An index of old-growthness for two BEC variants in the Nelson Forest Region

FINAL REPORT

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Prepared for:

Inter-agency Management Committee,
Land Use Coordination Office, Ministry of Environment, Lands and Parks.

March 31, 1999

Executive summary

Policy on landscape unit planning in British Columbia recommends areal targets for the retention of old-growth forest by designating Old Growth Management Areas (OGMAs) within landscape units. The Ministry of Forests defines old-growth forest using forest cover age class. However, there is increasing awareness that age class alone may miss functional attributes of old-growth forests, and may also be too coarse and inaccurate a scale for evaluating the biological value of older seral forests. In order to optimise the biodiversity value (unique habitat features critical for old-growth associated species) retained in OGMAs, it is important to identify and rank candidate OGMAs based on their distinctive structural features. Here we present a methodology for indexing the 'old-growthness' of older seral forest in two variants of the Interior Cedar-Hemlock subzone of the Nelson Forest Region. We sample structural attributes in stands ranging from approximately 100 to greater than 500 years in age from the two variants, and use a statistical methodology (Principal Components Analysis) to group stands based on these data. We define threshold values based on these groupings, and present look-up tables and a scorecard for ranking recruitment and old-growth stands based on their structural attributes.

Acknowledgements

We would like to thank the following people who contributed to this project: Jakob Dulisse, Bill Cumming, Grant Walton, Ted Evans, Bob Osmochenko, Stewart Clow, Pamela Dykstra, and Genevieve Lachance helped with locating stands and with field work. Andy Mackinnon, Kim Illes, John Pollack, and Ralph Wells provided useful comments on the methodology and on the issue of stand age. Val Lemay and Gary Bradfield provided statistical advice. Phil Burton, Ralph Wells, André Arsenault, Rob D'Eon, Mike Geisler, Pat Field, Andy Mackinnon, Marlene Machmer, and Chris Steeger made useful comments on the document.

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Introduction

Old forest is recognized as a valuable, and in places, a rare resource that warrants conservation effort because it often contains endemic or rare species as a result of its age (e.g. Goward 1993), and because this stage of forest development exhibits unique structures that are important wildlife habitat. Centuries may be required for these structures to develop, so replacement is not possible in the short term. In order to inventory, manage and conserve old-growth forest, a definition that adequately describes its identifying attributes is necessary. Various terms are used to name forests that have been free from stand level disturbances for a relatively long period of time, including old-growth, old seral, old forest, over-mature, decadent, and climax forest. We use the term old-growth most often in this report since it is most commonly used in literature.

Definitions of old-growth range from simplified working definitions, based solely on forest age estimates (BC Ministry of Forests and BC Environment 1995) to definitions based on principles of forest stand development (Oliver and Larson 1990). Several authors have endorsed the use of definitions based on multiple structural attributes, as these structures represent some of the functional aspects of old-growth (Franklin and Spies 1988; Franklin and Spies 1991; Marcot *et al.* 1991; Wells *et al.* 1998; Kneeshaw and Burton 1998). Attributes used in some ecological old-growth definitions include: large old trees, a multi-layered canopy, numerous large snags and logs, diverse tree community, great age of some trees, canopy gaps, hummocky microtopography, complex structure, wider tree spacing, and increased understory production (from Kneeshaw and Burton 1998; see also Franklin and Spies 1991; Holt and Steeger 1998).

The definition of old-growth currently employed by forest planners in British Columbia is based on stand age taken from forest cover maps. The age criteria vary according to Natural Disturbance Type (grouping of biogeoclimatic subzone /variants with similar disturbance return intervals, B.C. Ministry of Forests and BC Environment 1995), and in some cases, biogeoclimatic ecosystem classification (BEC) zone. This definition allows for utilization of the provincial forest inventory information without having to incur ground sampling costs. However, this simple working definition does not evaluate stand structural attributes. Structural attributes provide the unique habitat values and ecosystem function that confer special importance to old-growth, and can vary considerably among stands in the same age class. Defining old-growth without assessment of structure may therefore fail to identify the most biologically important areas of forest.

It is generally accepted that old-growth definitions will always be somewhat arbitrary (Hunter and White 1997). Ecological definitions of old-growth can take the form of minimum criteria or indices. Although minimum criteria may be easier to develop, many authors support the use of continuous indices as they are thought to better account for the inherent variability of old-growth stands, and can provide a relative ranking of stands (Well *et al.* 1998). Spies and Franklin (1988; Franklin and Spies 1991) use this assumption as the basis for their ‘index of old-growthness’ where the successional status of a stand is ranked on the basis of a number of attributes. Stands are not dismissed because they ‘fail to meet old-growth standards’, but are instead given a relative ranking based on the abundance of a number of attributes. This approach receives much support because it may avoid potential short-sighted errors in old-growth designation (Hunter and White 1997; Wells *et al.* 1998). We aim to use a similar conceptual approach in this paper, and use the term old-growthness to describe the probability that a stand is actually ‘old-growth forest’.

In British Columbia, the retention of old-growth forests within landscape units is recommended in the Forest Practices Code Biodiversity Guidebook (BC Ministry of Forests and BC Environment 1995) and the Landscape Unit Planning Guidebook (BC Ministries of Forests and Environment Lands, and Parks 1999). The areal targets are to be met by designating Old Growth Management Areas in landscape units as permanent reserves. Current policy dictates that OGMA targets be met outside the timber harvesting landbase (THLB) where possible, and then within the THLB (unless the landscape unit is to be managed under the low biodiversity emphasis option, in which case only one third of the target has to be met). In BEC variants (within landscape units) where the area of old-growth is higher than the recommended target, choices between competing areas must be made. In addition, many areas of the Province have a deficit of old-growth in some BEC variants (i.e. the amount of old-growth available is lower than the recommended target). In these areas, suitable ‘recruitment’ forest must be designated (in intermediate and high biodiversity emphasis option landscape units) and standards for designating recruitment old-growth patches are required. Using age as the sole definer of old-growth may provide insufficient information for planners to make meaningful decisions. Criteria for ranking stands based on multiple stand structural attributes would therefore be useful in making these choices. Previous work on refining old-growth definitions for the Nelson Forest Region consisted of deriving minimum standards for the number of live trees in various size classes by site series (Quesnel 1996) from an existing data set. The need to explore useful old-growth indices in this region was therefore recognised.

This pilot study was designed to address some of the issues surrounding old-growth management in two BEC variants of the Nelson Forest Region, British Columbia. The objectives of this pilot study were to:

1. determine what easily-assessed structural features are consistently associated with old forests in these variants; and
2. devise an objective index of "old-growthness" for field assessments.

The two biogeoclimatic variants studied were the ICHmw2 and ICHdw (Braumandl and Curran 1992). We focussed on these variants because they are widespread, relatively productive and have significant deficits of older forests in some areas. The attributes we chose to measure were some of those most commonly cited as being important structural features associated with old-growth forest while still being relatively quick to assess consistently. Other studies that have investigated old growth definitions (Kneeshaw and Burton 1998, Franklin and Spies 1991) have involved sampling efforts many times greater than those possible in this study. Hence the results of this study should be interpreted as exploratory in nature.

Methods

Study site selection

Thirty six stands were selected from non-TFL lands of the Arrow and Kootenay Lake Forest Districts within the ICHdw (18 stands) and the ICHmw2 (18 stands). Stands were generally selected from areas that had been delineated as candidate old growth management areas by the Arrow Forest District. Zonal site series (ICHdw/01 CwFd - Falsebox and ICHmw2/01 HwCw - Falsebox - Feathermoss) were predominantly sampled, however, it was necessary to expand to a wider range of site series for both variants since insufficient zonal sites were available. Other site series sampled were: ICHdw/02 FdPy - Oregon-grape - Parsley fern; ICHmw2/03 FdCw - Falsebox - Prince's pine; ICHmw2/04 CwFd - Falsebox; and ICHmw2/05 CwHw - Oak fern - Foamflower. Stands were selected to sample a range of stand ages from 100 to greater than 250 years (forest cover age classes 6, 7, 8, and 9), and were a minimum size of 10 ha. Three circular 0.1 ha (17.8 m radius) plots were sampled per stand. Plots were placed a minimum of 30m from the stand edge and spaced between 75 and 200 m apart along a transect. The transect was located to try to span a significant portion of the stand being sampled. Plots that fell on old roads or heavily selectively harvested portions of a stand were moved a minimum of 50 m along the transect. Some plots were established in areas that had some selective harvest, in which case stumps were counted as live trees and their stump diameter was treated as dbh.

Measures

The following variables were assessed:

- number of trees >50cm dbh
- largest tree diameter
- number of snags in 12.5-25, 25-50, >50cm dbh classes
- largest diameter snag
- % of trees >50cm dbh with pathological indicator
- % of trees >50cm dbh with dead or broken tops
- arboreal lichen presence (none, low, moderate, high; based on Armleder et al. 1992)
- number of tree species
- cover and modal height of total shrubs and herbs
- multiple canopy layer presence

- mean and modal LFH thickness (measured at 6 points)
- relative abundance and size of canopy gaps
- small trees (<1.3m tall) were counted in one quadrant of the plot (0.025ha)
- density of trees in the following dbh classes <12.5cm dbh; 12.5-40cm dbh; 40-50cm (assessed in one half of the plot (0.05ha)).

Four transects radiating out from plot centre to the edge of the plot on cardinal bearings were laid out and intersections were tallied for number of pieces of >30 cm diameter downed logs. Diameter of the largest piece was also noted. Age at breast height was measured on dominant or codominant trees and the largest trees in the stand. Generally a minimum of two trees per species per plot were cored. For trees with rotten centres, tree age was estimated if countable rings constituted more than one-third of the radius of the tree. The ages for rotten trees were estimated by multiplying the age count for the intact segment by radius of the tree divided by the intact core length. This is likely an under-estimate of the age of any trees which had experienced suppression early in life and now have a rotten centre. This approach is reasonable, however, in the absence of more detailed dendrochronological data which would have required extensive coring in the same stand (P. Burton, pers. comm. 1999).

Data analysis

Principal component analysis (PCA) was used to ordinate data collected from plots within stands. Ordination is the collective term for a group of multivariate techniques that arrange sites along multiple axes (ter Braak 1995). Our objectives were to (i) determine whether plots are grouped based on similarities among structural attributes and (ii) find a set of structural attributes that best describe the main relationships between plots. PCA uses a correlation matrix of multiple variables to find a number of indices (principal components) that each capture variation in a different dimension of the data. Each PCA axis is orthogonal (uncorrelated) with the others. PCA-1 describes the maximum variation in the data and therefore describes the major patterns in the data. PCA-2 is orthogonal to PCA-1 and captures the next largest amount of variation in the data, and so on (Tabachnik and Fidell 1996). A multivariate approach is most appropriate for our data because we are interested in the compounded effects of multiple variables. We use PCA to explore patterns in the data set, and our results are therefore hypotheses which require testing. This is in contrast with direct hypothesis testing approach. We used plot rather than stand data, since pseudo-replication is not an issue with exploratory data analysis (V. Lemay and G. Bradfield pers. comm. 1999).

PCA was performed separately for each BEC variant. Slight variation in data collection methodology and in snow conditions on some plots resulted in missing data for some attributes. Missing data for any variable results in that plot being removed from the analysis, and can considerably reduce the number of plots included. We therefore tried to optimise both the number of variables and the number of plots included in the analysis.

PCA was conducted on plot data from the ICHmw2 using the following structural variables:

- number of large trees (>50cm dbh),
- maximum dbh sampled in the plot,
- number of large pieces of CWD in plot (>30cm DBH),
- percent of large trees (>50cm dbh) with broken or dead tops
- percent of large trees with evidence of pathogens
- percent cover by herbs
- modal height of the herb layer
- percent cover by shrubs
- modal height of shrub layer
- estimated LFH thickness
- numbers of snags by size classes (12.5-25 cm dbh; 25-40cm dbh, 40-50cm dbh)
- lichen abundance
- number of tree species present

PCA was conducted on plot data from the ICHdw using the following structural variables:

- number of large trees (>50cm dbh),
- maximum dbh sampled in the plot,

- number of large pieces of CWD in plot (>30cm DBH),
- percent of large trees (>50cm dbh) with broken or dead tops
- % of large trees with evidence of pathogens
- percent cover of shrub layer
- estimated LFH thickness
- numbers of snags by size classes (10-25 cm dbh; 25-40cm dbh, 40-50cm dbh)
- numbers of smaller trees (12.5-40cm dbh)
- total density of trees (all size classes)
- lichen abundance

Percent data were arcsine square root transformed to approximate their distributions to normal and to compensate for upper and lower limits due to the percent scale (Sokal and Rohlf 1981). The remaining data were not transformed since normality and linearity assumptions are not in force as long as PCA is used for descriptive analyses (Tabachnik and Fidell 1996). Values were standardised as part of the PCA analysis in SPSS Factor.

For each BEC variant, PCA was used to explore whether any natural groupings occurred among the plots sampled (for example, see Fig. 3 and 9). Where groupings occurred, observation of the variables most strongly correlated with the axis (PCA-1) was used to assess whether the patterns were related to the ‘old-growthness’ of the plot (based on assumptions of attributes associated with old-growth forest). In order to explore the distribution of plots, individual plots were graphed in factor space with the primary axis (PCA-1) as the x-axis and PCA-2 as the y-axis. Output from the PCA was used to group similar plots. The mean age of each plot was graphed against the primary old-growth axis to assess how age related to PCA ordination (Fig. 4 and Fig. 10). Summary statistics of attribute values for each group are presented in their original units and are given on a per hectare basis. These values are then compared to summary statistics for old-growth reported in other studies.

Other authors have used this type of technique (PCA) to similarly explore multivariate data (e.g. Kneeshaw and Burton 1998). In some cases, (e.g. Franklin and Spies 1991), stepwise discriminant analysis was first used to reduce the number of variables in the data set. We did this step prior to field work, by focussing on the variables thought by other workers to be important in making these definitions and that could be easily assessed. We therefore used all variables that were complete (or almost complete) in the PCA, and only discarded those with significant numbers of missing values.

