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Assessing the relative quality of old-growth forest: An example from the Robson Valley, British Columbia

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Abstract

Forest planners in British Columbia are required to identify forests suitable for designation as Old-Growth Management Areas. However, the tools currently in use lack the ability to identify appropriate stands. In 2000, we examined the ecological attributes of older forest in the Robson Valley Forest District in east-central British Columbia. The purpose was to determine the old-growth habitat value of stands of different age classes and to develop field procedures for assessing the relative old-growth quality of stands. We examined the relationships between stand age (both photo-interpreted and field-estimated) and attributes normally associated with old forest; in particular, we evaluated the relationship between stand age and functionally important tree and coarse woody debris configurations. Results from a representative portion of our study identified several attributes that were generally more abundant in older stands. The results also demonstrated that stands less than 140 years old have poorly developed old-forest habitat attributes, whereas these attributes are consistently well developed in stands greater than 140 years old. Also, the significance of these same attributes increases only slightly with increasing stand age. We created a rank scoring system to help forestry practitioners assess old-forest stands—particularly in the Interior Cedar–Hemlock (ICH) biogeoclimatic zone—in terms of their value as old-growth wildlife habitat.

KEYWORDS: *coarse woody debris, conservation, forest cover age class, forest management, older forest, old growth, old-growth habitat, old-growth management, old-growth quality, stand age, stand assessment, stand attributes, stand structure, wildlife trees, British Columbia.*

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Introduction

Before the landscape was subject to exploitation, development, and management by humans, old-growth forest was likely the prevailing type of land cover in areas where the climate is moist and wildfires are rare, such as in the coastal and interior rainforests of British Columbia. Old-growth forest is considered valuable for maintaining biological diversity, as wildlife habitat, as a benchmark for forest management, and for aesthetic and intrinsic reasons (Spies 1997; MacKinnon 1998; Spies and Turner 1999; Vallauri *et al.* 2001). However, in much of North America, and around the world, undisturbed and older forests are now uncommon features because land was cleared for agriculture and urban expansion, and as a result of wild forest being converted to managed plantations. Consequently, most natural resource managers recognize the need to identify, protect, and manage the remaining high-value old-growth habitat.

It is recognized that forests develop along a continuum of time (Spies and Franklin 1988; Hunter and White 1997). Yet, the designation of "old-growth" forest is a useful construct for identifying a certain portion of the age continuum because old-growth stand structures are perceived to impart some unique and important functional attributes. It is helpful to describe the structural attributes of old-growth stands as a means of identifying the most appropriate areas for protection or special management.

Definition of Old Growth

Presently in British Columbia, the definition of old growth used for forest planning is based solely on estimated stand age, which can be derived from forest cover maps and (or) from provincial forest inventory information (Holt *et al.* 1999). However, many studies have shown that stand age alone may not be sufficient to adequately describe the progress of stand development in older stands and that other attributes must be considered (Burton and Coates 1996; Kneeshaw and Burton 1997; Holt *et al.* 1999). An alternative approach is to use definitions of old growth based on multiple structural attributes because it is structure that provides the unique habitat values and ecosystem functions that confer special importance to old growth (Old-Growth Definition Task Group 1986; Spies and Franklin 1988; Franklin and Spies 1991; Hunter and White 1997; Kneeshaw and Burton 1998; Wells *et al.* 1998). Another approach is to identify organisms, such as lichens or bryophytes, that depend on old-growth conditions (Soderstrom 1988); however, this approach depends on acquiring more knowledge of these organism groups, a process that is in its infancy in British Columbia (Newmaster *et al.* 2003).

Mapped, or "inventory," stand age often underestimates the time since disturbance, but time since disturbance is not synonymous with stand age or the mean or maximum age of living trees (Cumming *et al.* 2000). In addition, some old stands contain few old-growth attributes or other diverse habitat features, and so may be less desirable for conservation purposes than younger stands. However, some of the attributes used to differentiate age classes via airphoto interpretation, such as snags and large trees with broken tops, are the same attributes that are indicative of old-growth forest. So, although the age since disturbance may be misinterpreted, and forest planners may question the accuracy of available inventory information, it is possible that the old-growth quality of stands can be reasonably well inferred from the forest inventory.

Project Scope and Purpose

As a component of the Enhanced Forest Management Pilot Project (EFMPP[1]) in the Robson Valley Forest District,[2] our project is part of a larger study that focuses on some key issues related to managing sustainable forests. The scope of our project comes under the heading "biodiversity conservation design outputs," and its main objective was to determine if stands of different mapped age classes can be discriminated based on structural features that are demonstrated to be associated with old-growth forest. A key issue that led to this

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[1] The EFMPP is a co-operative effort between the B.C. Ministry of Forests; B.C. Ministry of Water, Land and Air Protection; B.C. Ministry of Sustainable Resource Management; Forest Renewal BC; the forest industry; and the academic community. Its goal is to establish new, or to enhance existing, forest-management processes or tools by utilizing the expertise and experience of other EFMPP sites, model forests, academia, and researchers. For further background, refer to: ***http://www.for.gov.bc.ca/hcp/enhanced/robson/efmpp/index.htm***

[2] Following a re-organization of the B.C. Ministry of Forests in 2002, the Robson Valley Forest District (previously part of the Prince George Forest Region) was combined with the Clearwater Forest District to become the Headwaters Forest District of the new Southern Interior Forest Region.

study is that, structurally and functionally, "old-growth forest"—which is provisionally defined as Age Class 9[3] for Natural Disturbance Types 1 and 2 (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995[4])—may not be correctly approximated on the basis of mapped age classes. Also, it was important to determine if key structural differences of known habitat value exist between Age Class 8 stands and Age Class 9 stands, because Age Class 9 stands can be relatively rare and because allowing only Age Class 9 to represent old-growth forest can lead to spatial harvesting constraints.

