# Definitions of old-growth in the MSdk BEC unit 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, 2001**

## 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 based solely on forest cover age class. However, it is known 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 the Montane Spruce dry cool (MSdk) unit in the Nelson Forest Region was examined to determine whether old seral stands can be ranked based on structural attributes. Structural attributes were sampled in 38 stands of MSdk, ranging in mean age from approximately 64 to 299 years. Stands were classified as 'wet' or 'dry' based on site series classification and these two groups were considered and analysed separately from each other. A statistical methodology (Principal Components Analysis) was used to look for the suites of attributes that explain the most variation in the data set, based on pre-defined notions of what constitutes useful old growth structural attributes.

The two groups of stands – wet and dry – responded differently. The wet stands were separated into two different groupings based on the combination of their structural attributes : those with high 'old-growthness' (with large or abundant structural attributes), and those with low or no large structural attributes. A threshold value for each attribute was calculated from the midpoints between each group, and a scorecard for ranking "wet" MSdk stands based on their structural attributes is presented.

Analysis using PCA for the 'dry' MSdk stands did not show any clear patterns based on groupings of structural attributes. For this reason we used an alternative approach and classified stands using an arbitrary age cut off and then described the attributes present. Even using this approach, it was impossible to differentiate between groups on the basis of structure. We suggest that the reasons pattern of structural development were not apparent in the dry MSdk are threefold: I) 'Dry' old stands in the MSdk are generally the result of varying amounts of fire resistant Douglas-fir and western larch surviving one or more low to moderate intensity fires. In these non-riparian situations, there were no instances found where a single cohort reached old age in the absence of fire. Thus stands with a wide range of average stand ages would have remnant old structure; ii) a number of dry stands had thickets of young Douglas fir which we suspect may have swamped any other patterns present in large size attributes, and iii) the high level of historic harvesting in this zone has resulted in almost no 'unmanaged' old growth present. The 'old', dry stands that remain in this area tend to be on very steep, rocky, low productive sites and are not necessarily representative of the stands sampled in earlier age classes

A brief summary of the literature on development of old growth MS forest, and suggestions for appropriate procedures for location of old growth management areas in this extensive variant are also presented.

## Acknowledgements

We would like to thank Al Neal and Mike Black for help with site locations. Jakob Dulisse, Pamela Dykstra, Emilee Fanjoy and Adam Steele for help with field work, tree core counting and data entry. Andre Arseneault, Walt Klenner, Doug Berglund, Steve Byford, Dan Leavell and Phil Burton provided additional comments on the approaches and patterns observed.

Three anonymous reviewers also provided useful comments on the methodology and approach (in a previous document that used this similar approach of analysis).

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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 some of these unique 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 defining 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 (Spies and Franklin 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, old age of some trees, canopy gaps, hummocky micro-topography, 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 include stand structural attributes in the old growth definition (and also assumes that Forest Cover age data are correct). 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 (Wells *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 shortsighted errors in old-growth designation (Hunter and White 1997; Wells *et al.* 1998). This paper takes a similar conceptual approach, and uses 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 (LUPG: BC Ministries of Forests and Environment Lands, and Parks 1999). Area-based targets are to be met by designating Old Growth Management Areas (OGMAs) in landscape units as permanent reserves. Current policy dictates that OGMA targets must 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 at this time.

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 biologically meaningful decisions. Criteria for ranking stands based on multiple stand structural attributes would 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 study is based on two previously completed, where 'indices of old-growthness' were developed for the ICHmw2, ICHdw and ESSFwm BEC units (Holt et al. 1999; Holt 2000). Old growth attributes were defined, and a scorecard produced for ranking old growth stands in the field based on their structural attributes. The methodology is considered reasonably robust, even with the low sampling effort available, because it uses multiple attributes rather than a single attribute cut-off for determining relative old-growthness. This current study was designed to address similar questions for the MS dry cool (MSdk) subzone (Braumandl and Curran 1992). Available sampling effort allowed the study to stratify sampling effort based on 'wet' and 'dry' site series groupings; these two subgroups were analysed separately. The objectives of this study were to:

1. determine what easily-assessed structural features are consistently associated with older forests in each of the "wet" and the "dry" site series groups; and
2. where feasible, to devise an index of "old-growthness" based on multiple structural attributes, for use in field assessments of older forest stands.
3. to provide suggestions on old growth management area designation based on this sampling effort and analysis.

