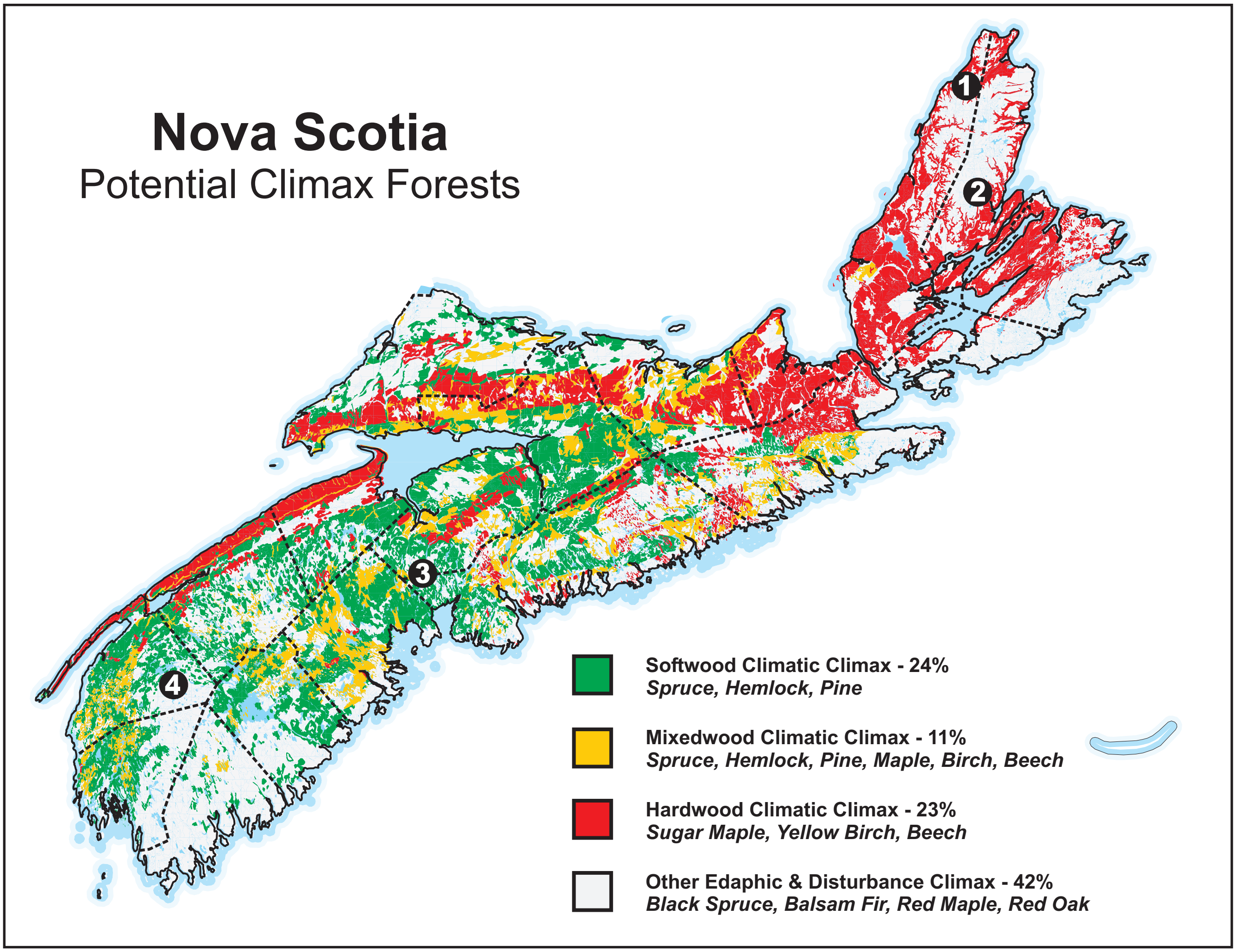

Fig 1. Location of study sites and distribution of potential regional climatic climax covertypes in Nova Scotia (NSDNR 2000). Study sites: 1. Grand Anse, 2. North River, 3. Panuke Lake, 4. Sporting Lake.

sect (van Wagner 1968, McRae *et al*. 1979). This was laid out in an equilateral triangle to reduce potential bias due to log orientation (Wei *et al.* 1997). Species, diameter at point of transect (cm), and decay class were recorded for each piece that was 10 cm or greater at the point of transect. Volume of CWD was estimated using the following equation (van Wagner 1968).

$$V = \pi^2 \sum \left(d^2 / 8L \right)$$

where, V = volume of wood per unit area (m^3/ha)
d = piece diameter at intersection (cm)
L = length of sample line (m)

As line intersect sampling is a probability-proportional-to-length technique, the easiest variable to obtain is total length of tree bole (m/ha) (Ducey and Gove 1999). Each tallied piece intersected by the sample line counts as a certain amount of length per hectare (length factor), which for the 150-m line transects used in this study was 105 m, determined from the following equation adapted from Ducey and Gove (1999).

$$F = 10\,000\pi/(2L)$$

where, F = length factor (m/ha)
L = length of sampling line (m)

Decay classes for both snags and CWD were assessed using a modification of the five class system outlined by Sollins (1982) (Appendix I). At each plot location, five to ten trees were aged, resulting in a total sample of 188 trees. These were selected to reflect the stand composition as determined by the species and diameter distribution obtained from the prism sample, and to ensure that the oldest and largest trees in the vicinity of each plot were included. Horizontal point (prism) sampling inherently weights the selection of sample trees proportional to diameter or individual tree basal area (Husch *et al.* 1982), which reflects crown size and canopy dominance. Therefore, selecting the age sample proportional to basal area provides a measure of age composition reflecting the crown dominance of the individuals within the stand. Increment cores were obtained from the sample trees, and the species, diameter, and heights recorded. Trees were bored close to breast height,

Table 1. Stand summary for all live trees ≥ 10 cm in diameter at breast height *(Standard Error)*

Stand	Sample Plots (#)	Species Composition[1] (10% Species)	Basal Area (m^2/ha)	Density (trees/ha)	Quadratic Mean DBH[2] (cm)	Mean Lorey's Height[3] (m)	Volume[4] (m^3/ha)	Old Growth Reference Age[5] (years)
Grand Anse	7	6SM 2YB 1RM 1Other	38.0 *(1.23)*	461 *(67.0)*	34.1 *(2.54)*	21.3 *(0.44)*	300 *(8.6)*	197 *(9.7)*
North River	4	7SM 3YB	32.5 *(1.26)*	366 *(51.9)*	34.3 *(1.96)*	22.9 *(0.40)*	269 *(9.7)*	178 *(10.2)*
Panuke Lake	7	8HE 2RS	58.3 *(5.63)*	497 *(69.3)*	40.5 *(4.05)*	23.4 *(0.90)*	563 *(64.1)*	214 *(17.1)*
Sporting Lake	4	5HE 2WP 2RS 1Other	55.5 *(2.60)*	520 *(18.8)*	36.9 *(1.47)*	24.0 *(0.25)*	540 *(28.3)*	164 *(29.6)*