Results

The results for the two BEC variants will be assessed separately. A summary of all data collected, by variant and by plot, is available in Appendix 2. Data are listed in order of measured mean stand age. Mean values for measured attributes in each stand are presented.

ICHmw2

Stand age

Eighteen stands were sampled in the ICHmw2 BEC variant. These ranged in age from approximately 107 to 542 years old (Fig. 1). Based on forest cover (FC) data, stands ranged from age class (AC) 7 to 9 (5% AC7; 66% AC8, 22% AC9, Appendix 2). A minimum of three and a maximum of seven trees were cored on each plot. Mean age rather than maximum age (as in Kneeshaw and Burton 1998) was used in the analyses since numerous stands showed evidence of moderate intensity fires (fire scars) that did not destroy the entire stand. Calculated ages of stands (from tree cores) differed from the FC typed information (Fig 1). Based on mean stand age, 7 of 18 stands were misclassified, with 5 of those younger than typed, and 2 older than typed (Fig. 1). The dominant and co-dominant trees were aged in each plot, as well as the largest tree(s) and the mean age, by species is shown in Fig. 2.

Principal components analysis

47 of 50 possible plots were included in the analysis. The first PCA axis (PCA-1) accounted for 32% of the variation in the data set[1]. The second axis (PCA-2) accounted for a further 13% of the variation in the data. PCA-3 and subsequent axes accounted for less variation in the data and are not addressed further in the analysis.

The following variables were positively associated with PCA-1: number of large trees in the plot, largest live dbh in the plot, percent herb cover and percent of the large trees with evidence of pathogens, while small and medium sized snags were negatively associated with PCA-1 (Table 1). This suggests that PCA-1 is therefore associated with old-growthness of the plot (based on cited structural associations with old forests). PCA-2 is highly associated with large snags and negatively associated with lichen loading (Table 1).

Mapping the plots in factor space produces two major plot groups. Firstly, a group of 22 plots with PCA-1 scores >0, which appear to be old-growth plots based on the combination of stand structural attributes (Fig. 3). Secondly, a group of 25 plots with PCA-1 scores <0 which generally lack old-growth attributes (Fig 3). We present summary data for three groups based on splits by PCA-1 and PCA-2. The first group consists of plots with PCA-1 > 0 which have a large number of stand structural attributes associated with old-growth (referred to as ‘old’ in future tables). Although PCA-1 > 0 plots appear to split into two groups (Fig. 3) this represents a split at approximately 400 years which is interesting ecologically, but is not relevant to current management objectives, since both groups would tend to be classified as ‘high quality’ old-growth. The second group consists of plots with PCA-1 < 0 and PCA-2 > 0 (top left hand corner), which appear to be higher quality ‘recruitment’ old-growth (termed ‘recruitment’ in future tables). The third group is characterized by PCA-1 < 0 and PCA-2 < 0 (bottom left-hand corner), which almost entirely lack old-growth attributes (termed ‘not-old’ in future tables). These categories are shown on Fig. 3 by the dotted breaks in the factor space.

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[1] A good result for ecological data (Gary Bradfield 1999 pers. comm.)

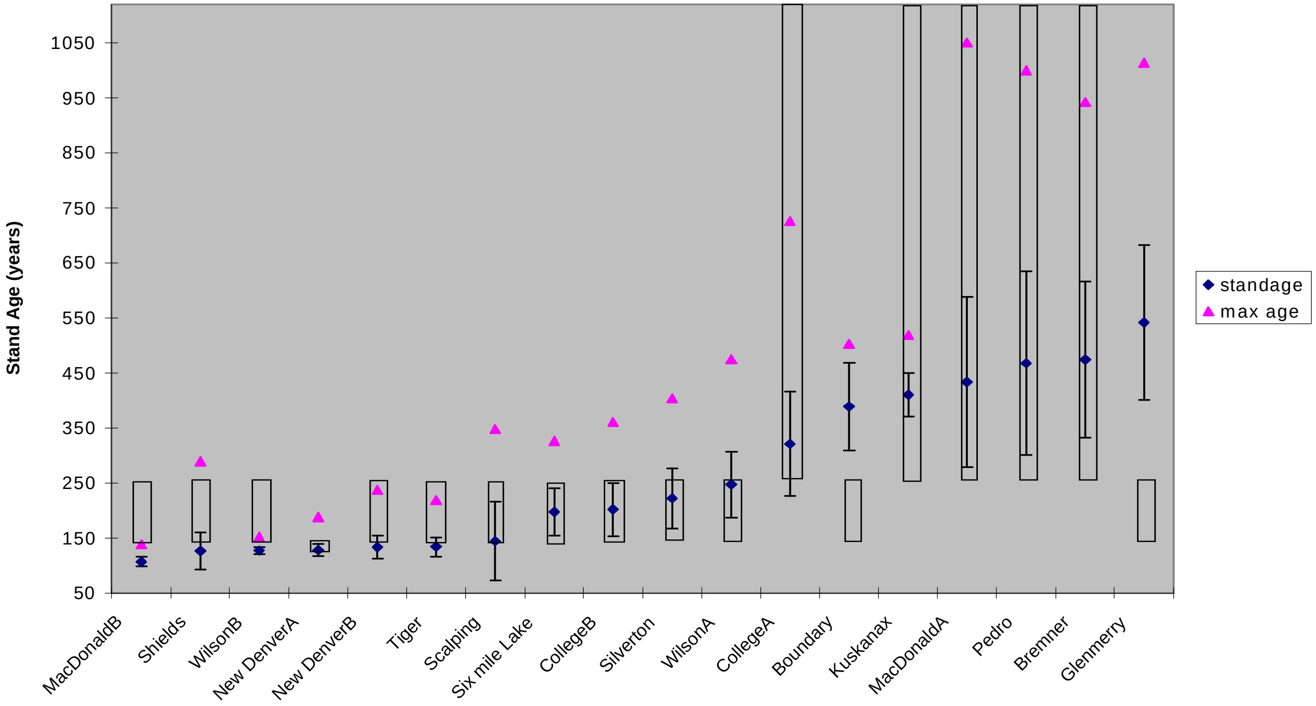

Figure 1. Measured mean and maximum age of stands sampled in the ICHmw2. Predicted forest age classes are shown as boxes.

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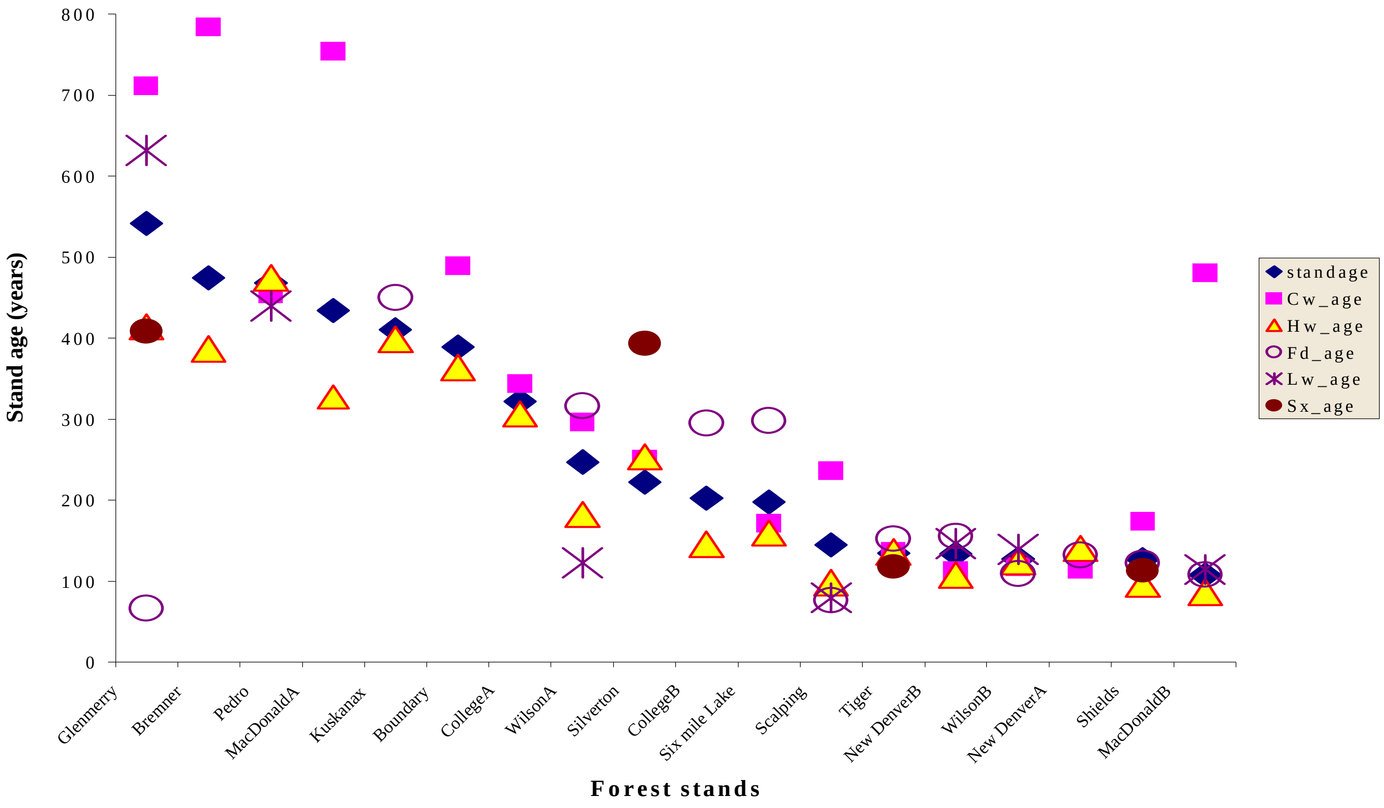

Figure 2. Mean age of stands and species sampled in the ICHmw2.

Table 1. Component matrix for PCA of ICHmw2 data.

	Component[a]				
	1	2	3	4	5
Maximum DBH	.866	-4.9E-02	-6.1E-02	2.94E-02	.168
Big trees	.851	-.133	3.98E-02	-.132	.196
Coarse woody debris	.349	.404	-.381	-.427	-.305
% big trees with dead tops[b]	.547	.271	-.483	.422	.176
Herb cover[b]	.638	-.268	.468	-3.5E-02	.376
Herb height	.457	-.243	.389	.442	2.25E-02
LFH thickness	.418	2.45E-03	-.236	-.652	.342
Lichen abundance	.398	-.639	2.35E-02	.227	-.396
% big trees with pathogens[b]	.628	.224	-.309	.287	.413
Shrub height	.437	.574	.555	-9.1E-02	-.246
Shrub cover[b]	.231	.538	.703	-.127	3.99E-02
Big snags	.181	.646	-.248	.338	-.176
Medium snags	-.631	.249	9.44E-02	.287	.204
Small snags	-.737	-.107	3.41E-03	-.142	.417
Number of tree species	-.602	.254	.126	.148	.383

[a] 5 components extracted

[b] Variable arcsine square root transformed

Figure 3. ICHmw2 plots mapped in factor space. The 'age-class' definitions used are based on measured plot ages.

We present the summary statistics for these groups in Table 2. Note that for some of the attributes the expected patterns are not apparent, and in some cases there is overlap between groups for some attributes. This results because the technique ordinates plots on the basis of all the attributes, rather than single attributes.

Table 2. Summary statistics for groupings in ICHmw2. Mean value and standard error for each group.

Variable	Not-old	Standard error	Recruit-ment	Standard error	Old	Standard error
Mean age	126.0	(6.6)	169.4	(13.3)	402.7	(31.8)
Mean max age	151.9	(15.1)	257.9	(28.8)	564.7	(48.6)
Big tree density (#/ha)	22.0	(6.0)	29.0	(6.0)	140.0	(12.0)
CWD (# of pieces on 72 m transect	38.0	(5.0)	29.0	(5.0)	53.0	(7.0)
Max live dbh (cm)	54.1	(2.6)	60.9	(3.0)	87.7	(2.8)
Deadtop (% of >50cm DBH)	4.5	(3.2)	22.3	(9.0)	35.4	(5.5)
Herbcover (%)	2.5	(0.9)	3.2	(1.4)	11.4	(2.1)
Herb height (cm)	9.1	(0.9)	10.0	(0.0)	13.5	(1.6)
LFH depth (cm)	3.5	(0.4)	2.8	(0.3)	4.7	(0.5)
Lichen Abundance[1]	1.1	(0.1)	0.9	(0.1)	1.4	(0.1)
Pathogen (% of >50cm DBH)	6.0	(3.4)	30.0	(10.9)	43.6	(4.0)
Shrub cover (%)	2.5	(0.9)	5.2	(1.7)	5.8	(1.6)
Shrub height (dm)	2.5	(0.7)	4.7	(1.3)	7.2	(1.5)
Snags big (#/ha)	2.0	(1.0)	20.0	(4.0)	17.0	(4.0)
Snags medium (#/ha)	30.9	(6.8)	72.3	(10.0)	12.2	(3.0)
Snags small (#/ha)	87.3	(11.0)	70	(15.5)	19.6	(3.8)
Number tree species	4.7	(0.2)	5.5	(0.4)	3.2	(0.2)

[1]: Lichen abundance classes: <1 = low; 1-2 medium; >3 high (based on Armleder et al. 1992)

Stand structure attributes and stand age

In order to investigate the relationship between plot age and the PCA-1 score (a surrogate for old-growthness), a scatterplot of mean plot age versus PCA-1 is shown (Fig. 4). If plot age and PCA-1 both exactly described 'old-growthness' you would expect to see a tight linear relationship between these two variables. However, it is apparent that, although there is a strong relationship between 'old-growthness' and stand age (Spearman correlation of 0.755), there is also further variation captured in the multivariate approach not captured solely by age. There is an especially wide range of PCA-1 scores found for stands between about 170 and 250 years from Figure 4. This suggests that using stand structural attributes in addition to age would add to the ability to define the old-growthness of a stand.