Sampling opportunity in this study was limited by budget availability. The attributes chosen for measurement include those most commonly cited as important structural features associated with old-growth forest as well as standard descriptors of forest parameters (e.g. density of trees by size class). Attributes that are relatively quick to assess consistently were specifically chosen, and attributes that are generally inconsistent or time consuming to obtain (including measures of vertical of horizontal heterogeneity, or canopy closure and size and age of all trees) were not included. Our sample sizes were n= 23 and n = 15 for wet and dry stands respectively, with 3 plots sampled within each stand. The data gathered have been compared with others (see discussion); however, the limitations of small sample sizes should remain with the reader throughout.

## Ecosystem Characteristics

The dry cool Montane Spruce biogeoclimatic subzone (MSdk) is one of the major Biogeoclimatic Ecosystem Classification units in the East Kootenay. It covers about 450,000ha of mid-elevation forest in both the Purcell and Rocky Mountains. It is found from elevations of approximately 1200 to 1600 metres, between the IDFdm2 and the ESSFdk. The MSdk extends from the US border (similar environments are found south of the border) to the lower Blaeberry River, north of Golden. The MS has a cool continental climate characterised by cold winters and moderately short warm summers (Meidinger and Pojar 1991).

The climatic climax tree species are hybrid white spruce (*Picea engelmannii* Parry ex Engelm x *glauca* (Moench) Voss) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), but due to widespread frequent fire of moderate to high severity, the dominant tree of this subzone is lodgepole pine lodgepole pine (*Pinus contorta* var *latifolia* Engelm). Mature Douglas-fir (*Pseudotstuga menziesii* (Mirb.) Franco), is found as a seral species on zonal sites and as a climax species on warm, south-facing slopes and dry soils. Western larch (*Larix occidentalis* Nutt.) is found as a seral species on dry and mesic sites.

To our knowledge, no fire history studies have been conducted in the Montane Spruce Zone in British Columbia. According to recent forest inventory statistics for the Cranbrook and Invermere Forest Districts (these two districts contain about 75% of the MSdk), lodgepole pine covers almost 50% of the subzone. Douglas-fir and western larch cover the next most significant area (about 25% and 10% respectively). Spruce and subalpine fir are found on about 8% of the subzone. The remaining 7% is primarily trembling aspen.

Old forest, as defined by the Ministry of Forests' age definition of greater than 140 years, is currently found on about 13% of the MSdk, while greater than 250 year old forest is found on less than one percent of the subzone (Braumandl pers. comm.). (Note problems with FC inventory data in the discussion).

There is a long history of logging in the MSdk. Considerable areas of large, old Douglas-fir and larch forests were harvested, particularly for railway ties in the early 20$^{th}$ century. Although the former extent of these forests has not been quantified, large stumps and old milling sites are common.

According to analysis of inventory data an additional 15.4% of the MSdk was logged between 1960 and 1990 (Pollack et al. 1997). Although the bulk of harvest (by area) was in lodgepole pine, Douglas-fir and larch stands, a disproportionate amount of large old spruce found in easily accessible valley bottoms was likely harvested. Spruce accounts for 16% of old forest now occurring in this zone, which is likely considerably lower than that found prior to harvesting.

Old spruce and subalpine fir forests are found in generally narrow riparian areas, on cool aspects and at higher elevations within the subzone. Topographically determined fire refugia are not widespread in the MSdk. The often-narrow riparian areas are also subject to stand replacing fires as was evidenced by a significant proportion of riparian areas consumed during large intense wildfires in the MSdk in the Invermere District in 1985.

In the Invermere Forest District (which contains 165,000ha of MSdk), comparing the amount of early and late seral forest between the timber harvesting landbase and the non-contributing landbase provides a rough estimation of harvesting versus fire history (though obviously patterns of natural disturbance and fire suppression will also vary between these two areas leading to an underestimation of the effects of harvesting), however, in the THLB approximately 53% if early/ mid seral and 15% is old, compared with the NC landbase where approximately 40% is early/ mid seral and 20% is old (again note problems with FC inventory data in discussion).