[1]SM = Sugar Maple (*Acer saccharum* Marsh.); YB = Yellow Birch (*Betula alleghaniensis* Britt.); RM = Red Maple (*Acer rubrum* L.); HE = Eastern Hemlock (*Tsuga canadensis* (L.) Carr.); RS = Red Spruce (*Picea rubens* Sarg.); WP = White Pine (*Pinus strobus* L.).
[2]Quadratic mean DBH = diameter of tree of average basal area (Husch *et al.* 1972).
[3]Lorey's Height = height of tree of average basal area, (Husch *et al.* 1972):
Height - Diameter regression equation: Height = a/(1+b* DBH**n)
Grand Anse: a = 36.64; b = 8.66; n = -.708; r squared = 0.60
North River: a = 32.11; b = 18.50; n = -1.085; r squared = 0.85
Panuke Lake: a = 27.85; b = 294.17; n = -2.0351; r squared = 0.88
Sporting Lake: a = 26.67; b = 783.91; n = -2.458; r squared = 0.66.
[4]Volume calculated using metric Diameter-Height Ratio equations (Honer *et al* 1983).
[5]"Old Growth Reference Age" represents the "threshold age" of the oldest third of the stand. Determined as the average age of the smallest diameter trees (±5cm) composing the largest third of basal area.

although the primary consideration was locating a sound section of tree bole to core. Despite a moderate amount of rot in the larger trees and the extraction of some broken cores, very few trees were encountered that could not be aged to centre. All cores were permanently mounted and prepared using standard tree chronology methods (Stokes and Smiley 1996). Ages were measured by counting rings under a dissecting microscope. The height–diameter relationship for each stand was developed using non-linear regression of the height and diameter measurements obtained from the age sample trees. (Table 1). This was used to estimate individual tree heights for the live trees measured in the prism sample, and to estimate Lorey's height (m) (Husch *et al.*1982). Volumes (m^3) were calculated using Honer *et al.*'s (1983) metric Diameter–Height Ratio equations.

Old forest scoresheet

Nova Scotia's Old Forest Scoresheet was developed within the Department of Natural Resources (NSDNR) over a number of years through discussion, literature review, and consultation of NSDNR inventory data. It is based on a 100-point score using six stand attributes: age, degree of anthropogenic disturbance, occurrence of large diameter live trees, amount of large diameter dead wood, presence of canopy gaps, and amount of understorey development (Table 5) (Nova Scotia Department of Natural Resources 1999). 1) The heaviest weighting (40%) is assigned to "age," recognizing that an important value of old-growth forests is sustaining an ecological continuity over a sufficiently long time span to allow the development of unique micro- and macro-processes, many of which remain unknown. The long lifelines in old growth provide potential for the evolution of complex biological "systems" diversity. 2) Absence of past human disturbance was recognized as an important attribute and given a 20% weighting. This recognizes the unique and extensive history of Nova Scotia, in which very little of the forest has escaped the direct effects of land-use practices, such as farming, logging, and burning, and none has entirely escaped the indirect effects of disease introduction, species extirpation and pollution. 3 and 4) The presence of large living trees, and large dead standing and fallen wood, are characteristic of most old-forest ecosystems (Leverett 1996). Both are important structural components that provide a wide variety of niche habitats. These two attributes were each given a weight of 15%. 5 and 6) Most old growth in Nova Scotia undergoes a gap replacement development pattern leading to an uneven-aged, multi-storeyed structure (Lynds and Leduc 1995). Both canopy gaps and multiple understorey layers were assigned a 5% value.

The Old Forest Scoresheet was developed as a single scoring system for use in all stand types, recognizing that comparisons between scores are truly only valid between similar community types. This fits with the management policy emphasizing the selection of a full range of communities. The scoring system was designed around the long-lived, uneven-aged forests of tolerant Acadian species, which constitute the potential climatic climax stage on most of the province's ecosystems. However, 42% of the forest land typically produces even-aged, edaphic and disturbance-based climax forests of shorter-lived species (e.g., balsam fir (*Abies balsamea* (L.) Mill.), black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), and red maple (*Acer rubrum* L.)) (Nova Scotia Department of Natural Resources 2000b). Some modification of the scoring system will be required to better fit the old-growth stage in these ecosystem types.

Results

Stand description

The two climax hardwood stands were located in Cape Breton along the relatively sheltered lower slopes of deeply dissected river valleys carved 250 to 300 m below the surrounding Highland Plateau. Both stands were located within large wilderness landscapes containing a complex of many old-growth stands. The Grand Anse stand was located in Cape Breton Highlands National Park along the toe and intervale of the Grand Anse River. The North River stand was located in the North River Wilderness Protected Area above the toe and along the lower slopes of the valley. No evidence of past human activity was observed within either stand, however, the smell of burning brakes from vehicles descending the nearby Cabot Trail was noted in the Grand Anse stand, confirming Selva's (1999) similar observation and speculation of possible negative impacts of this type of pollution on lichen populations. As well, the remains of an old sawmill from the 1800s were observed on the opposite side of North River within 200 m of the study site. Both stands were dominated by sugar maple, with significant yellow birch, and a scattering of red maple, beech, white spruce, and balsam fir. Basal areas were fairly high, indicating the stands were more than 90% and 80% stocked, respectively, for Grand Anse and North River (40 m^2/ha = full stocking for hardwood of 32 cm dbh) (McGrath 1997) (Table 1). The stands were quite tall, averaging 21.1 and 22.8 m, with maximum recorded heights of 30.0 and 30.6 m, respectively. The total volume of live wood larger than 10 cm diameter was calculated at 300 and 269 m^3/ha for Grand Anse and North River, respectively. Old growth reference ages of 197 and 178 years, respectively, were determined for these uneven-aged stands (refer to section "Old Growth Reference Age" for methods).

The two climax softwood stands were located in central and southwest Nova Scotia on gently sloping, moderately well-drained sites bordering lakes. Both are protected as ecological reserves, and exist as relatively isolated pockets of old growth within landscapes of younger forest. The Panuke Lake stand is surrounded by industrial managed forests, while Sporting Lake Island is situated within the Tobeatic Wilderness Protected Area. No evidence of past human activity was observed at Sporting Lake; however, the Panuke Lake stand contained a scattering of moss-covered stumps, suggesting a light selective harvest several decades in the past. Both stands were dominated by eastern hemlock along with a significant composition of red spruce. The Sporting Lake stand also contained a significant component of large, supercanopy, eastern white pine. Other infrequent species included red maple, white birch (*Betula papyrifera* Marsh.), red oak (*Quercus rubra* L.), and balsam fir. As with the hardwood stands, the basal areas were fairly high, indicating stocking levels above 90% for both stands (59 m^2/ha = full stocking for softwood of 37 cm dbh) (Nova Scotia Department of Lands and Forests 1990) (Table 1). Stand heights averaged 24 m, with maximums for both stands exceeding 30 m. The stands contained very high volumes of live wood, with over 500 m^3/ha of wood larger than 10-cm diameter calculated for both stands. Old growth reference ages of 214 and 164 years were calculated for the Panuke Lake and Sporting Lake stands, respectively.