Old-Growth Management Areas (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995) have been established in some parts of British Columbia. It is likely that more will be established in response to policy directives and (or) certification initiatives which require improved biodiversity conservation at the landscape level. Our study was conducted in part to develop an assessment tool for assisting forest managers to identify stands that have desirable old-growth structural features—as has been done for forests elsewhere by Mehl (1992), Burton and Coates (1996), Kneeshaw and Burton (1998), and Holt *et al.* (1999). This information should help forest managers make better-informed selections of Old-Growth Management Areas. In terms of initiatives for planning and managing sustainable forests, this information may also help refine the current standards for identifying old-growth forest, and for ensuring its representation in British Columbia.

We make use of a functional classification of wildlife trees and coarse woody debris developed by Keisker (2000). Keisker's report describes some common configurations (types) of wildlife trees and coarse woody debris used by wildlife for reproduction, resting, foraging, escape, and travel. The report describes the function and main users of each type, and how to identify each type in the field. We believe that this classification is functionally superior to those used in previous studies in which trees and coarse woody debris were classified based only on their current state (e.g., decay state, bark presence, etc.).

The purpose of our paper is to:

- outline the methods that we explored for assessing the wildlife habitat quality of old-growth stands;
- determine if a reliable relationship exists between forest cover age class and old-growth structural features within sampled stands;
- illustrate the field assessment tool that we developed by using results from one of the four biogeoclimatic units (Meidinger and Pojar 1991) we assessed; and
- indicate how this type of tool could assist in selecting Old-Growth Management Areas in the study area and elsewhere.

> ***Our study was conducted in part to develop an assessment tool for assisting forest managers to identify stands that have desirable old-growth structural features. This information should help forest managers make better-informed selections of Old-Growth Management Areas.***

Methods

Study Area

The study took place within the Robson Valley Forest District in east-central British Columbia, in forests on the slopes of the Cariboo Mountains and Rocky Mountains. The study was conducted in four of the main biogeoclimatic units occurring within the District. The biogeoclimatic unit that this paper addresses is the moist mild subzone of the Interior Cedar–Hemlock zone (ICHmm) (Ketcheson *et al.* 1991; Meidinger and Pojar 1991). The ICHmm subzone occurs at 750–1250 m elevation on the lower valley walls above Kinbasket Reservoir from Hugh Allen Creek to Valemount, on the southwest side of the valley between Albreda and Dunster, and again on both walls of the Rocky Mountain Trench between Dunster and the McKale River.

The ICHmm subzone has a mean seasonal (May to September) precipitation of 280 mm. The dominant

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[3] Age Classes 5–7 = mature forest, 80–140 years old. Age Class 8 = old forest, 141–250 years old. Age Class 9 = very old forest, > 250 years old.

[4] Natural Disturbance Type 1 ecosystems experience rare stand-initiating events; Natural Disturbance Type 2 ecosystems experience infrequent stand-initiating events.

climax tree species is western redcedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*) is codominant in most stands. Minor components of hybrid white spruce (*Picea glauca* x *engelmannii*) and subalpine fir (*Abies lasiocarpa*) also occur. Douglas-fir (*Pseudotsuga menziesii* var. glauca) is a common species of most stands on drier sites. Lodgepole pine (*Pinus contorta* var. *latifolia*) and trembling aspen (*Populus tremuloides*) are the most common seral species. Paper birch (*Betula papyrifera*) is scattered throughout the subzone, especially on warm slopes.

More seral stands and fewer old-growth stands occur in this subzone of the ICH than in any other subzone in the region. Two possible reasons for this are: the drier climate leads to drier forest fuel during the summer (which is when lightning occurs), and hence relatively frequent wildfires; and fire activity, associated with construction of the Grand Trunk Pacific railroad, spiked approximately 70 years ago. This subzone was classified as Natural Disturbance Type 2 according to the Forest Practices Code of British Columbia's *Biodiversity Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995).

Site Selection

Sites were selected within the ICHmm subzone across a range of stand ages. Stands were selected to represent three categories: Age Classes 5–7, Age Class 8, and Age Class 9.[5] Potential polygons were located using airphotos and geographic information system coverages of the 1998 forest inventory. For logistical reasons the number of candidate polygons was reduced by considering only those located within 500 m of a road. To reduce variation due to factors unrelated to age, we attempted to limit sampling to sites with zonal (mesic) attributes (i.e., gentle mid-slopes with medium-textured soils), but inclusion of some slightly wetter (subhygric) and slightly drier (submesic) sites was unavoidable due to the lack of suitable sampling sites. Selected polygons were assessed using airphotos to determine basic site features such as slope gradient, aspect, slope position, and parent material. This information then permitted us to choose areas as representative and homogeneous as possible in terms of site and soil conditions.

To be acceptable, a forest cover polygon selected for field sampling also had to contain a large proportion of climax tree species and show no evidence of stand-level disturbance (i.e., no harvesting, recent fires, or insect infestations). Stands also had to be large enough to accommodate three sampling transects (> 5 ha). Based on these factors, the 30 most uniform polygons (10 for each age class category) were selected as potential sampling locations.

In 2000, we sampled five stands from each category (mature, old, and very old) in the ICHmm subzone. Attributes of the sites are shown in Table 1. A shallow soil pit was dug to determine soil moisture regime and soil nutrient regime according to methods described by Luttmerding *et al.* (1990). Along with indicator plants, soil moisture regime and soil nutrient regime were used to determine the site series of each plot (DeLong *et al.* 1996).