The majority of old forest (defined as >140 years) is currently dominated by Douglas-fir (46%) or Douglas-fir with larch (18%). These forests are often found on warm aspects and/or relatively dry soil conditions that lead to relatively open stand structure and may serve to reduce fire intensity. Moderate and mixed intensity fires in these stand types typically led to stands of two or more distinct age cohorts or a wide range of ages within a stand.

According to forest cover inventory data, lodgepole pine greater than 140 years old is currently as widespread as greater than 140 year old spruce (T. Braumandl pers. comm.). This type of forest is prone to insect and fire disturbance or, in the absence of disturbance is expected to be replaced by more shade tolerant species. Fire suppression may be resulting in a lower frequency of fire and higher presence of old forest in these forest types than expected naturally.

Due to the very different successional pathways on drier, variable fire intensity sites compared with wetter / riparian sites it was decided these site types should be analysed separately. Our ability to sample sites is relatively limited (due to budgetary constraints) however, it was decided *a priori* that it would be preferable to reduce sample size in each pool rather than to combine ecosystems with different successional pathways.

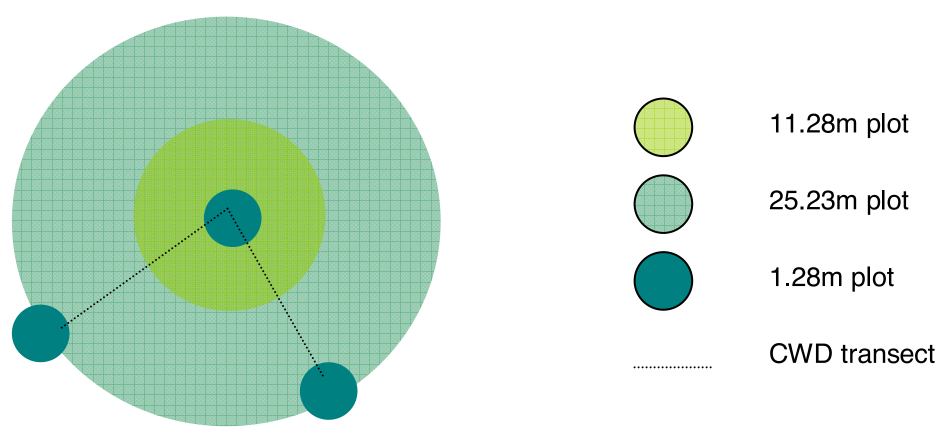
## Methods

### *Study site selection*

Thirty-eight stands were selected from non-TFL lands of the Cranbrook and Invermere Forest Districts within the MSdk. The aim was to sample equal numbers of 'wet' and 'dry' stands, evenly distributed throughout the age range 100 – 300 (or oldest available) years. Plots within stands were assigned to the 'wet' and 'dry' moisture groupings based on site series. Site series 05, 06 and 07 were considered 'wet' while site series 03 and 04 were considered 'dry'. Mesic (01) stands were assigned to either the wet or the dry group on the basis of leading species, dominance of spruce, slope position, adjoining site series, and on understory vegetation. An effort was made to not sample multiple stands from the same drainages, and a minimum patch size limit of 20 ha was set. A decision to sample a stand was based on the match between forest cover age and apparent age of the stand (see discussion for discrepancies), likely moisture grouping, and accessibility.

From a random starting point, a transect was walked through the stand, with plots placed a minimum of 50m from an edge, and a minimum of 100m apart. Plots that fell on old roads or selectively harvested portions of a stand were moved a minimum of 50 m along the transect. Three circular 0.04 ha (11.28 m radius) plots were sampled per stand (see Fig. 1). For all plots, a second concentric circular plot 0.2ha (radius 25.23m) was used to count large trees and snags (>40cm dbh), since these relatively rare features are not assessed accurately using a small plot. The length and diameter (at intersection point) for each piece of coarse woody debris >20cm in diameter were counted along 2 transects of 24m in length that joined at 90 degrees in the center of the plot (Fig. 1). Seedlings were counted in three 0.0005ha (1.28m radius) plots located at the end of each coarse woody debris transect and at the plot center.