Age structure

All four stands exhibited an uneven-aged structure, with trees occurring across a broad range of ages and diameters (Fig. 2). The relationship between age and diameter is demonstrated by non-linear regression with r^2 values ranging from 0.4 to 0.7. The considerable variation in this relationship indicates that, although diameter provides some indication of average age, it is a poor predictor of age for individual trees. Individual tree growth patterns vary considerably within these stands due to the uneven-aged, multi-layered stand structure, and variation in gap dynamics and suppression–release conditions.

In both the hardwood stands, most trees ranged in age from 125 to 200 years. The Grand Anse stand had a scattering of trees older than 200 years, with the oldest measured being a yellow birch of 313 years. Other than this one old tree, the age and diameter structure of both stands appeared to be fairly even, indicating that stand recruitment and development has been relatively steady, without evidence of significant disturbance events or major periods of recruitment. The graphs also clearly indicate that sugar maple is well adapted to this environment and is able to recruit and develop in these stand structure conditions. The ability of yellow birch to sustain itself under these conditions is less clear.

The softwood stands also had a wide range of ages represented; however, both contained evidence of at least two distinct age classes and recruitment phases (Fig. 2). In both stands, the oldest cohort was dominated by hemlock of 250 to 300+ years. Eastern white pine was also dominant in the older group at Sporting Lake. It appears that very few, if any, spruce occur in this older age class in either stand. This may be a reflection of either past recruitment patterns 300 years ago, or a mortality bias (either natural or by selective harvest) that affected spruce survival. Although the reasons for the second phase of recruitment (approximately 150–200 years ago) and development are not known, it is clear that, during this period, red spruce, hemlock, and eastern white pine were all able to establish and grow in the understorey of the older cohort, most reaching heights and diameters that now place them in a dominant position within the stand. Because the age sample was weighted by the basal area representation, the sample of small-diameter trees was small. However, the data suggest that there has been little recruitment of hemlock and pine into the softwood stands over the past 100 years.

For the climax species measured at the four sites, the oldest trees were eastern hemlock at 333 years, yellow birch at 313 years, red spruce at 294 years, eastern white pine at 288 years, sugar maple at 245 years, and beech at 132 years. The oldest ages of the less prominent species were red oak at 159 years, red maple at 133 years, and white birch at 125 years.

Old growth reference age

In evaluating old growth, determining the stand age of uneven-aged stands is a challenge. Successional descriptions of old-growth development often describe the "time since last disturbance," however, this is problematic when evaluating individual stands, as that time is usually unknown. It is difficult to use the "age of oldest tree(s)" as they are often not visually apparent, are often subject to extreme rot, and may often consist of a single tree in a stand of much younger growth. Finally, if "age of the average tree" is used, it will often miss a significant portion of the oldest cohort, falling in a much younger phase of recruitment. The approach used in Nova Scotia's Old Forest Policy is to focus on the oldest third of the stand, believing that this represents a significant proportion of stand composition appropriate for uneven-aged stands. An "old growth reference age" is determined that attempts to represent the threshold age (minimum age) of the oldest third of basal area. This is similar to the old-growth scoring system used by the United States Forest Service in Colorado, where average age of the oldest third of basal area is used to assign points (Swisher, *personal communication*). As the age structure of old-growth stands is not visually obvious, diameter is used as an indicator of the age range. Therefore, a reference age sample is obtained from the trees that are "the smallest diameter of the largest third of basal area." These trees are easily determined when prism sampling by dividing the total number of trees tallied by three, and counting back that number of tallies, beginning with the largest diameter class tallied. The dashed lines on the age–diameter graphs (Fig. 2) show the results of this approach, where the reference dbh was calculated from the prism sample, and the mean age of all sampled trees falling within 5 cm of this

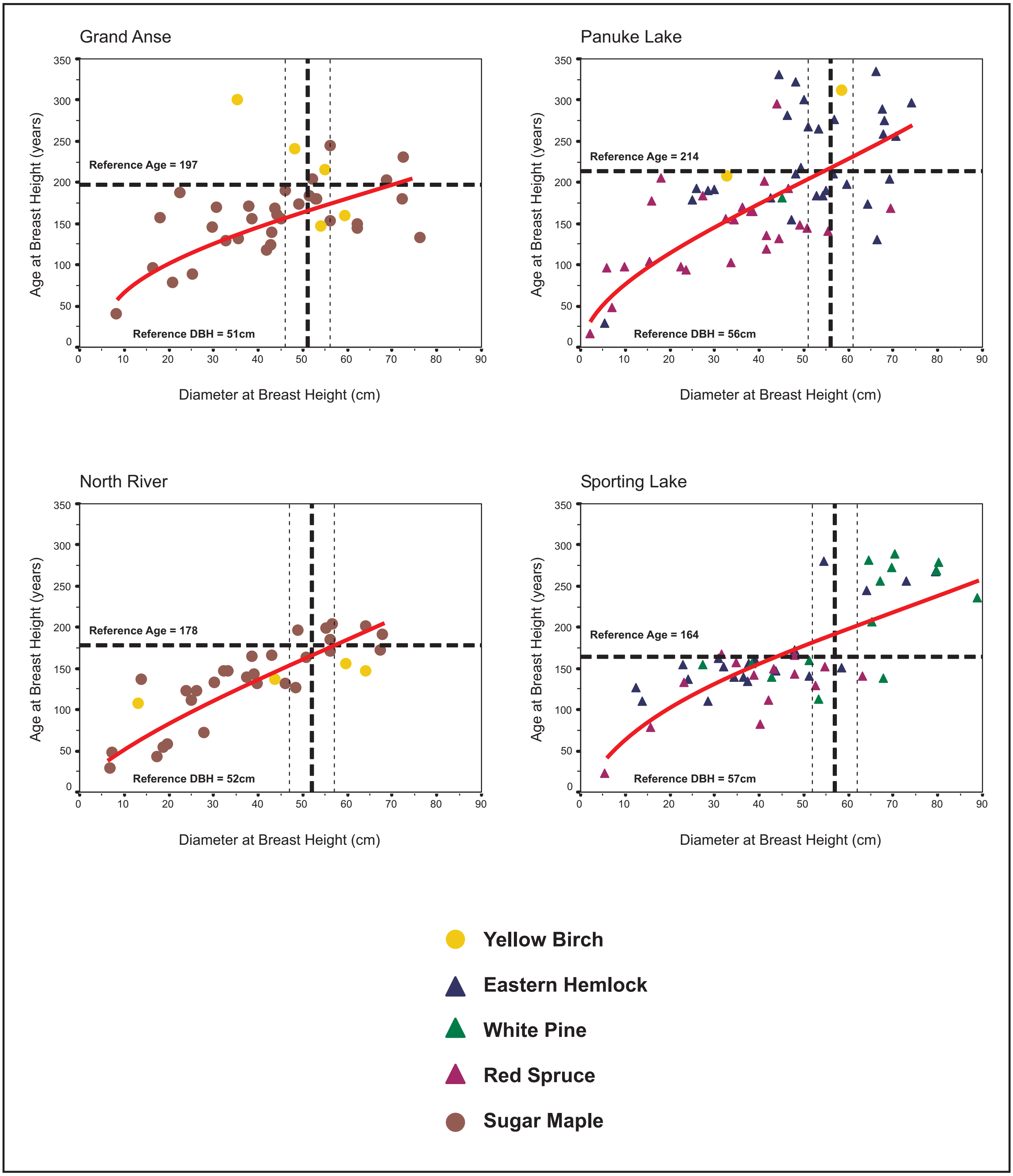

Fig. 2. Age structure by species and diameter (D) with "old growth reference ages and diameters." Regression model (power): Age = $b_o(D^{b1})$.

diameter was calculated to give each stand an "old growth reference age." Following this method, the stands ranged in age from 164 to 214 years.