Stand Structure Sampling

We walked 100 m into the stand denoted by each selected polygon, along a bearing roughly perpendicular to the polygon's edge. From this point we laid out a 100-m transect using a random bearing. From the end of this transect we laid out another 100-m transect at a different random bearing; and, likewise, a third transect was laid out from the end of the second one. We limited the choice of bearing such that each transect stayed at least 30 m from the polygon edge, to minimize edge effects. No transect overlapped another.

Along each 100-m transect, we conducted sampling at one randomly located, fixed-area, circular plot of 0.1 ha (17.84 m radius). We measured a number of attributes for each > 7.5-m-DBH tree within the plot. The attributes of importance to this paper were DBH, "Wildlife Tree Types" as per Keisker (2000) (see Appendix 1), and commonly used "tree damage codes" indicative of stem damage or tree pathogens. We also identified trees that fit the configuration described for Coarse Woody Debris Type 1 and Type 3 (Appendix 2). Dead trees that were broken at or below their estimated midpoint were recorded as stubs.

For each transect, height and age were determined for a minimum of two canopy trees per species, selected from trees within the stand structure plots. The selected canopy trees were generally the largest of the trees that appeared to be relatively healthy. To determine age, an increment core was taken at 1.3 m above the estimated point of germination. For trees with rotten centres (primarily redcedar or hemlock) the age was estimated, but only if the core length was at least one third of the

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[5] See Footnote 3.

TABLE 1. Summary of site information for sample stands

Stand no.	Age class: From forest cover maps	Age class: Actual[a]	Tree age: Mean (yr)	Tree age: Max. (yr)	Slope gradient (%)	Aspect (°)	Relative soil moisture regime[b]
H20-285	8	9	386	507	60	300	Mesic
H20-575	9	9	401	554	55–65	305	Submesic
H29-95	9	9	493	938	0	NA	Mesic–subhygric
H30-624	6	5	87	123	5–70	160	Mesic
D56-1650	8	8	154	232	20–30	65	Submesic
D65-1712	9	9	339	461	10–25	20	Mesic
D65-1545	8	9	269	487	30–40	50	Mesic
D65-1731	8	8	161	213	10–40	45	Mesic
D66-420	7	8	144	214	25–35	70	Mesic–submesic
D73-427	8	9	351	688	25–35	330	Mesic–subhygric
D74-142	6	7	139	166	5–40	60	Mesic
D74-440	5	5	89	132	30–50	150	Mesic–submesic
D75-492	9	9	380	644	0	NA	Submesic
E04-1171	9	9	415	603	10–15	120	Mesic–subhygric
E04-1191	5	4	73	94	0–10	NA	Mesic–subhygric

[a] Age class is based on mean age of oldest trees.

[b] Relative soil moisture regime according to methods in Luttmerding *et al.* (1990).

radius of the tree. For incomplete cores, tree age was estimated by multiplying the countable rings by the radius of the tree divided by the core length (Kneeshaw and Burton 1997; Holt *et al.* 1999). We also determined the age of any nearby Douglas-fir trees even if they were not in the sample plot. This species is early successional in this region (i.e., likely to have established soon after wildfire) and Douglas-fir boles tend to be sound; therefore they can provide a reliable estimate of stand age. Before determining the age of a Douglas-fir we checked for signs of basal fire scars to ensure that the tree had not survived a stand-replacing event. Stand age was calculated based on the mean age of the sampled trees (i.e., largest trees of each species). We decided not to designate stand age as the age of the oldest tree sampled, for two reasons. First, we had to estimate some tree ages (as described above) due to the presence of centre rot, so individual ages were sometimes not reliable. Second, if an individual tree had survived the last stand-initiating event without showing obvious signs of that event, it would be older than the rest of the stand.

Coarse Woody Debris Sampling

To measure coarse woody debris, we randomly selected a 30-m segment in each 100-m transect. Bole diameter at the point of intersection was measured for each piece greater than 7.5 cm in diameter. In addition, “Coarse Woody Debris Wildlife Type” (as per Keisker 2000) was described for each piece (see Appendix 2). The total volume density of coarse woody debris was calculated for each transect using the formula described in Van Wagner (1968, 1982):

$$v = \frac{\pi^2 \sum d^2}{8L}$$

where: v is volume in m^3/ha, d is diameter (cm) of each piece of coarse woody debris intersected by the transect, and L is the length (m) of the transect (i.e., 30 m here).

Data Analysis

Because this study was part of a pilot project, we collected data for a large number of exploratory variables used to characterize forest stands. To make the data more appropriate for analysis and for developing the decision tool, we used graphs and basic summary statistics to eliminate variables that had many zero values (i.e., were not consistently present) or had low mean values (i.e., were difficult to detect in a sample survey) across the sampled population of stands. We also limited analyses to variables that have been demonstrated to have functional value for wildlife (e.g., large trees or Wildlife Tree Types). Table 2 lists the variables considered in the analysis for the ICHmm subzone. To examine age trends, we produced a simple correlation matrix between stand age and the variables assessed. For some of the variables that correlated highly with stand age, we graphed and regressed attribute values against mean plot age. Combined with a visual inspection of the graphed data, these linear regression analyses determined whether the variables were changing along a continuous time scale, rather than in discrete steps according to arbitrary age or stage classes. For the purposes of regression analysis we used mean age per plot, rather than per stand.