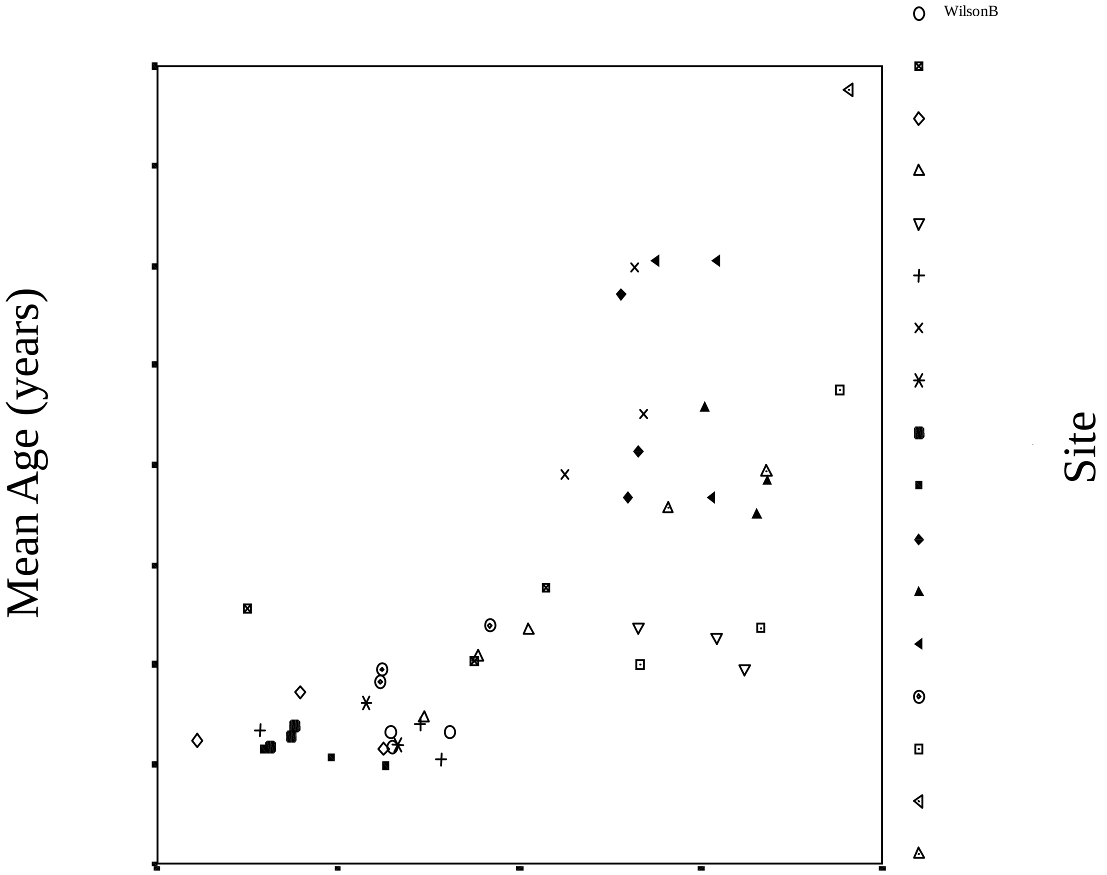

Figure 4. ICHmw2: Scatterplot of PCA-1 score and mean plot age.

It is also clear from Fig. 4 that plots with high values for PCA-1 include stands of a wide range of ages greater than approximately 200 years. This lends support to the current policy decision for an interim working definition for old-growth of 250 years in this variant.

Site series

Stands and plots sampled were from a range of site series. In our principal components analysis, we grouped data from different site series to increase our sample size, and because we were interested in broad patterns applicable to current old-growth policy. However, some of the variation in stand structural attributes among plots may be a result of differences in site series. We did not include site series in the PCA because it is not a 'structural attribute' of the stand, and because we had insufficient sampling ability to analyse individual site series. To examine the potential influence of site series, the number of big trees (>50cm dbh) per plot (square-root transformed to approximate a normal distribution) was used as an index of the productivity of a site. The mean age of plots (log transformed to approximate a normal distribution) was included as a covariate to account for differences in big tree density caused by plot age. In an analysis of covariance (ANCOVA), site series did impact the number of big trees observed in the plot, after correcting for differences caused by mean plot age (ANCOVA: log age $F_{1,4}$= 85.5, $p < 0.001$; site series:

$F_{1,4} = 5.3$, $p < 0.0012$). Site series means show a higher density of big trees in wetter 05 site series plots (Fig. 5; see discussion).

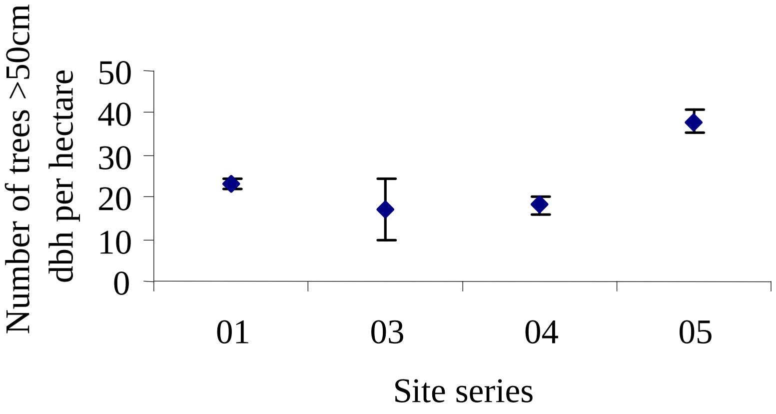

Figure 5. Number of large trees (>50cm DBH) (plus/ minus standard error) per hectare by site series in the ICHmw2.

Figure 6 shows the relationship between site series and position of the plot with PCA-1. It is difficult to see patterns in the data, because of the uneven sample size of the different site series. However, most plots with site series 05 have a PCA-1 > 0 and may be more often classified as old-growth because of the high density of large trees in these plots (Fig. 6).

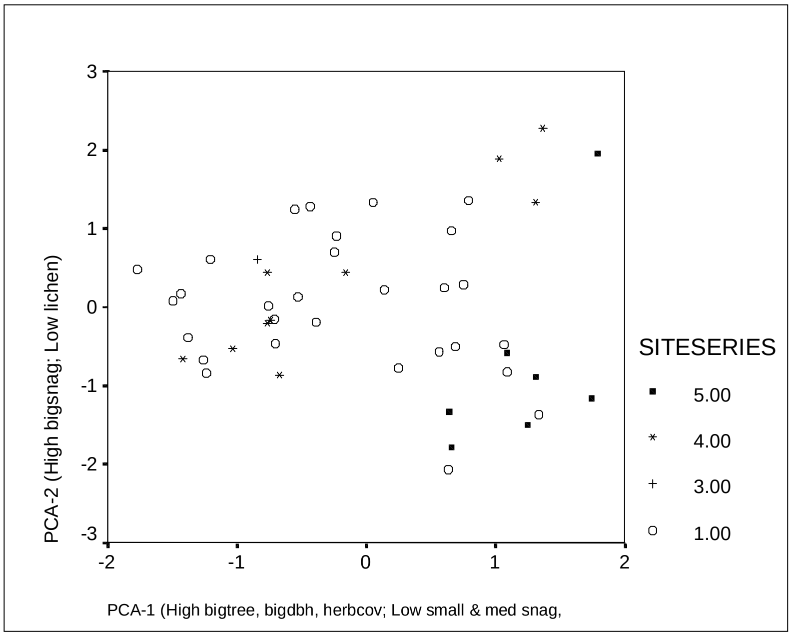

Figure 6. Ordination of plots in factor space by site series.

ICHdw

Stand age

Eighteen stands were sampled in the ICHdw BEC variant. An equal distribution of stands from age classes 6 – 9 were sought, but it was difficult to find examples of older stands which were (i) accessible, (ii) of sufficient size or (iii) had not been extensively high-graded. The stands were typed on forest cover maps as age classes 6 – 9 (22% age class 6, 11% age class 7, 44% age class 8, 11% age class 9). In terms of measured mean ages (totals for all species), there was a relatively even distribution of stands of different ages, ranging from 86 to 231 years , then a break to two stands with mean ages of 274 and 390 (Fig. 7). A comparison of observed versus FC age class information is shown (Fig 7). Of 18 stands, using mean stand age, 7 of 18 stands were misclassified. Of these seven, five were younger than typed on forest cover maps and two were older than mapped.

sPrincipal components analysis

42 of 56 possible plots were included in the analysis[1]. The first PCA axis (PCA-1) accounted for 26% of the variance in the data set. The second axis (PCA-2) accounted for a further 20% of the variation in the data. Axes 3 and 4 both accounted for a further 10% of the variation in the data set, however their contribution is not reported since the first two axes represent the main interpretable differences in the data. The number of axes used to explain ordinations in the data is a matter of judgement and will depend on the intended use of the analysis (Manly 1986).

The following variables were most positively associated with PCA-1: number of large trees in the plot, and percent shrub cover. Total tree density, density of small trees, and small snags, were most negatively associated with PCA-1 (Table 3). PCA-1 therefore appears to be associated with old-growthness (as determined from the literature). PCA-2 is highly associated with coarse woody debris, percent dead tops, LFH, number of large snags, and total density of trees (Table 3).

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[1] Note that the inclusion of variables in the PCA can change which variables factor highly with each PCA axis. For example, a second PCA removing percent shrub cover from the analysis was conducted. The overall layout of plots in factor space remained very similar to the PCA with shrub cover, but the contribution of variables to each PCA differed. For this reason, we do not use the correlation matrix scores to ‘weight’ attribute values in the index of old-growthness (see discussion).

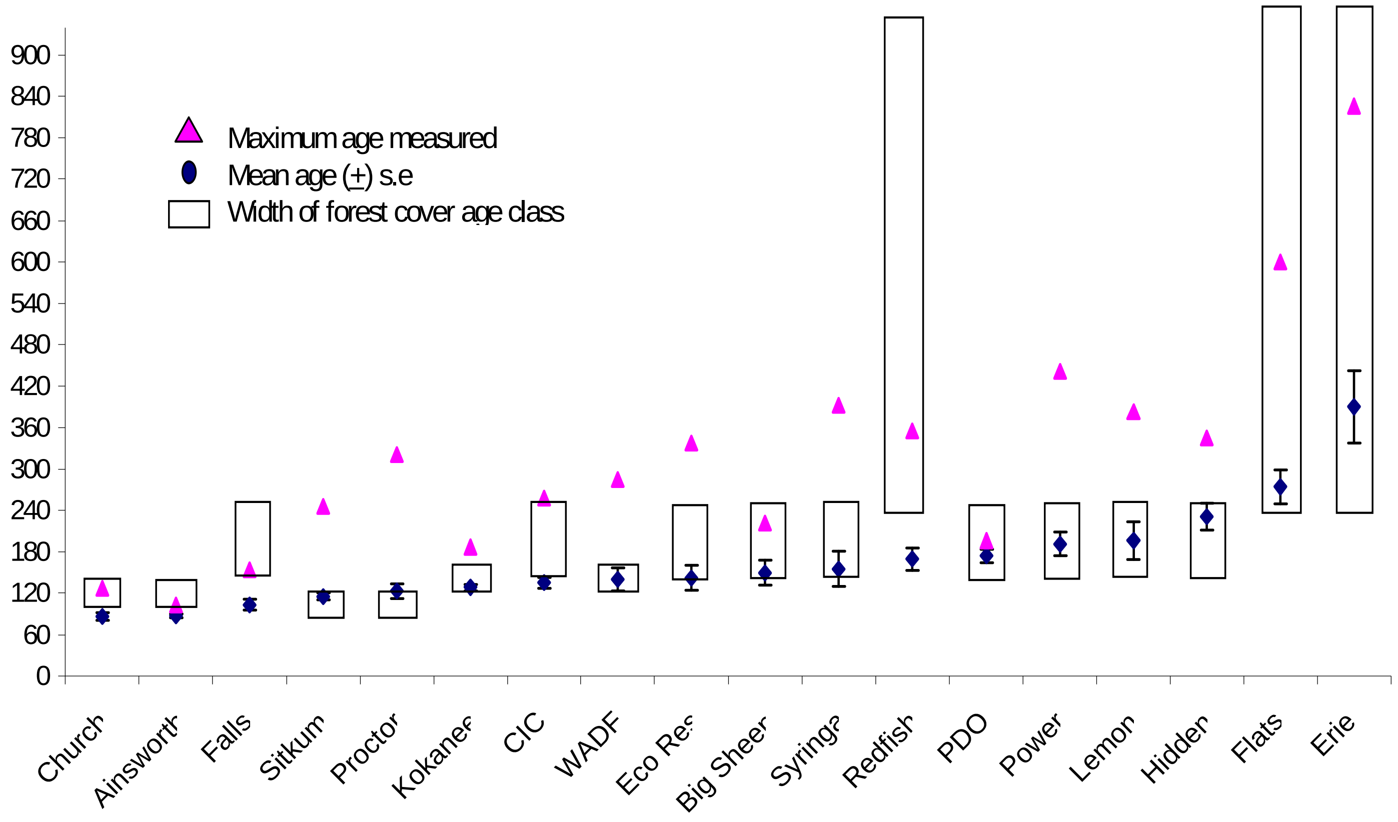

Figure 7. Measured mean and maximum age of stands sampled in the ICHdw. Forest cover age classes are shown as boxes.