Diameter distribution

All the stands exhibited a broad diameter distribution, characteristic of uniformly uneven-aged stands (Fig. 3). As well,

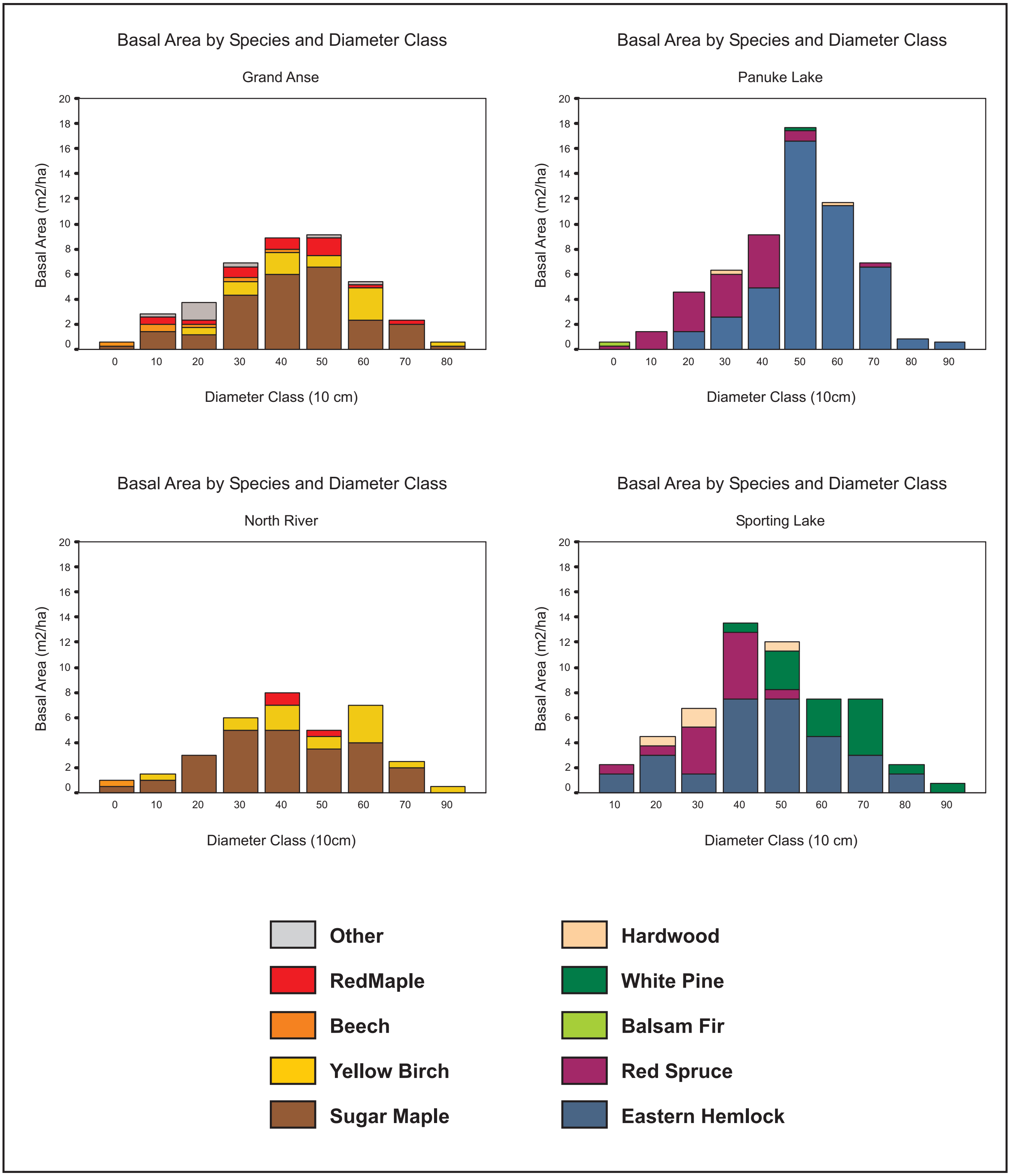

Fig 3. Distribution of live tree basal area by species and diameter class (10 cm).

all had their highest basal area representation in the 40–50 cm diameter classes, and maximum diameters measured in the stands ranged from 81.4 cm at Grand Anse to 90.4 cm at Panuke Lake. The hardwood stands were dominated by sugar maple, which was present in all diameter classes. Yellow birch was present primarily in the middle and large diameter classes, suggesting that it has difficulty recruiting under the current stand conditions of high stocking.

Table 2. Density (stems/ha) and basal area (m^2/ha) of live trees at 40, 50, and 60 cm diameter limits *(Standard Error)*

		Density and Basal Area of Trees by Diameter Limit at Breast Height							
		All Trees		> 40 cm		> 50 cm		> 60 cm	
Stand	Community Type	Density (#/ha)	Basal Area (m^2/ha)	Density (#/ha)	Basal Area (m^2/ha)	Density (#/ha)	Basal Area (m^2/ha)	Density (#/ha)	Basal Area (m^2/ha)
Grand Anse	Sugar Maple								
	Yellow Birch	1476	40.3	106	22.0	48	12.9	16	5.4
	American Beech	*(350.1)*	*(1.19)*	*(4.1)*	*(1.23)*	*(4.1)*	*(1.37)*	*(3.9)*	*(1.36)*
North River	Sugar Maple								
	Yellow Birch	1072	34.5	79	17.5	39	11.0	14	5.0
	American Beech	*(345.4)*	*(1.50)*	*(5.0)*	*(0.96)*	*(5.3)*	*(1.00)*	*(3.3)*	*(1.29)*
Panuke Lake	Hemlock								
	Red Spruce	1195	59.7	195	43.4	129	35	43	15.3
	White Pine	*(34.6)*	*(5.10)*	*(40.0)*	*(9.57)*	*(27.0)*	*(7.90)*	*(12.2)*	*(4.72)*
Sporting Lake	Hemlock								
	Red Spruce	1054	57.0	148	35.3	86	25.5	38	14.3
	White Pine	*(29.1)*	*(3.24)*	*(16.9)*	*(6.86)*	*(25.5)*	*(8.17)*	*(17.2)*	*(6.52)*

In the softwood stands, the highly shade-tolerant hemlock was dominant through all diameter classes. Red spruce was present in the small and middle diameter classes, with very little spruce basal area larger than 40 cm in either stand. At Sporting Lake, eastern white pine was prevalent in the large diameter classes but almost absent in the small diameter classes, suggesting that it may have recruitment problems under current stand conditions.