Discriminant Analysis

We chose to use discriminant analysis to determine whether stands in different age categories displayed differences in old-growth structural attributes or wildlife habitat values. Discriminant analysis provides linear or quadratic functions of the variables that "best" separate cases into two or more predefined groups (Wilkinson *et al.* 1996), which in this project were three different stand age categories.

We used SYSTAT (SPSS 1999) to determine Mahalanobis distances (multivariate differences) that then assign an individual stand to one age category or another. We used mean stand values for each variable, calculated as the mean of data collected from the three transects. The initial set of variables is shown in Table 2. We used backwards stepwise discriminant analysis at a significance level of $p < 0.05$ to limit the number of variables in the final model. We report the jackknifed classification matrix of properly classified stands. The jackknifing procedure attempts to approximate cross-validation by systematically omitting single cases (stands) in order to classify the remaining ones (Wilkinson *et al.* 1996). Although this presents a somewhat optimistic classification, it is the best we could do to create a validation dataset without undertaking further sampling. For each canonical variable, discriminant analysis produces a canonical score for each case. The first canonical variable is the linear combination of the variables that best discriminates among the groups (age categories), while the second canonical variable is orthogonal to the first and is the next best combination of variables, and so on. A canonical scores graph of the first two canonical variables is used to illustrate degree of separation of the groups (Figure 2).

Score Ranking

We developed a simple procedure to rank stands based on their structural value for wildlife. For each of the variables listed in Table 2, except the indicators of tree damage, we systematically ranked the sample stands from highest to lowest value. For each variable, the stand scored two points if it was in the top third of stands (i.e., top 5 of 15), one point if it was in the middle third, and zero if it was in the bottom third. We then summed these assigned values into an overall score for each stand. To simplify this for field use we selected a subset of variables that could be easily and quickly measured in the field. For this simplified scoring system we selected threshold values that roughly represent the lowest value for the top third and middle third of stands.

Results

Stand Age

Field-estimated stand age for the 15 sampled stands ranged from 73 to 493 years (Table 1). Stand ages calculated from tree cores differed from the forest cover labels for several polygons. Based on mean age of the largest trees, 6 of 15 stands were mistyped on the forest cover maps. All five stands mapped as Age Class 9 were indeed greater than 250 years in age, but three of the five stands mapped as Age Class 8 were also found to be Age Class 9, while the other two were correctly labelled. Of the five stands mapped as Age Classes 5, 6, or 7, two Age Class 5 stands were mapped correctly, while one was mapped as Age Class 6; as well, one Age Class 7 stand was incorrectly mapped as Age Class 6, while another one was actually Age Class 8 (Table 1).

Age Class Differences in Stand Attributes

A number of the 15 variables differed substantially among the three categories of mapped stand age, as shown in Table 2. When viewed across the continuous stand-age gradient, a number of stand attributes correlated significantly with the mean estimated tree age of the stand. Those attributes exhibiting the most

TABLE 2. Mean and standard deviation of selected variables for ICHmm stands mapped as Age Classes 5–7, Age Class 8, and Age Class 9

Variable	Mapped age category[a]					
	Age Classes 5–7 (n = 5)		Age Class 8 (n = 5)		Age Class 9 (n = 5)	
	Mean	SD	Mean	SD	Mean	SD
Coarse woody debris with concealed spaces – Coarse Woody Debris Types 1 to 3 (no. pieces per 30 m)	0.13	0.18	0.87	0.61	2.13	0.84
Coarse woody debris with concealed runways – Coarse Woody Debris Type 4 (no. pieces per 30 m)	1.73	1.09	2.2	0.87	2.13	0.61
Coarse woody debris with exposed travel lanes – Coarse Woody Debris Type 5 (no. pieces per 30 m)	4.27	2.31	3.60	0.98	5.27	1.40
Trees with large concealed spaces at base (no. stems per hectare)	14.7	15.0	98.7	31.1	104.0	26.0
Trees with hard outer wood surrounding soft inner wood – Wildlife Tree Type 1 (no. stems per hectare)	68.7	29.3	92	36.6	138.7	19.8
Trees with excavated or natural cavities – Wildlife Tree Types 3 to 5 (no. stems per hectare)	2.7	3.7	9.3	6.8	11.3	5.6
Trees with loose or furrowed bark – Wildlife Tree Type 6 (no. stems per hectare)	8.7	5.6	36.7	11.3	31.3	17.9
Trees with forked stems (no. stems per hectare)	10.0	8.2	41.3	18.3	45.3	9.6
Trees with frost cracking (no. stems per hectare)	8.0	5.1	14.7	11.2	23.3	22.5
Trees with dead or broken tops (no. stems per hectare)	14.7	6.5	38.7	15.2	41.3	10.2
Total tree damage indicators (no. stems per hectare)[b]	73	45	167	44	197	17
Stubs (no. stems per hectare)	14.0	2.4	21.3	5.3	24.7	6.0
Density of snags greater than 50 cm DBH (no. stems per hectare)	3.3	3.3	22.0	15.2	19.3	10.4
Density of trees greater than 50 cm DBH (no. stems per hectare)	45.3	48.2	110.0	57.6	152.0	49.6

[a] Age Classes 5–7 = mature forest, 80–140 years old. Age Class 8 = old forest, 141–250 years old. Age Class 9 = very old forest, greater than 250 years old.

[b] Sum of tallied trees that had dead or broken tops, scars, frost cracks, forks, or conks. A tree may have been counted more than once if it showed more than one indicator.