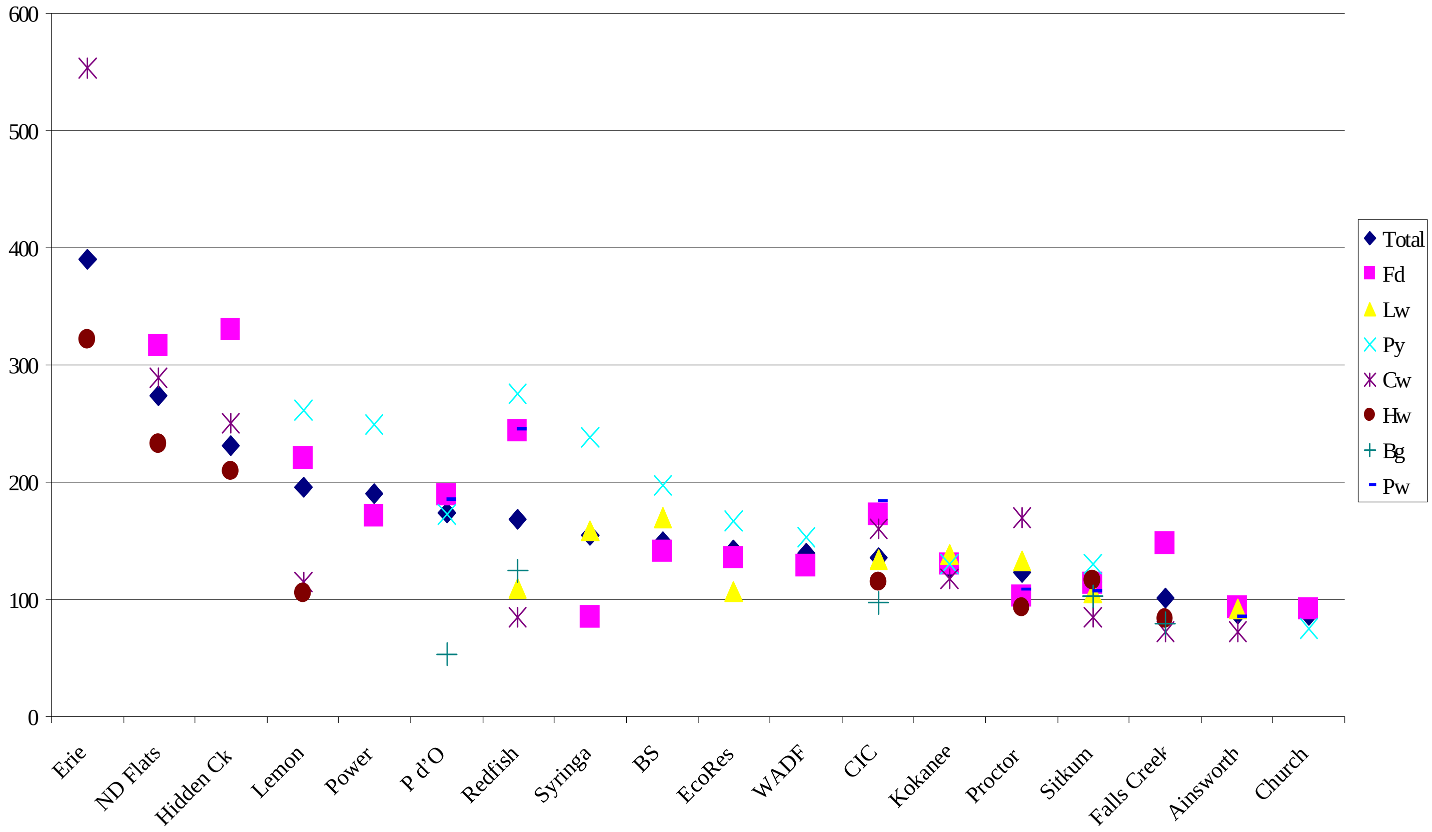

Figure 8. Measured mean age of stands and species in the ICHdw

Mapping the plots in factor space produces no obviously distinct grouping of plots (as in the ICHmw2). However there are gradients of plots in the factor space (Fig. 9). As with the ICHmw2, PCA-1 was used as the main dividing axis because it explains the most variation in the data. However, because there was not a clean split at PCA-1 = 0, we decided to present an intermediate group with PCA-1 between -0.5 and +0.5. The three groups are therefore (i) 'old' with PCA-1 > +0.5, (ii) 'recruitment' with PCA-1 > -0.5< +0.5, and (iii) 'not-old' with PCA-1 < -0.5. Because the partitioning of variation between PCA-1 and PCA-2 is fairly similar (26% versus 20% respectively), we tried to produce groupings based on both axes. However, the summary statistics derived from this more complex approach resulted in too many groups and were not readily useable, so we resorted to using this more simple grouping technique. Summary statistics for attributes in each of these groups (old, recruitment, and not-old) are given (Table 4).

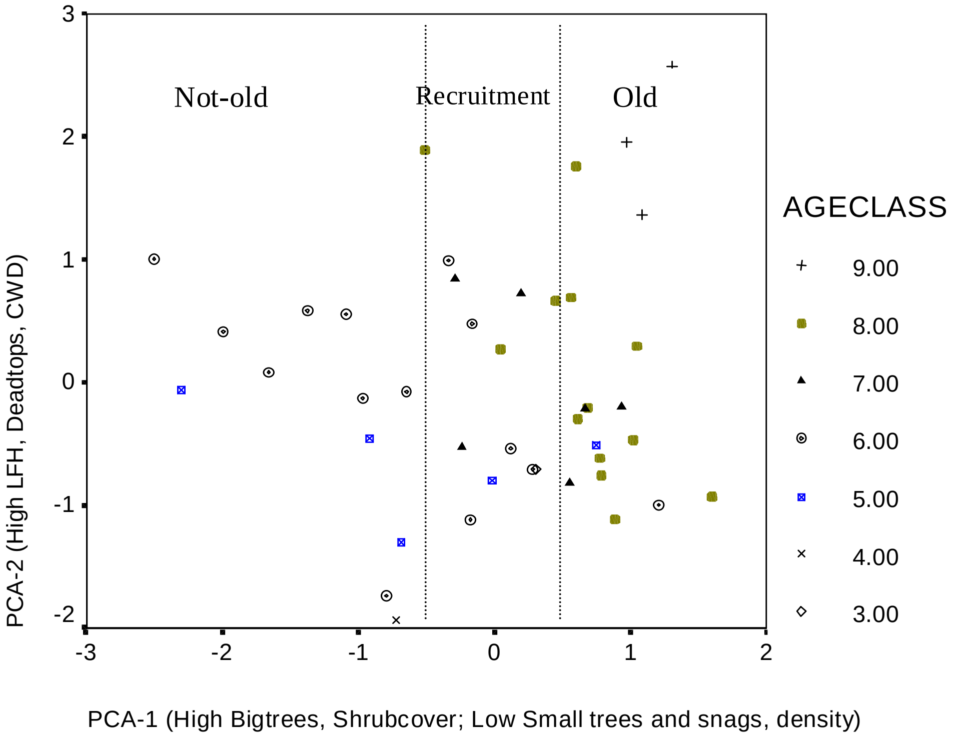

Figure 9. ICHdw: ordination of plots in factor space.

Table 3. Component matrix for PCA of ICHdw data.

Component Matrix[a]

	Component				
	1	2	3	4	5
Maximum DBH	.866	-4.9E-02	-6.1E-02	2.94E-02	.168
Big trees	.851	-.133	3.98E-02	-.132	.196
Coarse woody debris	.349	.404	-.381	-.427	-.305
% big trees with dead tops[b]	.547	.271	-.483	.422	.176
Herb cover[b]	.638	-.268	.468	-3.5E-02	.376
Herb height	.457	-.243	.389	.442	2.25E-02
LFH thickness	.418	2.45E-03	-.236	-.652	.342
Lichen abundance	.398	-.639	2.35E-02	.227	-.396
% big trees with pathogens[b]	.628	.224	-.309	.287	.413
Shrub height	.437	.574	.555	-9.1E-02	-.246
Shrub cover[b]	.231	.538	.703	-.127	3.99E-02
Big snags	.181	.646	-.248	.338	-.176
Medium snags	-.631	.249	9.44E-02	.287	.204
Small snags	-.737	-.107	3.41E-03	-.142	.417
Number of tree species	-.602	.254	.126	.148	.383

[a] 5 components extracted

[b] Variables arcsine square root tranformed

Table 4. Mean attribute values and standard errors for groups determined by the PCA analysis for the ICHdw.

Variable	Not-old	Standard error	Recruitment	Standard error	Old	Standard error
Mean age	101	4	119	9	228	28.7
Mean max age	170	20.6	184	21	377	68.2
Big tree density (#/ha)	16.5	6.5	53	9	74.5	6.5
Density live >12.5 cm DBH (#/ha)	293	74	255	51.4	251	31.2
Density medium trees (#/ha)	26	8	27	6.5	31	7
Density small trees (#/ha)	262	22.5	181	34	110	25.5
Largest live dbh (#/ha)	51	8.1	67	7.7	75	4.9
Deadtop (% of big trees)	0.05	0.05	0.25	0.05	0.5	0.1
Pathogens (% of big trees)	0.15	0.1	0.65	0.15	0.65	0.1
Density of all live trees (/ha)	785	120	483	78.5	412	64
CWD (#pieces on 34 m transect)	9.5	4	11.5	3	18	5
LFH (cm)	4.3	0.55	4.3	0.55	5.4	0.55
Lichen[1]	0.6	0.3	1.3	0.5	2.3	0.3
Shrub cover (%)	0.1	0.05	0.3	0.1	0.45	0.1
Snags >50 cm dbh (#/ha)	4.5	4	10.5	5	12	4
Snags 25-50 cm dbh (#/ha)	134	59.6	94	44.8	43	14.6
Snags 12.5-25 cm dbh (#/ha)	120	38	38	13.7	32	7.0
# Tree species	4.4	0.6	4.3	0.4	2.5	0.25

[1]:Lichen abundance classes: <1 = low; 1-2 medium; >3 high (based on Armleder et al. 1992)

Stand structure attributes and stand age

In order to investigate the relationship between plot age and the ‘old-growthness’ of the plot as defined by the PCA-1, a scatterplot of mean plot age versus PCA-1 is shown (Fig. 10). If plot age and PCA-1 exactly described ‘old-growthness’ you would expect to see a tight linear relationship between these two variables. However, it is apparent that, although there is a strong relationship between PCA-1 and stand age, there is also further variation captured in the multivariate approach not captured solely by age. Examination of the figure shows that in general, stands with many old-growth associated variables appear in stands greater than approximately 150 years of age. However, it is also clear that there are some stands younger than 150 years, which have old-growth attributes. We suggest this is a result of the different patterns of disturbance in this variant, which results in some younger stands having a considerable veteran tree component which survived low intensity fires (see discussion).

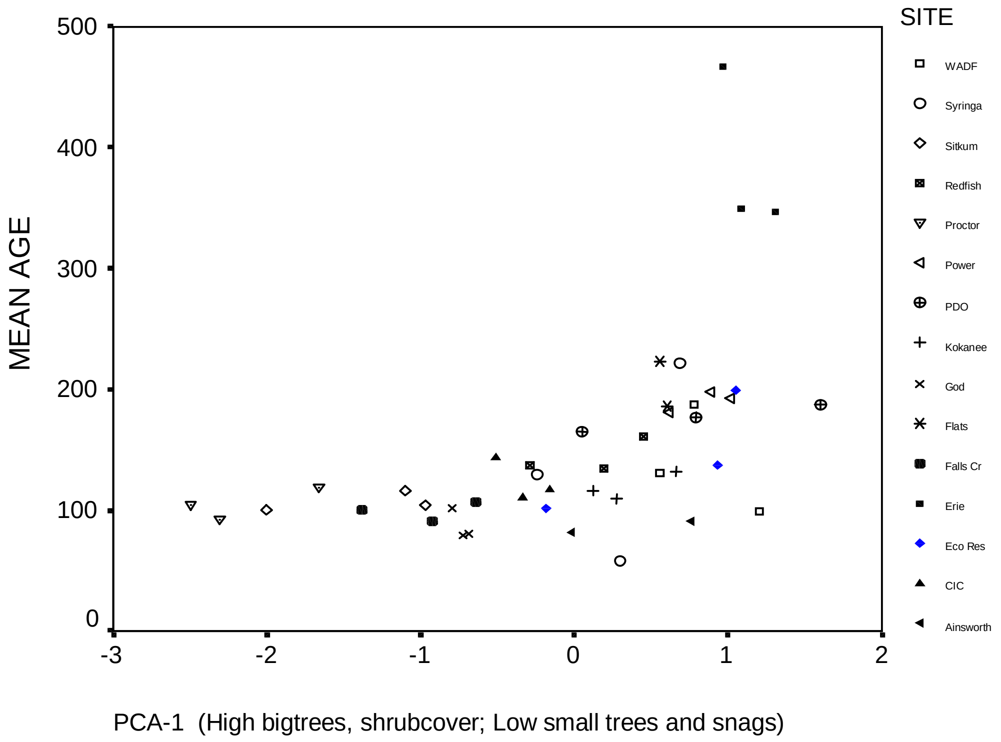

Figure 10. Relationship between PCA-1 and mean stand age.

Site series

Stands and plots sampled were from a range of site series. We grouped data from different site series to increase our sample size, and because we were interested in broad patterns at a BEC variant level, applicable to current old-growth policy. However, some of the variation in stand structural attributes among plots may be a result of differences in site series. In order to investigate this effect, the number of big trees (>50cm dbh) per plot (arcsine square-root transformed to approximate a normal distribution) was used as an index of the productivity of a site. The mean age of plots (log transformed to approximate a normal distribution) was included as a covariate to account for differences in big tree density caused by plot age. In an ANCOVA, site series did not impact the number of big trees observed in the plot, after correcting for differences in numbers of big trees by mean plot age (ANCOVA: log age $F_{1,2}$= 15, $p < 0.003$; site series: $F_{1,2} = 0.7$, $p = 0.49$). Mean numbers of large trees per hectare, by site series are shown (Fig. 11).

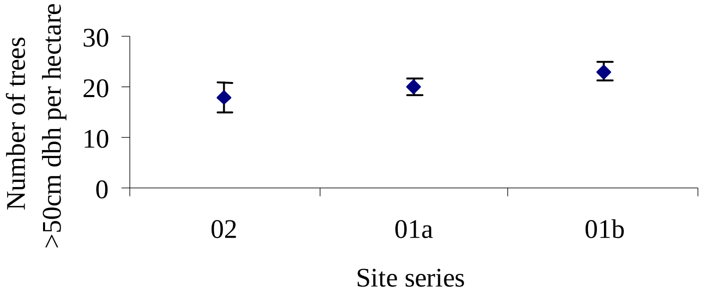

Figure 11 . Number of large trees (>50cm dbh), plus/ minus standard error) per hectare, by site series in the ICHdw.

In addition, we show the ordination of plots by site series (Fig. 12) to determine whether particular site series tend to result in higher 'old-growthness scores'. There are no obvious patterns in these data, except that the dry ICHdw - 02 sites are somewhat grouped on the PCA-1 axis.