Softwood stands in this study had approximately twice the density and basal area of large trees (> 40 cm) compared with the hardwood stands (Table 2). Softwood stands are inherently able to support approximately 30% more basal area than hardwood stands (Nova Scotia Department of Lands and Forests 1990, McGrath 1997).

When tree density was plotted against diameter class, the inverse J curve characteristic of uneven-aged stands was observed (Fig. 4). This relationship has been described by silviculturalists using a "Q-factor" equation that specifies the "quotient factor" by which the density of each successive diameter class is reduced (Smith and Lamson 1982, Leak 1987). A "Q-factor" curve is often used to develop silvicultural prescriptions for uneven-aged forests whereby the goal is to attain a balanced density–diameter structure as prescribed by a specific Q-factor line (Husch *et al.* 1982). All of the old-growth stands in the study had similar natural "Q-factor" curves ranging from 1.36 to 1.44. The softwood stands both had Q-factors of 1.36, and the hardwood stands had higher Q-factors of 1.44 and 1.41. Compared with the Q-line, all stands appeared to have an over-density of small (5 cm) stems, and a deficiency of trees in the diameter classes immediately above (10–25 cm), suggesting that stem recruitment and understorey growth may be non-uniform in unmanaged late-successional stands. In addition, a large portion (approximately 50%) of the small trees in the hardwood stands consists of beech. This species is no longer able to recruit into the large-diameter classes because of beech canker disease (*Nectria coccinea* var. *faginata*). It is noted that these results are based on a low sampling intensity of the small-diameter classes because of the inherent nature of horizontal point sampling to weight the selection of sample trees proportional to diameter (Husch *et al.* 1982).

Dead wood

Dead wood greater than 10 cm in diameter was measured as either snags (leaning ≤ 45° from vertical), or CWD (leaning > 45°). Snag volumes ranged from 17 to 57 m^3/ha (Table 3). Volumes of CWD were considerably higher than the snag volumes in all four stands, ranging from 45 to 91 m^3/ha. The softwood stands were found to contain almost twice the volume of dead wood as the hardwood stands, which was quite similar to the difference found in the volume of live wood between the two stand types. The ratios of dead wood to live wood were similar for all stands and ranged from 20 to 28%. Considerable variation was observed in the numbers of snags. A lower number of snags was measured in the hardwood stand at North River; however, these were all fairly large and contributed almost as much volume of dead wood as the Grand Anse hardwood stand that had nine times the number of snags.

All stands contained abundant dead wood in all decay classes, indicating that gap dynamic mortality and decay processes had been ongoing for many years (Fig. 5). There is no specific information available on decay rates under these stand conditions, however, the occurrence of the highest volumes of dead wood in decay classes 3 and 4 is likely a reflection that wood tends to remain in these decay classes longer than in others. It seems somewhat surprising that all stands contained a relatively high volume of wood in decay class 1, as only recently dead trees meet this classification. The consistently low volumes in decay class 5 may be due to a combination of a relatively rapid transition through decay class 5 to humus, coupled with a rapid loss of individual bole volume during this transition.

The volume of dead wood in snags was roughly half the volume of CWD in all stands. Although the proportion of snags was generally higher in the early decay classes, a considerable volume of snags remained standing through to decay classes 3 and 4. There did not appear to be any major patterns related to the species composing the snags and CWD, or to the species occupying particular decay classes. It is noteworthy that over half the dead wood at Sporting Lake consisted of eastern white pine, although pine composed only 20% of the live trees at the time of study. Coupled with the observation that pine has not been recruiting into the canopy in recent times, these

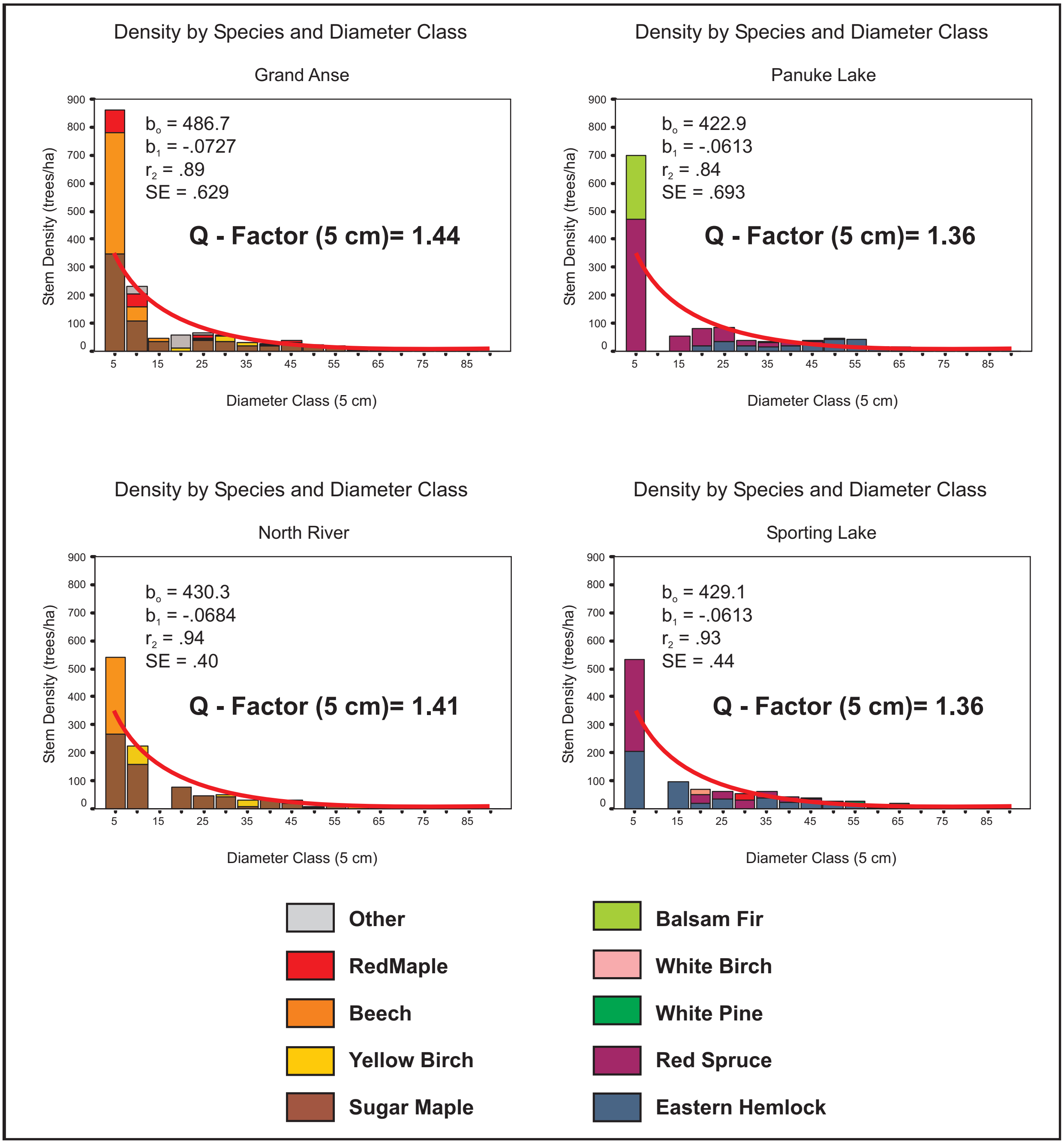

Fig 4. Tree distribution by species and diameter class (5 cm) with natural Q-factor line. Regression model (exponential): density = $b_o(e^{b1D})$.