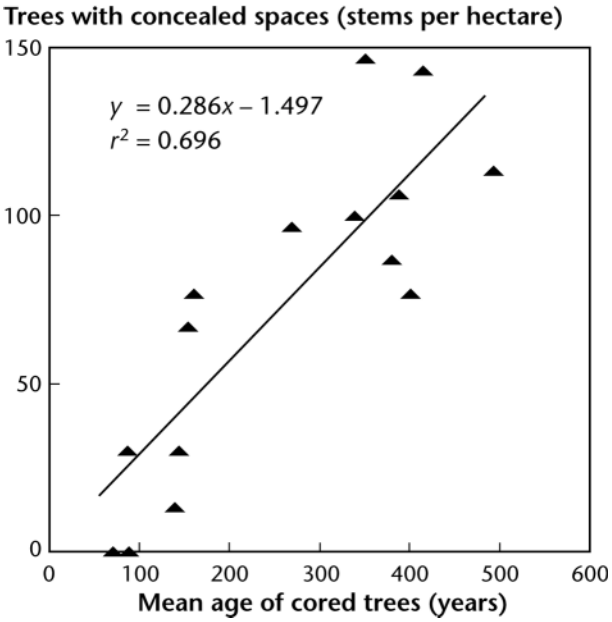

FIGURE 1. Relationship of the density of trees with concealed spaces at base (associated with denning habitat) to the mean age of two dominant trees of each species found in each plot sampled in old ICHmm stands.

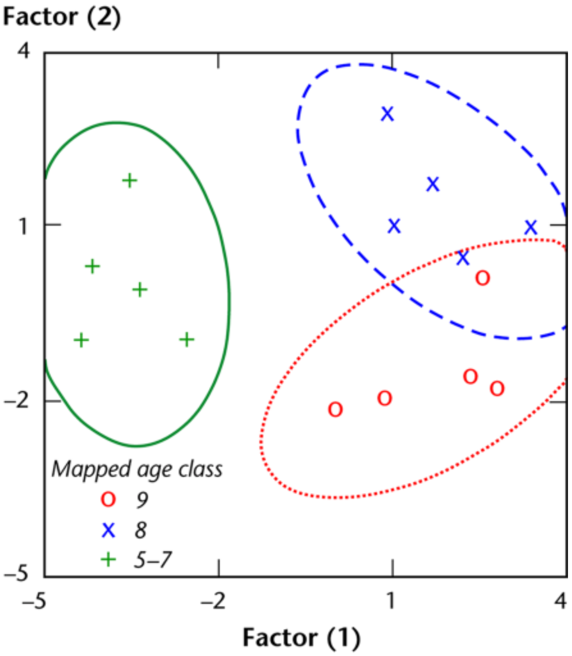

FIGURE 2. Canonical scores graph from discriminant analysis, showing relationship of stands of different mapped age classes.

significant ($p < 0.01$, $n = 15$) positive correlations with field-estimated stand age include the following:

- trees with concealed spaces at base (no. stems per hectare): $r = 0.85, p = 0.0001$
- pieces of coarse woody debris with concealed spaces (no. pieces per 30 m): $r = 0.79, p = 0.0005$
- density of live trees greater than 50 cm DBH (no. stems per hectare): $r = 0.75, p = 0.0012$
- density of trees with dead or broken tops (no. stems per hectare): $r = 0.71, p = 0.0032$
- incidence of all tree damage indicators (no. stems per hectare): $r = 0.70, p = 0.0038$

Figure 1 portrays the relationship of the density of trees with concealed spaces at the base to increasing stand age.

Discriminant Analysis

The best jackknifed classification for distinguishing mapped age class groupings classified 12 of 15 stands correctly. All of the stands in Age Classes 5–7 were classified correctly, while three of the five Age Class 8 stands and four of the five Age Class 9 stands were correctly classified. Both of the misclassified Age Class 8 stands were classified as Age Class 9. For one of these stands (stand D73-427) the mean age of cored trees was 351 years (Age Class 9), but for the other (stand D65-1731) it was 161 years (Age Class 8). The Age Class 9 stand that was incorrectly classified as Age Class 8 was the oldest stand sampled (stand H29-95); the mean age of its largest trees was 493 years.

The canonical scores graph demonstrates a clear separation of the stands mapped as Age Classes 5–7, but shows some overlap in the stands mapped as Age Class 8 and Age Class 9 (Figure 2). The two Age Class 8 stands closest to the Age Class 9 grouping in the graph are the stands that were misclassified as Age Class 8 in the jackknifed classification matrix. The Age Class 9 stand very close to them was the stand misclassified by the jackknifed matrix as Age Class 8. The Age Class 8 stand that is furthest from the other Age Class 8 and 9 stands is stand D56-1650, which had an estimated stand age of 154 years.

The variables used in the final classification were the density of:

- trees with concealed spaces at the base (i.e., trees classified as Coarse Woody Debris Type 1) (Keisker 2000);
- trees that were soft inside and hard outside (i.e., trees classified as Wildlife Tree Type 1) (Keisker 2000);

- total tree damage indicators identified in tree sampling;
- trees greater than 50 cm DBH; and
- snags greater than 50 cm DBH.

Stand Ranking

The top eight stands, ranked according to the stand attributes listed in Table 2 (but excluding the indicators of tree damage), had a mean age of largest trees greater than 250 years (i.e., they were truly Age Class 9) (Table 3). The other seven stands (i.e., ranked 9–15) had a mean age of largest trees of less than 170 years, with the bottom three having a mean age of largest trees less than 100 years (Table 3). The simplified field scoring system shown in Table 4 ranked the stands slightly differently: one stand (D65-1731) with a mean large tree age of only 161 years still ranked in the top eight. This same stand was misclassified as Age Class 9 by the discriminant analysis. The values for stands using the field scoring system were: ≥ 7 for stands greater than 160 years old, and ≤ 4 for stands less than 160 years old (Table 3).