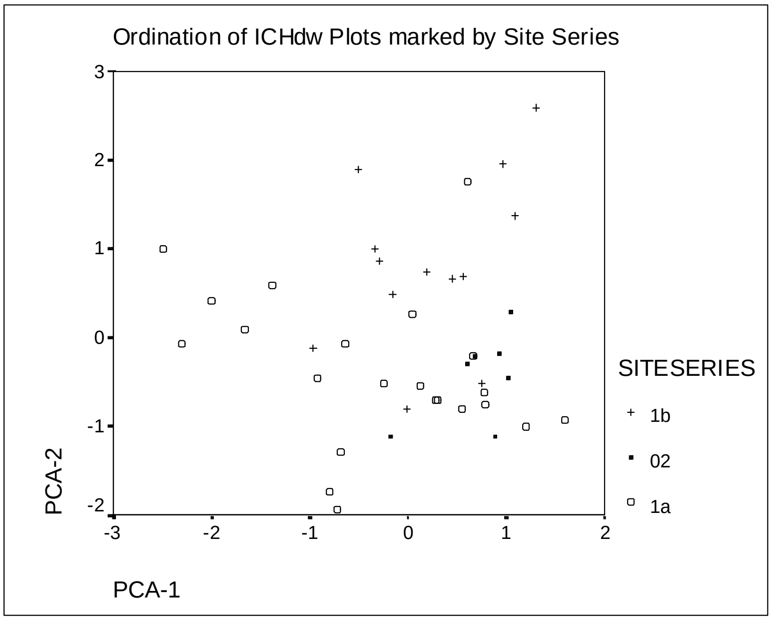

Figure 12.Ordination of ICHdw plots highlighted by site series.

An index of old-growthness

In order to provide an index for old-growthness from our limited pilot study data we decided to use an approach which does not attempt to weight attributes in order to produce an 'old-growthness' score. We considered using the correlation coefficients from the correlation matrix in the PCA however these changed quite considerably when different attributes were included or excluded from the analysis (although the general positions of plots in the factor space stayed quite constant). For this reason we felt it was inappropriate to use the correlation coefficients to weight attributes. As an alternative, we provide a 'transparent' process for ranking candidate patches which we feel would allow the practitioner to weight attributes themselves if they felt that was necessary or appropriate (see below for discussion).

Our approach is to use the groups of plots generated by the PCA for each BEC variant to produce a table of look-up threshold values for each attribute. The attributes in Tables 2 and 3 were examined to produce a subset of attributes which met the following criteria: (i) they did not overlap between groups (ii) their pattern makes ecological sense based on the literature, (iii) they did not have a U-shaped distribution (such as coarse woody debris and medium sized snags) caused by retention of attributes in younger stands from previous disturbance[1]. For attributes which met these criteria, threshold values were produced from the midpoints between adjacent plot groups (e.g. between 'not-old' and 'recruitment', and between 'recruitment' and 'old'). These threshold values are presented in Tables 5 and 6. We chose to produce two thresholds for each variant, because current landscape unit planning for old-growth in British Columbia requires planners to identify not only true old-growth forest, but also recruitment forest in areas that are currently in deficit for old-growth (as defined in: Province of British Columbia 1999). It is our experience that areas in deficit are the most controversial and will likely require the most field assessment in order to adequately protect suitable forest to meet landscape unit planning objectives. Although we did not include age in the multivariate analysis we include it as an attribute to evaluate because we suggest age provides further discriminatory power for choosing among stands (e.g. Goward 1993), however, note that we are not attempting to revise the current age criteria for old-growth in these variants.

Table 5. Threshold values for attributes in the ICHmw2, per hectare.

Attribute	Not-old	Threshold	Recruitment	Threshold	Old
SCORE	**1**		**2**		**3**
Mean age		**147**		**286**	
Mean Maximum age		**204**		**411**	
Density trees >50cm dbh		**25**		**84**	
Largest dbh		**57**		**74**	
Percent big trees with broken/ deadtops		**13**		**28**	
Percent big trees with pathogens		**18**		**36**	
Snags >50cm dbh		**11**		**18**	
Snags 10-25cm dbh		**78**		**44**	

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[1] Using attributes that have single directional trends simplifies the scoring process.

Table 6. Threshold values for attributes in the ICHdw, per hectare.

Attribute	Not-old	Threshold	Recruitment	Threshold	Old
SCORE	**1**		**2**		**3**
Mean age		**110**		**173**	
Mean Maximum age		**177**		**281**	
Density trees >50cm dbh		**34**		**64**	
# of CWD >30cm dbh on 34m transect		**10**		**15**	
Largest dbh on plot		**58**		**71**	
Percent big trees with dead/ broken tops		**20**		**49**	
Lichen abundance[1]		**Low**		**Medium**	
Percent big trees with pathogens		**40**		**70**	
Density of trees >12.5 < 40cm		**222**		**145**	
Density of snags >50cm dbh		**7**		**11**	
Density snags 12.5 – 25		**79**		**35**	

[1] Based on Armleder et al. 1992

A sampling methodology for old-growth assessment

The procedure for ranking a stand would work as follows:

(i) Determine (from existing cruise data, or from new field data) the values for as many attributes shown in Tables 4 or 5 for that variant, as possible. The more variables measured the better. If cruise data are available, additional ages should be measured in the field as ages are not a priority for cruising in stands over 120 years of age. Where the stand is field sampled (either when cruise data are unavailable, or where data on additional attributes is required[2]) we would recommend using a minimum of three plots per stand in order to gain a reasonable 'average' view of the stand.

(ii) For each stand, review the look-up threshold values and award a score based on the position within the table. For example, in the ICHmw2 if the density of big trees is 90/ha (Table 5), then a stand would get a score of 3 for that attribute. It would also get a check mark in the 'old' column for that variable.

(iii) Repeat for a number of attributes, multiply number of checks by appropriate value (1,2 or 3 for not-old, recruitment and old columns respectively), and sum to obtain a total score.

(iv) Stands with a higher score are more likely to be old-growth, or are potentially more suitable as recruitment stands. A review of the stand structure categories, i.e. not-old, recruitment, old, given for each attribute gives the user a relative idea of the value for each attribute in that stand. This approach is useful because it allows the planner to consider multiple objectives for a stand. For example, a suitable old-growth management area may be required within a caribou special management zone. In this case, preference would be given to stands which scored high (good old-growth) values for the density of big trees, lichen density and evidence of pathogens (Stevenson 1994). Note that any comparison among stands must involve assessment of the same set of attributes in each stand.

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[2] Present cruise data can provide most of the information required for the score card assessment. However there are a few attributes that are not available from the cruise (for example lichen abundance, cover and height of understory, and depth of LFH). Having these additional data gathered on the cruise is important since they were important in determining plot distribution in factor space, and so provide better data to evaluate the old-growth status as well as habitat suitability of stands.

Application

The procedure described in this paper offers practitioner a methodology for assessing the structural attributes present in a forest stand, and ranking competing stands based on structural attributes. We suggest that the methodology will be useful for practitioners faced with choosing between competing stands with fairly similar attributes. We do not envision that all candidate OGMAs would be tested using this ranking procedure (given current fiscal constraints), however, potential recruitment and ‘younger old’ stands could be ranked using this procedure. Some will be ‘obviously old’ or obviously not-old and not require assessment.

Note that the methodology only assesses stand level factors, and that designating OGMAs must also include an assessment of landscape level factors (position within the landscape, forest matrix context, size of patch etc – see Holt and Steeger 1998 for further details). The procedure for laying out OGMAs is detailed in the Landscape Unit Planning Guide (Ministry of Forests and Ministry of Environment Lands and Parks, 1999). In many cases, opportunities will exist for choosing combinations of OGMAs which provide higher biological benefit within the policy constraints outlined. Determining the stand level attribute value present in a stand should be the first step in this assessment procedure.

Stand ___________ Variant: ICHdw Size _____________
Slope ___________ Site series ________________ FC age ___________

Attribute	**Measured Value**	**Score**			**Thresholds**	
		Not-old	**Recruitment**	**Old**	**Recruitment**	**Old**
Mean age					**110**	**173**
Mean Maximum age					**177**	**281**
Density trees >50cm dbh					**34**	**64**
Largest dbh on plot					**58**	**71**
Density trees 12.5 -40cm					**222**	**145**
# CWD >30cm, on 34m[1]					**10**	**15**
% trees >50 w deadtops[2]					**20**	**49**
% trees >50 w pathogens[3]					**40**	**70**
Lichen abundance[4]					**Low**	**Medium**
Density of snags >50cm					**7**	**11**
Density snags 12.5 – 25cm					**79**	**35**
		sum (*1)	**sum (*2)**	**sum (*3)**		

+ + = ____ Total Score

Comments and Landscape Considerations:

1: # pieces of CWD with dbh > 30cm, on 34m transect through plot
2: % of large trees (>50cm dbh) with dead or broken tops
3: % of large trees (>50cm dbh) with evidence of pathogens
4: based on Armleder et al. 1992.

Figure 13. An example scorecard for a stand in the ICHdw.

Discussion

Defining what is an old-growth forest has received much recent attention. Definitions based solely on age are used since they are simple to employ, however, it is widely acknowledged that definitions based on stand structural attributes are more useful for describing ecological processes and habitat values (Franklin and Spies 1991, B.C. Ministry of Forests 1992, Kneeshaw and Burton 1998, Wells *et al.* 1998). It is generally accepted that old-growth forest is at the end of a continuum from stand initiation[3], and a review of existing literature has demonstrated the lack of functional ecological thresholds marking the development of old-growth from younger forest stands (Hunter and White 1997). Spies and Franklin (1988), working in coastal Douglas-fir forests, suggest two attribute development curves: a U-shaped function which describes attributes which are initially plentiful after a disturbance event (often remnants of the previous old stand) which then decrease through the mid-seral and then increase into the old-growth stage (e.g. volume of coarse woody debris); and an S-shaped curve which describes attributes that increase in abundance after a disturbance event and eventually taper off, or reach a plateau (e.g. biomass). Although, the rate of change of attributes over a short period of time can be quite rapid in some ecosystems (e.g. Tyrell and Crow 1994), it is generally thought that the rate of change of attributes does not follow a step function, and so cannot readily be considered useful for defining thresholds.

It must be accepted then that any old-growth definition will be somewhat arbitrary (Hunter and White 1997). Spies and Franklin (1988; Franklin and Spies 1991) use this assumption as the basis for their ‘index of old-growthness’ where the successional status of a stand is ranked on the basis of a number of attributes. Stands are not dismissed because they ‘fail to meet old-growth standards’, but are instead given a relative ranking based on the abundance of a number of attributes. This approach receives much support because it may avoid potential short-sighted errors in old-growth designation (Hunter and White 1997; Wells *et al.* 1998).

In this report, we use a multivariate technique to identify groupings of mid- and old-seral plots based on stand structural attribute data, and use these groups to identify threshold values for ranking the old-growthness of older seral stands of the ICHmw2 and ICHdw BEC variants. In general, we feel that this approach was successful in objectively grouping plots, and in producing meaningful threshold values for some attributes which can be used to rank candidate old-growth management areas (OGMAs) as ‘old-growth’, ‘recruitment’, or ‘not-old’ forest.

In our principal components analysis, the data for the ICHmw2 variant split into natural groupings more easily than did that for the ICHdw. This is perhaps due to the greater abundance of old stands sampled in the ICHmw2 which are then more easily discriminated from younger stands. Finding sufficient old ICHdw stands whose structures have not been altered by previous logging or which were not severely impacted by other developments proved to be a severe limitation to this study. The lack of ‘natural’ old stands (due to the combination of human development and fire suppression) may also result in lower values than natural old-growth for some of the attribute thresholds, and is a considerable problem for any study attempting to assess ‘natural’ old-growth in this variant. Another factor in the lack of groupings in the ICHdw may be the wider range of types and intensities of disturbance naturally occurring in the ICHdw. The ICHdw includes areas which naturally undergo light-intensity stand-maintaining fires (e.g. Beck (1984) calculated a fire return of just over 11 years for an ICHdw/ 01a stand), as well as severe stand-destroying fires and intermediate-intensity fires, in which portions of the stand survive. We had hoped not to include the drier sites in sampling the ICHdw, however, it was very hard to find sites of a suitable age class which were not dry or rocky, or alternatively, were not riparian. We decided to avoid riparian areas since these appeared to be quite different, and instead used drier sites. Although we do not see obvious patterns of increased productivity (density of big trees used as a surrogate) with site series, an effect would be expected, and our negative result could be due to a lack of power to detect an effect on a single variable.

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[3] Some authors recognize antique or ancient forests as distinct from old growth. These climax forests have been free of stand level disturbances for longer than the maximum life span of the climax trees.

In future work to develop thresholds, we suggest that it may improve the ability of the PCA to explain variation in the data if a number of extra variables were sampled. These might include measures of vertical or horizontal heterogeneity (see Kneeshaw and Burton 1998 for examples). We originally noted the presence and distance from the plot of gaps in our stands. However, we observed almost no variation in the data, with almost all stands (except the very youngest) having gaps present. An improvement may be to count the number of gaps within 30 m of plot centre. In addition, it would be useful to include a specific diameter measure for coarse woody debris to allow measures of volume / hectare to be included in the analysis. Our initial intention was to focus on attributes which are both easily and repeatably measured, however, we feel that in some s these additional attributes may be worth the effort to sample. More extensive attribute sampling will provide additional information to discriminate between the old-growthness of stands.

Alternative Methods of Old-growth Definition

Defining whether a stand is old-growth can be achieved using a variety of techniques. Age-class structure is one approach to determining whether an individual stand has attained the functional stand development stage of old-growth (Oliver and Larson 1990; Kneeshaw and Burton 1998). This definition is based on the point at which the replacement cohort becomes dominant over the immediate post-disturbance cohort. The advantage of this approach is that it does not rely on threshold values based on other stands, however, it requires intensive sampling of ages within the stand, does not allow relative ranking between stands, and does not directly evaluate structural attributes important to habitat. These attributes may be present long before the replacement cohort dominates the stand, especially where the post-disturbance trees are long-lived.