Table 3. Stand summary of dead wood ≥ 10 cm in diameter *(Standard Error)*

Stand	Snag Basal Area (m²/ha)	Snag Quadratic Mean DBH (cm)	Snag Density (stems/ha)	Snag Volume (m³/ha)	Downed Volume (m³/ha)	Total Dead Wood Volume (m³/ha)	*Total Live Tree Volume (m³/ha)*	Dead to Live Volume Ratio (D/L) (%)
Grand Anse	4.0	32.4	100	25	58	84	*300*	28
	(0.87)	*(9.80)*	*(42.4)*	*(7.5)*	*(12.8)*	*(14.6)*	*(8.6)*	
North River	2.5	55.4	11	17	45	62	*269*	23
	(.50)	*(4.58)*	*(2.2)*	*(4.0)*	*(15.9)*	*(19.8)*	*(9.7)*	
Panuke Lake	5.4	42.8	47	40	71	110	*563*	20
	(1.56)	*(4.62)*	*(17.7)*	*(9.7)*	*(15.7)*	*(18.3)*	*(64.1)*	
Sporting Lake	7.5	23.8	149	57	91	148	*540*	27
	(3.10)	*(11.00)*	*(74.9)*	*(29.7)*	*(21.4)*	*(43.4)*	*(28.3)*	

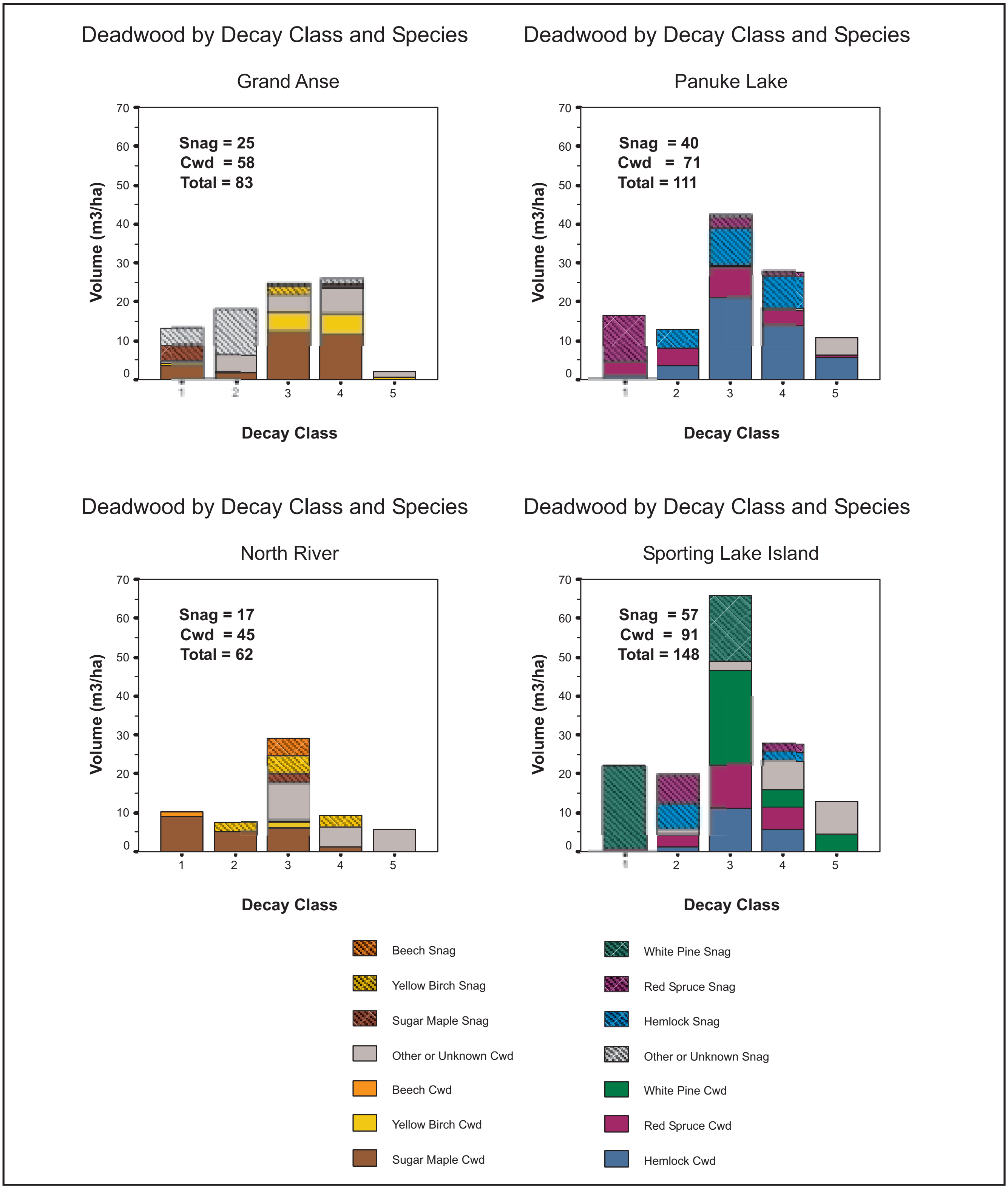

Fig 5. Volume (m3/ha) of snags and coarse woody debris by species and decay class.

trends suggest that, in the absence of a disturbance to create "pine-friendly" conditions, pine composition will decline.