Discussion

The definition of old-growth forest, and the best way to determine areas most suitable for selection as Old-Growth Management Areas in British Columbia, have recently received much attention (Burton and Coates 1996; Quesnel 1996; Wells *et al.* 1998; Kneeshaw and Burton 1998; Holt *et al.* 1999). Currently, land managers rely on forest cover age class, which is generally photo-interpreted, to determine the amount of old-growth forest present and—in the absence of any better

TABLE 3. Values for selected old-growth stand structure features, and ranking scores for old-growth features, for stands sampled in the ICHmm subzone

Stand no.	Mean age (yr)	Concealed space[a] (stems/ha)	Soft tree[b] (stems/ha)	Damaged tree (stems/ha)	Large tree[d] (stems/ha)	Large snag[d] (stems/ha)	Ranking score[e]
E04-1171	415	143	127	190	217	20	21 (10)
D65-1712	339	100	153	216	163	27	21 (12)
H20-575	401	77	157	210	117	17	21 (8)
H20-285	386	107	57	110	173	20	20 (10)
H29-95	493	113	110	173	173	30	19 (11)
D73-427	351	146	110	226	103	7	18 (8)
D75-492	380	87	146	193	90	3	18 (7)
D65-1545	269	97	67	143	150	23	16 (9)
D65-1731	161	77	147	180	100	47	14 (10)
D56-1650	154	67	80	173	23	13	13 (4)
D74-142	139	13	116	147	33	3	9 (2)
D66-420	144	30	70	77	43	0	8 (4)
E04-1191	73	0	47	53	127	0	5 (3)
D74-440	89	0	43	63	23	6	5 (2)
H30-624	87	30	67	27	0	7	(2)

[a] Concealed space = tree with spaces at the base (minimum 10 cm diameter opening), where an animal (mustelid and larger) can hide from view.

[b] Soft tree = tree that is soft on the inside, as determined by direct observation or based on indicators of internal rot (e.g., conks).

[c] Damaged tree = tree that has a fork or a broken top, or has scars, frost cracks, or conks.

[d] Large tree and large snag = tree or snag > 50 cm DBH.

[e] Ranking score not in brackets was obtained by using the full set of variables in Table 2 (excluding the indicators of tree damage). Score in brackets was obtained by using reduced set of variables for the field scoring tool shown in Table 4.

TABLE 4. Field scoring tool for assessing old-growth wildlife habitat value of an ICHmm stand

Value	Threshold (stems/ha)	Score[a]
Tree with large concealed spaces at the base	≥ 100	2
	≥ 50	1
Tree soft on the inside, but hard on the outside	≥ 120	2
	≥ 70	1
Tree with loose or furrowed bark	≥ 30	2
	≥ 10	1
Stub	≥ 20	2
	≥ 10	1
Snag greater than 50 cm DBH	≥ 20	2
	≥ 10	1
Live tree greater than 50 cm DBH	≥ 150	2
	≥ 90	1

[a] Total stand score is determined by adding the scores for all the values. Score for each value is 2 if the value exceeds the upper threshold, 1 if the value exceeds the lower threshold, and 0 if the value is below the lower threshold.

information—to choose Old-Growth Management Areas. The age thresholds for what constitutes "old-growth forest" are selected fairly loosely on the basis of the expected fire return interval and the resulting classification of natural disturbance type by biogeoclimatic subzone (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995). But both the identification of old-growth thresholds and the age of mapped forest polygons would benefit considerably from a better understanding of these ecosystems and better empirical data from ground-based inventories. Below we discuss the implications of having inadequate information, how to make the best of what we have, and how to apply the results reported here.

Use of Available Forest Inventory Classifications

Using the existing forest cover age classification appears to be an unreliable means of identifying the true age of stands. The error rate of 40% for the ICHmm subzone is a rough estimate based on only 15 stands where a number of sampled trees did not have complete cores. However, this error rate is not uncommon; the larger study, from which the ICHmm data are taken (Harrison *et al.* 2001), indicated an error rate between 20 and 40%. Similar problems have been identified in the Nelson Forest Region by Holt *et al.* (1999).

The ability of the existing forest cover age classification to identify stands with more well-developed old-growth attributes important to wildlife is also unreliable; but, with only 20% of stands misclassified, it is more reliable than identifying stand age. Stands mapped as Age Class 7 (120–140 years old) and lower clearly have not developed the same number of stand structural elements of potential value to wildlife as stands mapped as Age Class 8 or 9. While stands mapped as Age Class 9 tend to have higher numbers of wildlife structures than stands mapped as Age Class 8, the overlap is considerable. On the canonical scores graph (Figure 2), two of the three stands that were classified by the discriminant analysis as belonging to the Age Class 8 group were close to the Age Class 9 stands. These stands also had estimated ages of greater than 250 years. The other stand classified as Age Class 8 by the discriminant analysis, but which was further away from the others on the graph, had an estimated stand age of 154 years. These findings indicate that stands mapped as Age Class 8 may have similar structural value for wildlife as stands mapped as Age Class 9.

The finding that a 161-year-old stand was grouped with older stands by both the discriminant analysis and the field ranking tool (Table 4) lends support to the notion that stand age alone is insufficient to describe or determine the emergence of old-growth attributes valued for biodiversity (Kneeshaw and Burton 1998; Wells *et al.* 1998; Holt *et al.* 1999). Some stands, on some sites, acquire large trees, gaps in the canopy, multiple canopy layers, and a diversity of snag and downed wood habitats before other stands do. Furthermore, "stand age" is not always the simple attribute that forest inventory conventions would lead us to believe; many stands have veteran survivors from a previous generation of trees, or several cohorts of trees that may or may not correspond to time since fire, which may or may not have killed all trees in a given mapped polygon (Johnson 1992). Consequently, when land managers and planners assess the value of old-growth stands, stand age (as conventionally defined) should be just one of several attributes they consider.