Alternatively, Quesnel (1996) summarised statistics from an existing data set (biogeoclimatic classification system data) for stands assumed *a priori* to be old-growth (in this case greater than 140 years). A threshold value for each attribute was determined, based on one standard error lower than the mean value for each attribute. Any stand that reaches this lower threshold for any attribute is then considered to be old-growth (Quesnel 1996). Potential problems with this approach include: (i) assuming that all stands measured are actually old-growth; (ii) assuming that the attributes used for thresholds are positively correlated with old-growthness (e.g. trees with a DBH 30 – 50 cm are not correlated with old-growth (as defined by PCA-1 scores) in our data: PCA-1 component matrix score of 0.036 in the ICHdw), (iii) that meeting the threshold for one attribute is sufficient to make the stand old-growth, (iv) that all attributes have equal weight in defining old-growthness. However, it does provide a conservative approach for defining old-growth stands.

More complex indices have also been developed. For instance, Kneeshaw and Burton (1998) used threshold values for attributes positively associated with old-growth development based on the mean values between the maximum level found in mature stands and the minimum level found in old stands. These threshold values were then weighted by the correlation with PCA-1.

We investigated the use of an approach similar to that of Kneeshaw and Burton and examined the potential to use correlation coefficients from the PCA as weighting factors. However, we noticed that, although the position of plots in factor space was relatively stable with changes in attributes, the correlation matrix score was quite significantly affected by the attributes used in the analysis. We therefore decided that it was inappropriate to use the PCA correlation scores as weighting factors. Instead, we used PCA to determine natural splits in the data, and then provide threshold values for different levels of old-growth based on these splits. We feel this is the most useful approach since it not only provides a ranking approach for stands, but also allows direct evaluation for each attribute. It can then easily be adapted to identifying OGMAs which overlap with other biodiversity values. For instance, Mountain Caribou Special Management Zones often overlap with OGMAs (R.F. Holt unpubl. obs), but have additional specific stand structure requirements (Stevenson et al. 1994).

Using any single approach to define old-growth is inherently circular since there is only hypothesis generation, and no independent way to test the hypothesis. Kneeshaw and Burton (1998) overcame this problem by intensive field sampling and comparing the results of multiple approaches to rank the old-growthness of stands. They found that the stands on extreme ends of the scale (definite old-growth and definite ‘not’ old-growth) retained the same relative position and category irrespective of the approach. However, some intermediate stands changed relative rank and category depending on the method used. This was because different methods targeted different attributes. We were unable to compare different methodologies since the scope of the project did not allow intensive sampling on a suitable scale. We hope that the scorecard approach will assist planners in selecting from these intermediate stands based on the biodiversity objectives for their landscape unit.

Stand Age

Stand age, while appearing to be a straightforward concept, has some problematic aspects. The most widely applied definition in B.C. is that of B.C. Ministry of Forests Inventory Branch, which theoretically relates to the mean age of the one hundred tallest trees in a stand. Practically, it is the mean age of two individuals per species of the dominant and codominant trees and in the case of forest cover mapping is photo-interpreted. Other authors have considered stand age to be the age of the oldest tree in the stand where there was no evidence of subsequent disturbance (i.e. fire scars; Kneeshaw and Burton 1998). In environments such as the ICHmw2 and ICHdw, disturbances are of variable severity and frequency and fires often do not destroy the entire stand as evidenced by fire scars on living trees. One of the problems in interpreting stand age arises when applying the same definition to stands that have had very different stand development histories. Using two 140 year old stands as an example: one could have arisen from a severe fire about 150 years ago with most dominant and codominants establishing shortly after that fire, while the other stand may have numerous 300 year old stems that survived a moderate intensity fire about 80 years ago. Although sharing the same nominal stand age, these stands would contain very different structural attributes. Using the mean age of trees currently in the stand is therefore inappropriate since it ignores the fact that the overall stand age may be much older.

In forest types dominated by stand-replacing fires, the age of the oldest trees on the plot may be a more true measure of stand age (and even so may still be an underestimate of true stand age). In stands typically dominated by stand-maintaining or moderate intensity fires, the mean age of the canopy (excluding veteran trees) may be a suitable stand age, but the appropriateness of this will depend on the basal area of veteran trees retained. If they constitute a large percentage of the basal area then this should be reflected in the stand age. Another approach to try to simplify the interpretation of stand age is to sample ages based on basal area above a minimum DBH limit (K. Illes, pers. comm. 1998). In areas where variable severity disturbances occur (such as the bulk of the Nelson Forest Region), using mean stand age as the only criteria for assessing old-growth status can be very misleading, and some measure of the variability in tree age is necessary in order to interpret stand age.

One conclusion from this project is that forest cover age classes are insufficient to define the true old-growth status (and biological value) of forest stands. There are a number of reasons for this. Firstly, forest cover age classes are often incorrect. This was shown in our presentation of measured age versus predicted age from forest cover labels (figures 1 and 7). Across the two variants, 39% of labeling was incorrect, with 27% of the stands being younger than the inventory label. In addition, in some instances a stand may in fact be ‘old’ but may contain few old-growth attributes, particularly at high elevations (S. Clow pers. comm.). These stands may fail to provide adequate habitat values for species reliant primarily on old-growth forests.

It was not one of our express objectives to reassess the age class cut-offs for old-growth suggested in the Forest Practices Code Biodiversity Guidebook (B.C. Ministry of Forests and BC Environment 1995), given our limited sampling. However, our analyses do suggest some mean ages for the different groupings of old-growthness. For the ICHdw, we derived a threshold age for older stands of 174 years, with a younger threshold of 110 years for recruitment old-growth. These thresholds (and the associated means for the old, intermediate and young groups) are somewhat similar to the current FC age class definition of 140 years. For the ICHmw2, we determined threshold ages of 286 years for older stands, and 147 years for recruitment stands, which also brackets the Biodiversity Guidebook value of a 250 year threshold for this variant. Examination of plots of age versus PCA scores (Figures 4 and 11), there are no high old growth scores below about 200 years and by 270 years all stands rank high in the ICHmw2. In the ICHdw the break to high scores is not so well defined but by age 140 scores are uniformly high, which again is in general agreement with current age-class definitions. Our approach, however, allows stands at different places along this continuum to be ranked and classified irrespective of age. This will increase flexibility in landscape unit planning while maintaining biodiversity values as a priority in OGMA selection.

Comparisons of our results with existing data

Three other authors (see below) have examined structural attributes of stands in the Nelson Forest Region and in ecologically similar area. Quesnel (1996) used data collected by the BEC program, and compiled live tree and snag data by site series for stands greater than 140 years (considerably younger than the present definition of 250 years for old growth in the ICHmw2; B.C. Ministry of Forests and BC Environment 1995). Quesnel did not subdivide snags into size classes, and since trends in distribution of snags in different size classes will differ with stand age, these snag data do not provide useful comparisons. For the ICHdw, our attribute values fall within the range reported by Quesnel (Table 7), even in the case where our stand age is considerably older. We also found considerably more large trees in our 'old' category in the ICHmw2 than in Quesnel's most productive site series (though our stands were also considerably older than Quesnel's).

The US Forest Service generated definitions based on minimum standards for old-growth in areas immediately south of the Nelson Forest Region (Green et al. 1992). The process used to derive minimum standards is unclear, but it appears to have involved subjective assessment of inventory plot data for stands above a specific (unstated) age. The definitions are based on the number of large trees, large tree age, and basal area. Their definitions are presented for groups of similar habitat types (equivalent to site associations) and geographic area. Their North Idaho, Douglas-fir, grand fir, western larch, Engelmann/subalpine fir, western hemlock, white pine types in cool, moist environments are most equivalent to the sites sampled in the ICHdw. The North Idaho western red cedar type in moist environments is most equivalent to the ICHmw2 site series sampled. Their minimum standards for both forest types are considerably lower than those from other studies (Table 7). These relatively low numbers and young age particularly for the ICHmw2, may be due to having minimum standards based on only three criteria or to having a limited selection of very old stands for purposes of comparison. Having stringent minimum criteria based on a number of features may lead to rejecting stands with other old-growth attributes (Franklin and Spies 1991). In our analysis, when a subset of attributes were input into PCA, a split between old and not-old was still very evident on the PCA-1 axis, however several younger stands were ranked as 'old' (Holt et al. unpubl. data). This suggests that using fewer variables in the assessment of thresholds for old-growth results in a reduction in accuracy, particular in differentiating between old and not-old stands.

Gulyas and Elm (1998) used MLSIS (Major Licensee Silviculture Information System) and ISIS (Integrated Silviculture Information System)[4] data to produce summaries of live and dead trees for 50 stand types (leading species / site class) in 21 biogeoclimatic variants throughout the province. In their report they present data for four size classes (<20cm. 20.1-50.0 cm, 50.1 - 100 cm, and >100 cm dbh), and we present the data for trees > 50.1 cm dbh in Table 7. They present no data for the ICHdw and use only two old-growth (250 years or greater) stands in the ICHmw2. In addition, their two plots had only one size class of snags represented (neither plot had any small snags), in contrast to our data in which all plots had small snags, the vast majority had medium sized snags, and most old plots had >50cm snags.

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[4] MLSIS and ISIS are information management systems that capture, organize and processe land-based information required for silviculture management for major licensees and Forest Service respectively. Documentation on ISIS is contained on the following web site: http://www.for.gov.bc.ca/isb/isis/index.htm

Table 7. Summary of available and comparable data for the density of live trees in stands similar to the ICHdw and ICHmw2.

Site series or variant/old growth category	number of plots / stands sampled[1]	mean stand age	Big tree density[2] / hectare
<u>ICHdw, or similar:</u>			
Old - our data	18[a]	228	75[a]
Recruitment – our data	13[a]	120	53[a]
ICHdw/01a – Quesnel	3[b]	189	39[a]
ICHdw/01b – Quesnel	3[b]	152	104[a]
ICHdw/03 – Quesnel	2[b]	157	70[a]
Similar Idaho stands – Green et al.	-	150	25[b]
<u>ICHmw2 or similar</u>			
Old – our data	13[a]	402	140[a]
Recruitment – our data	22[a]	179	29[a]
ICHmw2/01 – Quesnel	14[b]	198	77[a]
ICHmw2/03 – Quesnel	1[b]	221	105[a]
ICHmw2/04 – Quesnel	6[b]	184	100[a]
ICHmw2/05 – Quesnel	12[b]	185	121[a]
Similar Idaho stands – Green et al.	-	150	25[c]
Gulyas and Elm 1998	2	-	93[a]

1: Scale of analysis unit: (a) plots, (b) stands.
2: a: > 50cm dbh; b: >53cm dbh; c: >63cm dbh.

Stand versus landscape level considerations

The procedure we present to index ‘old-growthness’ is a stand level structural attribute ranking procedure only. It does not include other stand and landscape level variables which should (ecologically) be considered when delineating old-growth management areas. At the stand level these include: size of the patch (for interior habitat conditions), human-initiated disturbance within or adjacent to the patch (e.g. old roads, old high-grading, location of housing, powerlines, etc.), and other rare features within the patch. At the landscape level, additional considerations include: position in relation to other OGMAs within the landscape unit and with adjacent landscape units, connectivity potential of the patch, state of the surrounding forest cover matrix (an OGMA buffered by surrounding forest may have higher short term value than one surrounded by clearcuts), other special management zone or biodiversity values in the landscape. Note that many of these stand and landscape level attributes are not included in the current guidelines for landscape unit planning and old-growth management area designation. Current policy is that these features may not be managed for unless it is known that this will not significantly impact timber supply over other choices of old-growth management area (BC Ministries of Forests and Environment, Lands, and Parks 1999). However, there will be many scenarios either when there is an excess of old-growth outside the timber harvesting landbase, or where OGMAs must be designated within the THLB, when it will be possible to consider the variables outlined above without having any further impact on timber supply. In is the authors opinion that designation of old-growth management areas without consideration of both stand and landscape level parameters will result in an inefficient use of the ‘timber budget’ allocated to biodiversity management in British Columbia.

Shortcomings of methodology

There were a number of areas where our methods could have been improved. If future work of this type is undertaken, these deficiencies should be addressed. It should be remembered that this was a low budget project and inevitable shortcomings stem from this constraint.

1. The number of samples within a site series should be increased so that site series effects, such as that seen in the ICHmw2, can be accounted for. Subhygric sites should be treated separately from drier site series.
2. Although our method of assessing CWD was very quick and allows for a relative assessment of abundance, it does not allow for calculation of volume. This would be very useful when comparing to other sites since many published reports quote volumes of CWD. Measuring dbh of pieces encountered on line transects would alleviate this shortcoming (Marshall and Bugnot 1997).
3. Large-sized snags and live trees are often present at very low densities and our plot size was too small for an accurate assessment of large snag density. The threshold for the not-old group in the ICHdw would equate to finding less than one snag per plot. A larger plot size for these variables would likely increase the efficacy of this measure.
4. We did not consistently evaluate the presence of fire scars or veteran trees and so do not have a good assessment of how many stands were subject to moderate intensity fires during their development.
5. Vertical structure was not directly assessed. Diameter distribution of smaller diameter trees was assessed, which should reflect vertical structure. In our search of the literature we did not find a quick means of assessing canopy structure.
6. We did not assess the presence of gaps with sufficient resolution to identify variation among plots. A count of the number of gaps above a certain minimum size within sight of plot centre might yield useful information. Otherwise methods to quantify gaps are very time consuming. The use of simple measures of gap structure are unlikely to distinguish mature from old-growth stands (R. Wells, pers. comm. 1999).
7. We did not characterize age class structure, which is important in assessing old-growth status from a stand development viewpoint. This, however, would again be extremely time-consuming.
8. Our method of ranking stands does not include a weighting of factors. Some factors are more strongly correlated than others with old-growth status. The fact that our correlation coefficients were unstable may be a result of our small sample size.

Future work

The field card method presented in this paper should be field-tested. A number of stands should be selected to sample a range of stand ages and structural attributes. These stands would then be subjectively evaluated with regards to their old-growthness and these subjective rankings would be compared to rankings using the scorecard. This is especially relevant given the relatively low sample size of this pilot project. This field test is currently in progress by the authors.