Total length of dead tree boles (m/ha) is one of the easiest measured and summarized attributes for describing dead wood quantities (Ducey and Gove 1999) and is, therefore, used in the old forest scoring system. When reported by diameter range, it provides a similar indication of dead wood habitat to volume. Table 4 shows that, as with the volume measures, there is con-

Table 4. Length of dead tree bole larger than specified diameter limits *(Standard Error)*

Stand	Bole Type	Length of Dead Tree Bole (m/ha) Bole Diameter ≥ 20 cm	Bole Diameter ≥ 30 cm	Bole Diameter ≥ 40 cm	Bole Diameter ≥ 50 cm
Grand Anse	Snag	158	88	30	13
		(43.5)	*(28.7)*	*(18.0)*	*(10.5)*
	CWD	534	192	85	43
		(79.0)	*(53.8)*	*(44.5)*	*(27.6)*
	Total	**692**	**281**	**115**	**56**
		(97.7)	***(66.7)***	***(50.3)***	***(28.5)***
North River	Snag	109	93	62	27
		(28.4)	*(27.3)*	*(16.2)*	*(10.5)*
	CWD	411	224	112	0
		(127.7)	*(96.6)*	*(37.4)*	*(0)*
	Total	**521**	**317**	**174**	**27**
		(155.1)	***(118.5)***	***(42.4)***	***(10.5)***
Panuke Lake	Snag	338	198	87	38
		(95.5)	*(64.0)*	*(34.6)*	*(22.1)*
	CWD	769	321	107	21
		(100.2)	*(89.0)*	*(53.8)*	*(21.4)*
	Total	**1107**	**518**	**193**	**59**
		(166.6)	***(106.0)***	***(40.5)***	***(28.5)***
Sporting Lake	Snag	545	349	150	24
		(231.2)	*(168.1)*	*(88.8)*	*(15.5)*
	CWD	860	524	224	37
		(206.0)	*(155.7)*	*(74.8)*	*(37.4)*
	Total	**1406**	**873**	**374**	**61**
		(304.4)	***(314.1)***	***(135.7)***	***(32.4)***

siderably more bole length of CWD than snags. Also similar to the volume summaries, the total length of dead tree boles was considerably greater in the softwood stands, however, these differences were much smaller for the larger diameter classes (bole exceeding 40 and 50 cm).

Scoring old growth stand attributes

A summary of the scores for the study stands is presented in Table 5.

1) All stands obtained an age ranking as "Old Growth" in the summary, with three out of four exceeding the "Advanced Old Growth" age threshold of 175 years and, therefore, scoring a full 40 points. The Sporting Lake reference age of 164 years was a reflection of the significant basal area occurring in a younger age class. This perhaps points to a weakness in the use of thresholds, as this stand has a long ecological continuity represented by the significant cohort of trees older than 250 years. However, the fact that the age was close to the threshold, and the stand scored very high overall is evidence that the system worked fairly well.
2) Typical of the long history of human influence in Nova Scotia, only one stand (Sporting Lake) scored full marks for the absence of human disturbance. Although the Grand Anse site did not contain any suggestion of past logging, there is strong evidence that it is being directly affected by air pollution from the nearby Cabot Trail highway and, therefore, it was scored at the high end of the "light evidence..." category. The North River site also did not contain logging evidence, but its close proximity to an old sawmill and settlement, along with an apparent absence of very old trees, suggests that some logging may have occurred in the 1800s. Panuke Lake contained a scattering of old stumps throughout, providing evidence of light partial harvesting several decades ago. Although Sporting Lake scored a full 20 points, it is possible that a logging disturbance 150 years ago was responsible for the development of the second oldest cohort, but there was no direct evidence of this.
3) All stands contained many large trees, exceeding the thresholds for maximum diameter scores.
4) Despite the fact that mortality processes were well advanced and had been operating for a long time in all stands, none of them scored above the maximum threshold, and three of the four actually scored quite low. This suggests that the dead wood threshold may be set too high, and points to the need for further study. Although the stands had similar scores for large diameter live and dead wood, data show that there is a distinct difference between softwood and hardwood stands, pointing out the possibility that scoring may favour higher scores in softwood stands.
5) and 6) All stands had developed an uneven-aged structure due to gap dynamics and, therefore, scored full marks for evidence of canopy gaps and understorey layering.

All stands in the study had high, but not perfect, total scores. This is a positive indication that the scoring system was able to correctly rank this selection of high-quality stands near the high end of the scale. To date, only one of over 150 stands assessed in the province has scored a perfect 100. Although the study pointed out some potential weaknesses, generally the score sheet worked well for both the softwood and hardwood stand types. Further research will be required to look into dead wood dynamics and to investigate an apparent bias towards scoring softwood stands higher due to their inherently higher basal areas and densities.

Table 5. Old growth score sheet with summary evaluations

Feature	Score	Grand Anse	North River	Panuke Lake	Sporting Lake
1. Age of oldest 30 % of the basal area					
60 - 79 years "Immature"	5				
80 - 99 years "Mature"	10				
100 - 124 years "Mature"	20				
125 - 174 years "Early Old Growth"	30				30
≥ 175 years "Advanced Old Growth"	40	40	40	40	
2. Primal Forest Value					
Extensive or recent logging	0				
Light evidence of old partial logging	5–10	10*		5	
Past logging suspected but not evident	10–15		15		
Past logging unlikely	20				20
3. Diameter of Living Trees					
≥ 50 trees/ha with Dbh ≥ 40 cm	3				
≥ 70 trees/ha with Dbh ≥ 40 cm	6				
≥ 100 trees/ha with Dbh ≥ 40 cm	9				
≥ 20 trees/ha with Dbh ≥ 50 cm	12				
≥ 5 trees/ha with Dbh ≥ 60 cm	15	15	15	15	15
4. Bole Length of Snags and CWD					
≥ 400 m with diameter ≥ 20 cm	3				
≥ 200 m with diameter ≥ 30 cm	5	5	5	5	
≥ 200 m with diameter ≥ 40 cm	10				10
≥ 200 m with diameter ≥ 50 cm	15				
5. Overstory Crown Closure					
Uniform, little light penetration	2				
Uniform with scattered openings (hardwood)	5	5	5		
Mosaic of different densities (softwood/mixedwood)	5			5	5
6. Understory Structure					
One Understory	2				
Multiple understory layers	5	5	5	5	5
Total Score		**80**	**85**	**75**	**85**

*Direct disturbance in the form of car pollution and burning brakes was noted by Selva (1999) and research crew.

Conclusion

A study of four old-growth stands in Nova Scotia was conducted to document the ecological characteristics of these currently rare Acadian forest ecosystems. The study was used to gauge the utility of a recently developed Old Forest Scoring System that is currently employed in the province for old-growth inventory under the Interim Old Forest Policy (Nova Scotia Department of Natural Resources 1999). Two stands each were selected from both of the dominant climax forest types in the province, hemlock–spruce–pine and sugar maple–yellow birch–beech. The major findings are summarized below.

1. All stands were determined to be uneven-aged. An old growth reference age was calculated to represent the threshold (minimum) age of the oldest third of the trees (by basal area representation). The two hardwood stands had old growth reference ages of 178 and 197 years, and the two softwood stands 164 and 214 years.
2. Most trees in the hardwood stands ranged from 125 to 200 years old, with the oldest tree measured being a yellow birch of 313 years. The softwood stands contained evidence of two distinct age classes, the oldest being approximately 250–300^{+} years, and the second being 150–200 years old. Among the climax species, the oldest trees measured were eastern hemlock (333 years), yellow birch (313 years), red spruce (294 years), eastern white pine (288 years), sugar maple (245 years), and beech (132 years).
3. All stands had broad diameter distributions characteristic of uneven-aged stands. Peak basal area representation occurred at the 40- to 50-cm diameter classes, and maximum diameters measured in the stands ranged from 81.4 cm at Grand Anse to 90.4 cm at Panuke Lake. Hardwood stands were dominated by sugar maple throughout all diameter classes, with yellow birch present primarily at the middle and larger diameters. In the softwood stands, hemlock dominated through all diameters, with red spruce occurring at small and middle diameters. In the stand where it was common, eastern white pine was present primarily at large diameters. The softwood stands supported approximately twice the density and basal area of large diameter trees (≥ 40 cm dbh) as the hardwood stands.
4. Natural Q-factors were similar for all stands, with the hardwoods being slightly higher (1.41 and 1.44) than the softwood stands (1.36)
5. Volumes of dead wood (snags and CWD) were 111 and 148 m^3/ha in the softwood stands and almost half that for the hardwood stands (63 and 83 m^3/ha). However, the percentage of dead to live volume was similar for all stands, ranging from 20–28%. The total volume of dead wood in the stands consisted of roughly one-third snags and two-thirds CWD. All stands contained abundant dead wood in all decay classes indicating steady and ongoing gap dynamic mortality and decay processes.