Because airphoto interpreters place a good deal of weight on the stature of trees, gaps in the canopy, and the heterogeneity ("texture") of the tree layer to indicate forest cover age class, they are often mapping indicators of old-growth forest. All of these features are more indicative of structural attributes associated with old growth than of a one-to-one match with stand age. If airphoto interpreters were to receive more specific training in identifying old-growth features, we suggest that airphoto assessment could be a very effective tool for selecting Old-Growth Management Areas; however, this remains to be tested. In a recent study in the Kootenay region of British Columbia, McCleary and Mowat (2002) were successful in using stand structural features interpreted from airphotos to identify six structural classes of forest, including an old-forest category.

Use of Functional Coarse Woody Debris and Wildlife Tree Classifications

We believe our study represents the first reported attempt to use a functional classification of wildlife trees and coarse woody debris to rate stands for their value as wildlife habitat and old growth. Other studies (e.g., Kneeshaw and Burton 1998; Holt *et al.* 1999) have used classifications that employed the state (e.g., decay level), rather than the potential use, of large trees or coarse woody debris.

Many of the functional types were used in the scoring system. But only two types—trees with large concealed spaces at the base (Coarse Woody Debris Type 1), and trees that were hard on the outside and soft on the inside (Wildlife Tree Type 1)—were used in the final discriminant analysis and for developing the field scoring tool.

One concern regarding the use of coarse woody debris and wildlife tree categories for identifying old-growth stands may be that these classifications involve a greater degree of subjective judgement than using other measures (such as, snag density, coarse woody debris volume, or the density of trees > 50 cm DBH). However, the more objective measures do not directly relate to a particular utility to wildlife; that is, even though the objective measures may be more abundant in old stands, this fact may not impart any special wildlife habitat value to these stands. Furthermore, providing field staff with training, and encouraging them to rely on their local experience and use judgement checks (calibrations), together can help ensure a high degree of reliability and repeatability in the classification of functional coarse woody debris and wildlife tree categories.

Assessing Stands for Old-Growth Attributes

Most researchers and forestry practitioners acknowledge that definitions of old growth based on stand age alone, though often easy to employ, are not the most useful for assessing stands for old-growth attributes (Spies and Franklin 1991; Kneeshaw and Burton 1998; Wells *et al.* 1998; Holt *et al.* 1999). Our study demonstrates that great age alone is neither necessary nor sufficient for a stand to function as old-growth wildlife habitat. However, it also demonstrates that mapped age class provides a good first step for differentiating stands of higher old-forest value from those with lower old-forest value. Any mapped or actual age class relationship with old-growth attributes needs to be determined empirically in each forest type, not just arbitrarily set at a particular value (e.g., Age Class 9 for Natural Disturbance Types 1 and 2, as per the *Biodiversity Guidebook*) (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995).

The density of large trees and (or) snags was a common diagnostic feature in all of the biogeoclimatic units examined by Harrison *et al.* (2001), of which the ICHmm subzone is a subset. Large tree and snag density was also found to be a discriminatory feature in other studies, including studies in the Interior Cedar–Hemlock zone in the Nelson Forest Region (Quesnel 1996; Holt *et al.* 1999), in the Sub-Boreal Spruce zone (Burton and Coates 1996; Kneeshaw and Burton 1998), and in Washington and Oregon forests (Spies and Franklin

1991). In Douglas-fir and western hemlock stands in Oregon and Washington, overstorey features were found to be most important in discriminating stands, with decline in tree density and increase in tree size being important features of structural change (Spies and Franklin 1991).

Variables with the greatest power to distinguish stands that are mapped or field-aged to be greater than 250 years old include a number of attributes that are recognized to serve potentially important functions in old-growth stands. The density of trees having large concealed spaces (Coarse Woody Debris Type 1) and the density of trees soft on the inside, but hard on the outside (Wildlife Tree Type 1) were key distinguishing attributes for Age Class 8 stands in the ICHmm subzone.

Deciding which attributes should be considered when identifying old growth can be difficult. Harrison *et al.* (2001) found 8 to 16 attributes that were significantly different among stand age classes for different biogeoclimatic units. Because it is impractical to always inventory all attributes, it is important to identify those that exhibit the strongest relationship to old-growth value. Harrison *et al.* (2001) also found that such attributes varied widely between biogeoclimatic units, indicating that assessment procedures need to be specific to an area (i.e., biogeoclimatic subzone or variant), and that attributes selected for identifying old-growth stands may not be the same as those that other studies define as being most central to the definition of old growth.

The field scoring system developed for the ICHmm subzone (Table 4) can be used to rank assessed stands on their value for old-growth wildlife habitat. The scores can be used to assess the "quality" of stands based on a number of attributes that relate to the function of old growth as wildlife habitat. Each stand scored can be compared with others in order to select the best stands in a sample of potential sites, or stands can simply be assessed as appropriate or inappropriate for protecting old-growth wildlife habitat value. With this system, it is suggested that a score of seven or better for the ICHmm subzone would identify a stand as having acceptable old-growth wildlife habitat value. Because sampling was conducted on submesic to subhygric sites, this tool should be used cautiously on drier or wetter sites.