The process of OGMA delineation is underway throughout the province. Candidate areas need to be evaluated by a quick, reproducible, objective method. We propose that this method be extended to other variants, especially in areas where (i) there are significant deficits of old forest (compared to guidelines for old-growth retention) and (ii) where there are multiple choices available to planners (e.g. in high elevation areas with large areas of old-growth).

Conclusions and Recommendations

1. Age provides a basis for defining old-growth, but there is considerable additional variation in old-growth quality unaccounted for by broad age-class definitions. Stand structural attributes should be used to refine definitions and ranking procedures.

2. Stand age descriptions on forest cover maps are inadequate for designating OGMAs. Many were incorrect based on mean age, and no indication of variation in age class structure is given. Maximum age may be a more suitable measure in stands where no disturbances have occurred since stand initiation. In addition, some ‘old’ stands contain poor representation of old-growth habitat attributes and may therefore be less desirable for conservation purposes than old stands with higher structural attributes diversity. Forest cover mapping is still the most easily available and useful tool for initial identification of candidate OGMA’s, however, additional information gained by aerial surveys and final ground checking for attributes is necessary to evaluate attributes quality.

3. The methodology for sampling and indexing old-growth patches proved quite effective. A single stand could be assessed in about four to eight hours (including age core examination under binocular microscope). We suggest that this will provide a suitable way to resolve questions about old-growth quality in the field.

4. The ICHdw has an extreme deficit of old-growth forest (compared to guidelines for old-growth retention). The low availability of natural old-growth is a result of the combination of historical fire-setting (for mineral exploration), high urban and industrial development, creation of travel corridors, harvesting (past and present), and fire suppression (allowing ingrowth in some of the drier site series). Regardless of the cause, the lack of a representative natural old forest in this variant is a severe obstacle in the attempt to manage forests by mimicking natural disturbance patterns (B.C. Ministry of Forests and B.C. Environment 1995), since it is difficult to even gather baseline data. Protection of the remaining old-growth and suitable recruitment old-growth in this variant must be a priority.

5. Disturbance intensity is variable in both the ICHdw and ICHmw2. This is evidenced by the widespread occurrence of veteran trees and fire scars in both old and younger stands. Stand structural attributes retained after disturbance provide important habitat (Steeger et al. 1998) and should be conserved across the landscape in stands of all ages.

6. Although the sample design was not intended to test for differences in attributes by site series, there is significant variation in at least one variable (density of large trees) in ICHmw2 with site series. Current policy in British Columbia is to designate OGMAs at the level of the variant, and not at any finer scale. Representation of old-growth at the variant level, in concert with policy to preferentially locate all OGMAs outside the timber harvesting landbase will result in the majority of OGMAs located on steep slopes and in riparian areas in some areas of the Province. More research is required to evaluate whether, and to what extent, important ecological variation will be lost as a result of this policy. A limited analysis of the potential risk to biodiversity as a result of this policy is underway (M. Eng. pers. comm.), however the scope of the analysis should be expanded to allow a thorough evaluation of potential risks (R.F. Holt, pers. obs).

References

Armleder, H.M., S.K. Stevenson and S.D. Walker. 1992. Estimating abundance of arboreal forage lichens. Land Management Handbook Field Guide Insert 7. Ministry of Forests Research Program, B.C.

Beck, J. 1984. Fire history and range enhancement study for the Cayuse Creek Area. Unpublished report. Selkirk College Library, Castlegar, BC.

Braumandl, T.F. and M.P. Curran. 1992. A field guide for site identification and interpretation for the Nelson Forest Region. BC Min. For. Research Branch, Victoria, B.C., Land Manage. Handb. No 20.

B.C. Ministry of Forests. 1992. An old-growth strategy for British Columbia. Victoria, BC.

B.C. Ministry of Forests and BC Environment. 1995. Biodiversity Guidebook. Forest Practices Code of British Columbia, Victoria, BC.

BC Ministries of Forests and Environment, Lands, and Parks. 1999. Landscape unit planning guidebook. Forest Practices Code of British Columbia. Victoria, B.C.

Franklin, J.F. and T.A. Spies. 1991. Ecological definitions of old-growth Douglas-fir forests. *in* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, tech. coordrs. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-285, USDA, Forest Service, Portland, OR.

Goward, T. 1993. Crown of the ICH: epiphytic macrolichens of old growth forests in the interior cedar-hemlock zone. Bioline, Vol. 11, No. 2, Fall/winter 1993. Pages 15-17.

Green, P., J. Joy, D. Sirucek, W. Hann, A. Zack, and B. Naumann. 1992. Old-growth forest types of the Northern Region. R-1 SES 4/92. USDA Forest Service. Northern Region, Missoula, MT.

Gulyas, G. and T. Elm. 1998 Structural Attributes of Forest Stands. Contract report for B.C. Ministry of Forests, Forest Practices Branch. Victoria, B.C.

Holt, R.F and C. Steeger 1998. An ecological methodology for old seral identification, assessment and ranking at a landscape scale, in the Nelson Forest Region. Final report of phase II. Prepared for Kootenay Boundary Land Use Implementation Task Force, Nelson Forest Region. 36 pp.

Hunter M.L. and P. White. 1997. Ecological thresholds and the definition of old-growth forest stands. Natural Areas Journal 17: 292-296.

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 18:293-308

Manly, B.F.J. 1986. Multivariate Statistical Methods: A Primer. Chapman and Hall, New York.

Marcot, B.G., R.S. Holthausen, J. Teply, and W.D. Carrier. 1991 *in* L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff, tech. coordrs. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-285, USDA, Forest Service, Portland, OR.

Marshall, P.L. and J.L. Bugnot. 1997. Review of some designs for sampling coarse woody debris. Research Report prepared for the BC Ministry of Forests, Vancouver Region, 55 pp.

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

Quesnel, H.J. 1996. Assessment and characterization of old-growth stands in the Nelson Forest Region. Technical Report TR -013. B.C. Ministry of Forests, Forest Sciences Section, Nelson, B.C.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. The Principle and Practice of Statistics in Biological Research. 2nd Edition. W.H. Freeman and Co. New York, NY.

Spies, T.A. and J.F. Franklin. 1988. Old-growth and forest dynamics in the Douglas-fir region of western Oregon and Washington. Natural Areas Journal 8: 190-201.

Steeger, C., R.F. Holt, H. Quesnel and M-A. Beaucher. 1998. Post-disturbance residual stand structure: its value as wildlife habitat. Report prepared for BC Environment, Nelson, B.C. 56pp.

Stevenson, S.K., H.M. Armleder, M.J. Jull, D.G. King, E.L. Terry, G.S. Watts, B.N.McLellan, and K.N. Child,. 1994. Mountain caribou in managed forests. Research Branch, B.C. Ministry of Forests.

Tabachnik, B.G. and L.S. Fidell. 1996. Using Multivariate Statistics, 3rd Ed. HarperCollins College Publishers. 880 pages.

ter Braak, C.J.F. 1995. Ordination. Pages 91-173 in: Data analysis in community and landscape ecology. (Jongman, R.H.G; ter Braak, C.J.F; Van Tongeren, O.F.R Eds.) Cambridge University Press.

Tyrell L.E. and T.R. Crow 1994. Structural characteristics of old-growth hemlock hard-wood forests in relation to age. Ecology 75: 370-386.

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

Appendices 1-2

Appendix 1: Example scorecards completed for three stands in each of the ICHmw2 and ICHdw, and photorerepresentation of plots.

Appendix 2: Summary data for stands sampled in the ICHmw2 and ICHdw.

Appendix 1. Example scorecards for the ICHmw2 and ICHdw.

Below, we present three examples of using the scorecard and the threshold tables from data we collected. Our intent is not to ‘test’ our thresholds, but to demonstrate the utilisation of the methodology. The examples chosen are to illustrate a very high quality old-growth stand (example A), a recruitment stand (Example B) which has some old-growth attributes, and a “not-old” (example C) stand, which has almost no old-growth attributes.

ICHmw2:
Example A (old-growth).

Stand: Glenmerry	Variant: ICHmw2	Size 60 ha.
Slope 20%	Site series 01	FC age 140 - 250

Attribute	Measured Value	Score			Thresholds	
		Not-old	**Recruit-ment**	**Old**	**Recruit-ment**	**Old**
Mean age	**542**			✓	**147**	**286**
Mean Maximum age	**1014**			✓	**204**	**411**
Density trees >50cm dbh	**223**			✓	**25**	**84**
Largest dbh on plot	**115**			✓	**57**	**74**
% trees >50 w dead tops[1]	**45**			✓	**13**	**29**
% trees >50 w pathogens[2]	**45**			✓	**18**	**37**
Density of snags >50cm	**13**		✓		**11**	**18**
Density snags 10 – 25cm	**50**		✓		**77**	**45**
		sum (*1)	**sum (*2)**	**sum (*3)**		
		0 +	**4** +	**18** =	22	**Total Score**

Comments and Landscape Considerations:

1: % of large trees (>50cm dbh) with dead or broken tops
2: % of large trees (>50cm dbh) with evidence of pathogens

Glenmerry – old-growth stand.

Example B (Recruitment).

Stand: Six Mile Lake	Variant: <u>ICHmw2</u>	Size 60 ha.
Slope 60%	Site series 01	FC age 140 - 250

Attribute	**Measured Value**	**Score**			**Thresholds**	
		Not-old	**Recruitment**	**Old**	**Recruitment**	**Old**
Mean age	**197**		✓		**147**	**286**
Mean Maximum age	**327**		✓		**204**	**411**
Density trees >50cm dbh	**67**		✓		**25**	**84**
Largest dbh on plot	**78**			✓	**57**	**74**
% trees >50 w dead tops[1]	**35**			✓	**13**	**29**
% trees >50 w pathogens[2]	**27**		✓		**18**	**37**
Density of snags >50cm	**13**		✓		**11**	**18**
Density snags 10 – 25cm	**10**			✓	**77**	**45**
		sum (*1) **0** +	**sum (*2)** **10** +	**sum (*3)** **9** =	**19**	**Total Score**

Comments and Landscape Considerations:

1: % of large trees (>50cm dbh) with dead or broken tops
2: % of large trees (>50cm dbh) with evidence of pathogens

Six Mile Lake – recruitment site

Example C (Not-old).

Stand: MacDonald B	Variant: ICHmw2	Size 60 ha.
Slope 15%	Site series 01	FC age 120 - 140

Attribute	**Measured Value**	**Score**			**Thresholds**	
		Not-old	**Recruit-ment**	**Old**	**Recruit-ment**	**Old**
Mean age	**107**	✓			**147**	**286**
Mean Maximum age	**139**	✓			**204**	**411**
Density trees >50cm dbh	**17**	✓			**25**	**84**
Largest dbh on plot	**61**		✓		**57**	**74**
% trees >50 w dead tops[1]	**11**	✓			**13**	**29**
% trees >50 w pathogens[2]	**11**	✓			**18**	**37**
Density of snags >50cm	**0**	✓			**11**	**18**
Density snags 10 – 25cm	**61**		✓		**77**	**45**
		sum (*1)	**sum (*2)**	**sum (*3)**		
		6 +	**4** +	**0** =	**10**	**Total**

Score

Comments and Landscape Considerations:

1: % of large trees (>50cm dbh) with dead or broken tops
2: % of large trees (>50cm dbh) with evidence of pathogens

MacDonald B – ‘not-old’ stand.

ICHdw: Example A (old-growth).

Stand: Erie	Variant: ICHdw	Size 25 ha
Slope 20%	Site series 01b	FC age 9

Attribute	**Measured Value**	**Score**			**Thresholds**	
		Not-old	**Recruitment**	**Old**	**Recruitment**	**Old**
Mean age	**390**			✓	**110**	**173**
Mean Maximum age	**826**			✓	**177**	**281**
Density trees >50cm dbh	**90**			✓	**34**	**64**
Largest dbh on plot	**88.5**			✓	**58**	**71**
Density trees 12.5 -40cm	**57**			✓	**222**	**145**
# CWD >30cm, on 34m[1]	**40**			✓	**10**	**15**
% trees >50 w deadtops[2]	**55**			✓	**20**	**49**
% trees >50 w pathogens[3]	**39**	✓			**40**	**70**
Lichen abundance[4]	**-**				**Low**	**Medium**
Density of snags >50cm	**33**			✓	**7**	**11**
Density snags 12.5 – 25cm	**17**			✓	**79**	**35**
		sum (*1)	**sum (*2)**	**sum (*3)**		

1 + 0 + 27 = 28 Total Score

Comments and Landscape Considerations:

1: # pieces of CWD with dbh > 30cm, on 34m transect through plot
2: % of large trees (>50cm dbh) with dead or broken tops
3: % of large trees (>50cm dbh) with evidence of pathogens
4: based on Armleder et al. 1992.

Erie Creek – old-growth site

Example B. Recruitment.

Stand : Kokanee	Variant: ICHdw	Size : 20ha
Slope 45 %	Site series 01a	FC age : 7

Attribute	Measured Value	Score			Thresholds	
		Not-old	Recruitment	Old	Recruitment	Old
Mean age	**128**		✓		**110**	**173**
Mean Maximum age	**187**		✓		**177**	**281**
Density trees >50cm dbh	**47**		✓		**34**	**64**
Largest dbh on plot	**67**		✓		**58**	**71**
Density trees 12.5 -40cm	**157**		✓		**222**	**145**
# CWD >30cm, on 34m[1]	**17**			✓	**10**	**15**
% trees >50 w deadtops[2]	**6**	✓			**20**	**49**
% trees >50 w pathogens[3]	**61**		✓		**40**	**70**
Lichen abundance[4]	**0 – low**	✓			**Low**	**Medium**
Density of snags >50cm	**7**		✓		**7**	**11**
Density snags 12.5 – 25cm	**33**			✓	**79**	**35**
		sum (*1)	**sum (*2)**	**sum (*3)**		

2 + 14 + 6 = 22 Total Score

Comments and Landscape Considerations:

[1] # pieces of CWD with dbh > 30cm, on 34m transect through plot
[2] % of large trees (>50cm dbh) with dead or broken tops
[3] % of large trees (>50cm dbh) with evidence of pathogens
[4] based on Armleder et al. 1992.