6. Measurements from the stands were used to evaluate Nova Scotia's recently developed Old Forest Scoring System. Six stand attributes were rated: stand age, primal value, number of large-diameter trees, length of large-diameter dead wood, canopy structure, and understorey structure. The scores were relatively high, ranging from 75 to 85, as would be expected from some of the best old-growth stands in the province. The research suggested that the scoring system may favour higher scores for softwood in the evaluation of the diameter of live trees due to the inherent ability of softwoods to support higher densities of trees. In addition, all stands scored fairly low in the dead wood evaluation despite evidence of ongoing gap dynamics, suggesting that the dead wood thresholds may be set too high.

References

Bormann, F.H. and G.E. Likens. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, New York, NY.

Ducey M.J. and J.H. Gove. 1999. Downed wood as seedbed: measurement and management guidelines. *In* K.A. McManus, K.S. Shields and D.R. Souto (eds.). Proceedings: symposium on sustainable management of hemlock ecosystems in eastern North America. pp. 34–42. USDA GTR-NE-267. 234 p.

Honer, T.G., M.F. Ker and I.S. Alemdag. 1983. Metric timber tables for the commercial tree species of central and eastern Canada. Environment Canada, Canadian Forest Service – Atlantic Forestry Centre. Information Report M-X-140. 139 p.

Husch, B., C.I. Miller and T.W. Beers. 1982. Forest mensuration. 3rd edition. John Wiley and Sons, Inc. ISBN 0-471-04423-7. 402 p.

Kneeshaw, D.D. and P.J. Burton. 1998. Assessment of functional old-growth status: a case study in the Sub-Boreal Spruce Zone of British Columbia, Canada. Natural Areas Journal 18(4): 293–308.

Leak, W.B. 1987. Characteristics of five climax stands in New Hampshire. USDA Forest Service Research Note NE-336. 5 p.

Leverett, R. 1996. Definitions and history. *In* M.B. Davis (ed.). Eastern old-growth forests: prospects for rediscovery and recovery. pp. 3–17. Island Press, Washington, D.C.

Lynds, A. and J. Leduc. 1995. Old forests of Nova Scotia. Nova Scotia Department of Natural Resources Occasional Papers No.1. 18 p.

McGrath, T.P. 1997. Nova Scotia hardwood growth and yield model. Beta version. Nova Scotia Department of Natural Resources, Forest Management Planning.

McRae, D.R., M.E. Alexander and B.J. Stocks. 1979. Measurement and description of fuels and fire behavior on prescribed burns: a handbook. Canadian Forest Service – Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario. Information Report O-X-287.

Mehl, M.S. 1992. Old-growth descriptions for the major forest cover types in the Rocky Mountain region. *In* M.R. Kaufmann, W.H. Moir and R.L. Basset (tech. coords.). Old-growth forests in the southwest and Rocky Mountain Regions: proceedings of a workshop. pp. 106–120. USDA Forest Service General Technical Report RM-213.

Nova Scotia Department of Lands and Forests. 1990. Revised normal yield tables for Nova Scotia softwoods. Nova Scotia Department of Natural Resources. Forest Research Report 22. 45 p.

Nova Scotia Department of Natural Resources. 1999. Nova Scotia's old-growth forests: interim old forest policy. http://www.gov.ns.ca/natr/forestry/planresch/oldgrowth/policy.htm

Nova Scotia Department of Natural Resources. 2000a. Nova Scotia forest inventory – based on forest inventory permanent sample plots measured between 1994 and 1998. Report FOR 2000-1. 16 p.

Nova Scotia Department of Natural Resources. 2000b. Ecological land classification for Nova Scotia. Nova Scotia Department of Natural Resources. Digital Data DNR 2000-01.

Oliver, C.D. and B.C. Larson. 1990. Forest stand dynamics. McGraw-Hill. New York, NY, USA.

Selva, S.B. 1998. The caliciales of Nova Scotia and Prince Edward Island. Unpublished report prepared for the National Geographic Society (Scientific Research Grant Project # 5980-97). 31 p.

Selva, S.B. 1999. Survey of epiphytic lichens of late-successional northern hardwood forests in northern Cape Breton Island.

Sollins, P. 1982. Input and decay of coarse woody debris in coniferous stands in western Oregon and Washington. Canadian Journal of Forest Research 12:18–28.

Smith, H.C. and N.I. Lamson. 1982. Number of residual trees: a guide for selection cutting. USDA Forest Service General Technical Report NE-80. 33 p.

Spies, T. 1997. Forest stand structure, composition, and function. *In* K.A. Kohm and J.F. Franklin (eds.). Creating a forestry for the 21st century: the science of ecosystem management. pp. 11–30. Island Press. Washington, D.C.

Stokes, M.S. and T.L. Smiley. 1996. An introduction to tree ring dating. The University of Arizona Press. (First published in 1968 by the University of Chicago Press.) 73 p.

van Wagner, C.E. 1968. The line intersect method in forest fuel sampling. Forest Science 14(1): 20–26.

Wei X., J.P. Kimmons, K. Peel and O. Steen. 1997. Mass and nutrients in woody debris in harvested and wildfire-killed lodgepole pine forests in the central interior of British Columbia. Canadian Journal of Forest Research 27: 148–155.

Wells, R.W., S.C. Saunders and K.P. Lertzman. 1998. Old-growth definitions for the forests of British Columbia, Canada. Natural Areas Journal 18(4): 279–292.

Appendix I

Decay Classes

I. Freshly dead, bark intact, branches intact (including small), needle/leaf retention, bole sound, bole raised off ground on branches.

II. Beginnings of decay but rot not well established in wood that was sound at time of death. Bark mostly intact, branch stubs, bole not raised on branches, bole mostly sound.

III. Rot becoming established but sound at core. Bark loose and mostly flaked off, bole beginning to rot but maintaining structural strength—round, straight, not sinking into ground.

IV. Advanced decay. Bark mostly absent, bole mostly decayed with little or no sound wood present. Colonized with vegetation. Lacking structural strength—bole oval and bending to shape of ground. Last stage for snags, which will be rotted, wobbly, and could be easily pushed over.

V. Rotted through, becoming humus. Sunken into mound on the ground, but retaining a woody character, not yet part of the soil.