This scoring system is analogous to the old-growth scorecards published by Mehl (1992) for stands in the southern Rocky Mountains and by Kneeshaw and Burton (1998) for stands in the moist cool variant of the Sub-Boreal Spruce zone (SBSmc).

Conclusions and Recommendations

For the ICHmm subzone, stands mapped as different age classes can be discriminated from one another based on stand structural attributes associated with old forest, although the discrimination between Age Class 8 and 9 stands is weak. Some Age Class 8 stands exhibit old-growth attributes more characteristic of Age Class 9 stands. Although wildlife habitat values for Age Classes 8 and 9 stands appear to be similar, values may not be the same for specialized organisms such as arboreal lichens because lichens may continue to develop species diversity with increasing stand age (Goward 1993). Stands mapped as being less than 140 years old in the ICHmm subzone have poorly developed old-growth stand structure; these stands have little value for wildlife that require old-growth structural features for reproduction, resting, foraging, escape, and travel.

We believe that Keisker's (2000) functionally based assessment of stand structural elements is superior to traditional mensuration-based criteria for assessing the quality of old-growth stands. We recommend that forestry practitioners be trained to identify Keisker's structural habitat types.

Field tools, like the one described here for the ICHmm subzone, can be relatively efficient for identifying suitable Old-Growth Management Areas, but a separate tool needs to be developed for each climatically different area (e.g., biogeoclimatic unit). Forest planners can use these tools to rank stands for old-growth designation or old-growth recruitment while considering a number of other factors. It is suggested that the tool be the last step in a procedure. First, potential stands are selected based on their mapped age class or based on more refined airphoto interpretation. Second, the number of candidate stands is reduced by assessing the ability of each to comply with the current harvesting plans, other conservation values (e.g., old-growth-dependent lichens), and other social values (e.g., visual quality). Finally, by using the field tool to assign a score to each stand—whereby a minimum score of seven represents acceptable old-growth wildlife habitat value—the number of candidate stands is further reduced. Even when these tools are used to rank old-growth stands, we acknowledge that some high-quality old-growth stands may not receive protection in one area, while poorer quality stands may come under old-growth management in another area. In all cases, it is important that land managers and planners consider what particular attributes of stand structure and wildlife habitat are being traded off. We hope that projects like the one discussed in this paper will help support wise decision making in the recognition and management of old-growth forest.

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APPENDIX 1. Wildlife Tree Types, arranged by function, as defined by Keisker (2000)

Main functions of wildlife trees	Configurations of wildlife tree features required by wildlife species in the Sub-Boreal Spruce, Engelmann Spruce–Subalpine Fir, and Interior Cedar–Hemlock zones		Main users of wildlife trees
	Wildlife tree type	Description	
REPRODUCTION/RESTING			
Substrates for excavation of cavities	WT-1	Hard outer wood surrounding decay-softened inner wood	Woodpeckers (stronger excavators)
	WT-2	Outer and inner wood softened by decay	Woodpeckers (weaker excavators), chickadees, red-breasted nuthatch
Existing cavities	WT-3	Small, excavated, or natural cavities	Chickadees, nuthatches, northern pygmy-owl, swallows, other passerines, bats
	WT-4	Large excavated or natural cavities	Ducks, American kestrel, owls, mountain bluebird, European starling, northern flicker, swallows, other passerines, bats, squirrels, marten
	WT-5	Very large natural cavities and hollow trees	Vaux's swift, mustelids, barred owl, bats, red squirrel
	WT-6	Cracks, loose bark, or deeply furrowed bark	Brown Creeper, bats
Large open-nest supports and other non-cavity sites	WT-7	Witches' broom	Squirrels, mustelids, merlin, owls
	WT-8	Large branches, multiple leaders, or large-diameter broken tops	Great blue heron, diurnal raptors, owls, common raven
FORAGING			
Feeding substrates	WT-9	Arthropods in wood or under bark	Woodpeckers
Hunting perches	WT-10	Open-structured trees in or adjacent to open areas	Diurnal raptors, owls, various passerines, belted kingfisher

APPENDIX 2. Coarse Woody Debris Wildlife Types, arranged by function, as defined by Keisker (2000)

	Configurations of coarse woody debris features required bywildlife species in the Sub-Boreal Spruce, Engelmann Spruce–Subalpine Fir, and Interior Cedar–Hemlock zones		
Main functions of coarse woody debris	**Coarse woody debris type**	**Description**	**Main users of coarse woody debris**
REPRODUCTION/ RESTING[a]/ESCAPE			
Concealed spaces	CWD-1	Large concealed spaces	Cats, mustelids, grouse, snowshoe hare, bushy-tailed woodrat, porcupine, canids, black bear
	CWD-2	Small concealed spaces (or soft substrate allowing excavation of such spaces) at or below ground level beneath hard material	Amphibians, snakes, shrews, voles, squirrels, deer mouse, jumping mice, weasels
	CWD-3	Small concealed spaces above ground level	Winter wren, Townsend's solitaire, northern waterthrush, Pacific treefrog, flycatchers, other passerines, deer mouse
TRAVEL			
Concealed runways	CWD-4	Long concealed spaces (or soft substrate allowing construction of runways)	Long-toed salamander, voles, rubber boa, shrews, deer mouse, squirrels, weasels
Exposed, raised travel lanes	CWD-5	Large or elevated long material, clear of dense vegetation	Squirrels, marten
FORAGING			
Feeding substrates	CWD-6	Invertebrates in wood, under bark or moss cover, or in litter/humus accumulated around coarse woody debris	Amphibians, woodpeckers, winter wren, shrews, deer mouse, striped skunk, bears

[a] Including hibernation, thermoregulation, and hygroregulation.