Kokanee Creek : Recruitment stand

Example C. “Not-old” forest.

Stand : Falls Creek	Variant: ICHdw	Size: 30ha
Slope 40 %	Site series	FC age: 8

Attribute	**Measured Value**	**Score**			**Thresholds**	
		Not-old	**Recruitment**	**Old**	**Recruitment**	**Old**
Mean age	**103**	✓			**110**	**173**
Mean Maximum age	**154**	✓			**177**	**281**
Density trees >50cm dbh	**30**	✓			**34**	**64**
Largest dbh on plot	**81.4**			✓	**58**	**71**
Density trees 12.5 -40cm	**270**	✓			**222**	**145**
# CWD >30cm, on 34m[1]	**13**		✓		**10**	**15**
% trees >50 w deadtops[2]	**0**	✓			**20**	**49**
% trees >50 w pathogens[3]	**12.5**	✓			**40**	**70**
Lichen abundance[4]	**0 – low**	✓			**Low**	**Medium**
Density of snags >50cm	**0**	✓			**7**	**11**
Density snags 12.5 – 25cm	**57**		✓		**79**	**35**
		sum (*1)	**sum (*2)**	**sum (*3)**		
		8 +	**4 +**	**3 = 15**	**Total Score**	

Comments and Landscape Considerations:

1: # pieces of CWD with dbh > 30cm, on 34m transect through plot
2: % of large trees (>50cm dbh) with dead or broken tops
3: % of large trees (>50cm dbh) with evidence of pathogens
4: based on Armleder et al. 1992.

Proctor: “not-old” stand.

Appendix 2. Summary data for stands sampled in the ICHmw2 and ICHdw.

Summary table of data for ICHmw2

Site	Site series	FC age class	Mean age measured	SE age	Maximum age	mean # of live trees >50cm dbh	SE #/ha >50cm live trees	max stand DBH (cm)
MacDonaldB	ICHmw2/04	8	107	9	139	17	9	61
Shields	ICHmw2/01	8	126	34	289	13	3	53
WilsonB	ICHmw2/01	8	127	7	152	33	13	63
New DenverA	ICHmw2/01	7	128	11	188	10	6	58
New DenverB	ICHmw2/04	8	134	21	238	10	10	57
Tiger	ICHmw2/01	8	134	18	219	17	9	53
Scalping	ICHmw2/01	8	144	71	348	70	40	114
Six mile Lake	ICHmw2/01	8	197	43	327	66	19	78
CollegeB	ICHmw2/04	8	202	48	361	50	6	84
Silverton	ICHmw2/05	8	222	55	404	133	37	110
WilsonA	ICHmw2/01	8	247	59	475	53	24	70
CollegeA	ICHmw2/05	9	322	94	726	193	29	102
Boundary	ICHmw2/01	8	389	80	503	105	15	90
Kuskanax	ICHmw2/04	9	402	40	519	137	17	97
MacDonaldA	ICHmw2/01	9	434	154	1051	100	21	87
Pedro	ICHmw2/01	9	468	167	1000	87	12	85
Bremner	ICHmw2/01	9	474	142	942	117	38	106
Glenmerry	ICHmw2/01	8	542	140	1014	223	22	115

Site	seedlings/ha	SE seedlings/ha	average live trees<12.5 /ha	SE live trees<12.5 /ha	average live trees 12.5-40/ha	SE live trees 12.5-40/ha	average live trees 40-50/ha	SE live trees 40-50/ha
MacDonaldB								
Shields	1000	0	753	346	224	97	10	6
WilsonB	917	83	454	168	201	89	7	3
New DenverA								
New DenverB								
Tiger	600	32	331	143	152	75	30	6
Scalping	75	65	328	249	238	328	15	5
Six mile Lake	293	189	181	88	69	31	23	7
CollegeB								
Silverton	480	130	172	62	77	47	20	6
WilsonA	873	85	193	121	204	92	17	17
CollegeA								
Boundary	290	20	193	94	43	56	5	5
Kuskanax								
MacDonaldA								
Pedro								
Bremner	430	310	30	12	48	26	10	8
Glenmerry								

Site	average snags 10-25/ha	stdev snags 10-25/ha	average snags 25-50/ha	stdev snags 25-50/ha	average snags >50/ha	stdev snags >50/ha	max stand snag DBH	average % of >50 with path indicator	SE % of >50 with path indicator
MacDonald B	123	17	20	12	0	0	34	11	11
Shields	77	32	73	9	33	7	68	50	29
WilsonB	53	19	27	22	3	3	80	6	6
New DenverA	100	6	43	9	0	0	47	0	0
New DenverB	120	38	53	15	0	0	37	33	33
Tiger	63	28	103	27	13	9	55	0	0
Scalping	70	10	45	15	17	11	75	56	11
Six mile Lake	10	6	33	18	13	3	85	0	0
CollegeB	63	12	40	17	13	3	65	27	7
Silverton	23	9	3	3	3	3		38	15
WilsonA	70	35	60	35	37	9	62	38	22
CollegeA	3	3	10	6	7	3	109	42	10
Boundary	15	5	15	15	25	15	85	25	8
Kuskanax	7	7	20	10	33	9	85	60	7
MacDonald A	20	12	13	9	23	15	99	49	11
Pedro	20	10	7	7	7	7	65	46	10
Bremner	77	67	17	7	23	9	82	50	17
Glenmerry	50	10	27	17	13	9	85	45	3

Site	average CWD #>30/ha	SE average CWD #>30/ha	MaximumCWD diameter	Lichen Range
MacDonaldB	43	13	52	L
Shields	30	6	61	L
WilsonB	30	6	47	L
New DenverA	53	3	53	L
New DenverB	10	10	39	0 - M
Tiger	33	7	46	L
Scalping	80	20	58	L
Six mile Lake	37	15	61	L
CollegeB	17	7	49	L
Silverton	27	9	70	L - M
WilsonA	33	18	61	L
CollegeA	47	12	75	M
Boundary	45	25	61	L - M
Kuskanax	67	9	52	L
MacDonaldA	90	15	94	L
Pedro	40	23	35	A - M
Bremner	50	35	96	L
Glenmerry	43	15	58	L - M

ICHmw2: Total mean age for the stand, plus mean age and standard error by species.

	Mean age measured	Cw_age	Cw_age SE	Hw_age	Hw_age SE	Fd_age	Fd_age SE	Lw_age	Lw_age SE	Sx_age	Sx_age SE
MacDonaldB	107	480		86	7	108	5	114	7		
Shields	126	173	36	96	6	122	.			113	7
WilsonB	127	117	9	124	2	109		139	3		
New DenverA	128	114	1	140	17	132	4				
New DenverB	134	112	9	107	10	155	21	146	32		
Tiger	134	136	10	136	14	152	28			118	
Scalping	144	236	49	98	21	76	7	79			
Six mile Lake	197	171	26	159	18	298	19				
CollegeB	202			145	7	295	15				
Silverton	222	250	18	253	77					393	
WilsonA	247	296	73	182	25	316	39	122			
CollegeA	322	343	103	306	43						
Boundary	389	489	7	363	45						
Kuskanax	402			398	22	450					
MacDonaldA	434	753	165	327	55						
Pedro	468	454	230	474	106			439			
Bremner	474	783	159	386	67						
Glenmerry	542	711	122	414	74	66	5	631	38	408	

Summary table of data for ICHdw

Data are given per hectare where appropriate.

Site	Site series	FC age	Mean age measured	SE age	Max age	Mean # live trees>50cm dbh	SE live trees>50cm dbh	Largest dbh > 50cm dbh
Erie	01b	9	390	52	826	90	6	89
Flats	01a, 01b	9	274	24	600	77	12	84
Hidden Cr	01b	8	231	20	345	77		105
Lemon	01a, 01b	8	196	28	383	33	20	82
Power	2	8	191	17	441	60	15	85
PDO	01a	8	174	9	196	77	12	91
Redfish	01b	9	169	16	355	83	18	80
Syringa	01a, 02	8	155	26	392	53	12	102
Big Sheep	02, 01a	8	149	18	222	50	21	65
Eco Res	02, 01a	8	142	18	338	50	26	88
WADF	01a	7	140	17	284	77	17	91
CIC	01b	8	135	8	258	60	6	86
Kokanee	01a	7	128	5	187	47	13	67
Proctor	01a	6	123	11	321	10	0	72
Sitkum	01a, 01b	6	115	5	245	23	9	63
Falls Cr	01a/01b	8	103	8	154	30	10	81
Ainsworth	01b	6	87	3	103	60	10	76
Church	01a	6	86	6	127	0	0	

Site	Mean # live trees <12.5cm dbh	SE live trees <12.5cm dbh	Mean live trees 12.5-40cm dbh	SE live trees 12.5-40cm dbh	Mean # live trees 40-50cm dbh	SE live trees 40-50cm dbh	Mean # snags 10-25cm dbh	SE snags 10-25cm dbh	Mean # snags 25-50cm dbh	SE snags 25-50cm dbh
Erie	483	180	57	23	53	9	17	3	20	12
Flats	237	57	183	48	33	3	20	6	37	12
Hidden Cr	200	75	153	24	30	0	23	9	57	9
Lemon	67	42	87	12	40	10	33	15	13	9
Power	63	27	73	17	37	15	23	7	17	12
PDO	420	287	33	15	13	3	0	0	100	95
Redfish	133	27	190	55	30	10	30	10	33	3
Syringa	160	53	197	77	23	7	3	3	20	10
Big Sheep	90	71	87	32	10	10	20	6	20	10
Eco Res	57	12	147	35	13	3	7	3	27	15
WADF	43	19	110	6	27	18	17	9	10	6
CIC	397	53	220	15	33	20	23	7	27	7
Kokanee	23	19	157	7	23	12	33	9	33	12
Proctor	790	244	297	43	23	9	97	30	143	32
Sitkum	530	241	253	45	33	12	53	28	103	44
Falls Cr	315	143	270	33	30	24	57	43	13	3
Ainsworth	33	15	90	32	17	3	7	3	30	6
Church	170	52	227	15	13	9	13	3	0	0

Site	Mean # snags >50cm dbh	SE snags >50cm dbh	Max snag dbh	Mean % trees >50cm dbh with path. indicator	SE % trees >50cm dbh with path. indicator	Mean % trees >50cm with broken/ dead tops	Mean CWD # >30cm	SE CWD # >30cm	Max CWD diameter	Lichen range
Erie	33	9	82	39	13	55	40	10	70	L-H
Flats	7	3	67	58	22	71	27	7	67	H
Hidden Cr	13	7	72	3	1	27	17	3	45	M
Lemon	3	3	81	10	10	11	13	3	42	L-M
Power	0	0		46	16	10	0	0	0	H
PDO	0	0		23	10	3	13	3	65	H
Redfish	7	7	61	40	25	26	13	3	52	M-H
Syringa	3	3	51	53	25	10	3	3	35	0
Big Sheep	3	3	59	0	0	0	17	9	61	L
Eco Res	13	7	62.5	36	14	45	17	3	70	M-H
WADF	7	3	87	74	5	0	0	0	0	L
CIC	20	12	74	51	5	51	10	6	40	0
Kokanee	7	7		61	11	6	17	7	52	0-L
Proctor	13	9	55	0	0	0	17	7	52	0
Sitkum	3	3	52	25	14	12	3	3	35	0-M
Falls Cr	0	0		13	13	0	13	3	40	0-L
Ainsworth	3	3	52	4	4	0	17	7	40	M
Church	0	0	-	-	-	-	3	3	0	L

ICHdw: Total mean age, plus mean age and standard error (in parentheses), and sample size, by species.

Site	Total	Fd	Lw	Py	Cw	Hw	Bg	Pw	Sx	Pl
Erie	390 (214) 17	-	-	-	553 (298) 5	322 (131) 12	-	-	-	-
ND Flats	274 (117) 19	316 (125) 6	-	-	289 (175) 5	233 (54) 8	-	-	-	-
Hidden Ck.	231 (70) 13	330 (-) 1	-	-	251 (72) 4	209 (64) 18	-	-	-	-
Lemon	196 (105) 14	221 (105) 6	-	261 (127) 3	115 (7)3	106 (6)2	-	-	-	-
Power	191 (72) 16	171 (26) 12	-	249 (132) 4	-	-	-	-	-	-
P d’O	174 (39) 13	189 (5) 7	-	172 (31) 3	-	-	53 (-) 1	185 (3) 2	-	-
Redfish	169 (87) 27	244 (44) 6	109 (-) 1	275 (20) 4	85 (8)6	-	124 (45) 6	245 (155) 2	-	99 (13) 2
Syringa	155 (103) 13	85 (48) 5	159 (46) 4	238 (142) 4	-	-	-	-	-	-
BS	149 (59) 11	141 (64) 9	170 (-) 1	197 (-) 1	-	-	-	-	-	-
EcoRes	142 (71) 14	135 (52) 6	107 (-) 1	167 (98) 6	-	-	-	-	-	108 (-) 1
WADF	140 (67) 16	129 (58) 8	-	153 (79) 8	-	-	-	-	-	-
CIC	135 (42) 31	173 (9) 6	134 (44) 5	-	160 (64) 5	115 (9) 4	97 (7) 6	184 (-) 1	143 (-) 1	100 (10) 3
Kokanee	128 (21) 19	130 (12) 6	138 (17) 2	130 (33)6	118 (24) 5	-	-	-	-	-
Proctor	123 (54) 20	103 (25) 6	133 (43) 4	-	170 (103) 4	93 (5) 2	-	108 (23) 4	-	-
Sitkum	115 (30) 28	114 (10) 6	106 (23) 4	130 (68) 5	85 (7) 2	116 (19) 5	103 (12) 2	107 (7) 4	-	-
Falls Creek	102 (37) 13	148 (11) 5	-	-	73 (11) 3	83 (11)3	79 (17) 2	-	-	-
Ainsworth	87 (11) 18	93 (6) 6	92 (8) 6	-	72 (10) 4	-	-	85 (2) 2	-	-
Church	86 (22) 11	92 (25) 7	-	75 (12) 4	-	-	-	-	-	-