Figure 1. Sampling design




### *Variables measured:*

The following variables were recorded on the 11.28m radius plot unless specified otherwise:

- presence of veteran trees in the stand (defined as residual trees that are larger in diameter, taller and totaling less than 25 stems per hectare[4])
- presence of disturbance indicators (blowdown, firescars, etc)
- presence of ecologically significant gaps in overstory
- number of live trees >40cm dbh (on 25.23m radius plot)
- number and wildlife tree classification[5] of live trees >40cm dbh (on 25.23m radius plot)
- number, species and wildlife tree classification of live trees 25-40cm dbh; 12.5-25cm dbh; and <12.5cm dbh >1.3m tall classes
- largest tree diameter and species (on 25.23m radius plot)
- number and wildlife tree classification of snags >40cm dbh (on 25.23m radius plot)
- number of snags in 25-40cm dbh; and 12.5-25cm dbh
- largest diameter snag
- arboreal lichen presence (using scores of 6 dominant trees in the plot, based on Armleder et al. 1992)
- percent cover of layers A (>10m), B1 (2-10m), B2 (<2m – shrubs), C (herbs), D (mosses)
- coarse woody debris along two 24m transects intersecting at plot centre (approximate length and diameter-at-intersection were measured for all pieces >20cm)
- age at breast height measured on two dominant and two codominant trees of each species per 25.23m plot, a minimum of eight trees were aged.

In addition, the following biophysical information was taken:
- Site series
- Aspect
- Elevation
- Slope

Age at breast height was measured on two species of the dominant and the codominant trees in each large plot. 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 that had experienced suppression early in life and now have a rotten center. This approach is reasonable, however, in the absence of more detailed dendrochronological data that would have required extensive coring in the same stand (P. Burton, pers. comm. 1999).

In the analysis, we used two different measures of age in the stand. “Max-age” is the age of the oldest dominant or codominant tree cored in the plot. The “max-age” parameter *does not* include the age of veteran trees[6] in the stand and is intended to reflect the time since the last major stand-altering disturbance. Alternatively, “ave-age” is the mean age of the dominant and codominant layer excluding veterans. Max-age is a more ecologically relevant measure of stand age, while ave-age is more representative of the forest cover age classes and is to compare age estimates from maps to measured ages from ground samples.

[4] Vegetation Resources Inventory Website: Veteran - “A *residual* tree is defined as a living remnant of a former stand; in even-aged stands, the occasional (< 25 per ha) large stem of an older age class than the stand as a whole. Typically, these trees may have larger diameters, a higher incidence or indications of decay, thicker bark, larger branching and "ragged" or flat tops. These trees must be clearly residual. Uneven-aged stands do not generally have residual trees.” (http://www.for.gov.bc.ca/ric/pubs/teveg/gsp/ground-15.htm#P2380_91008)

[5] http://www.for.gov.bc.ca/ric/pubs/tebiodi

[6] http://www.for.gov.bc.ca/ric/pubs/teveg/gsp/ground-15.htm#P2380_91008

## Data analysis

### *1. Age data summary*

Mean ages of dominant and codominant trees as counted from tree cores are presented for each stand, and compared to age class categories taken from Forest Cover Inventory information (Fig. 2); this information is used to provide a preliminary analysis of the reliability of forest cover data for locating OGMAs solely on age.

### *2. Principal Component 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). The objectives were to (i) determine which combination of structural attributes best described similarities between plots and (ii) whether similarities between plots appeared to be related to the "old-growthness" of the plot (based on expected patterns from theory or literature information). PCA uses a correlation matrix of variables to find indices (principal components) that capture variation in different dimensions 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 here in order to look for compounded effects of the multiple variables. PCA was used to explore patterns in the data set that may reflect underlying processes affecting the data. The results are hypotheses that require testing, which is in contrast to a direct hypothesis testing approach. Plot rather than stand data were used, since pseudo-replication is not an issue with exploratory data analysis (V. Lemay and G. Bradfield pers. comm. 1999).

PCA was conducted on plot data from the MSdk. Percent cover 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 number of pieces of CWD and the stems per hectare of live trees <12.5cm dbh were square-root transformed to more closely approximate the normal distribution. Transformations did not improve the distribution for other non-normal variables. Although they improve the output, normality and linearity assumptions are not in force as long as PCA is used for descriptive analyses (Tabachnik and Fidell 1996).

PCA was used to explore whether any natural groupings occurred among the plots sampled (although PCA does not actually look for clusters in the data). The analysis was first conducted using all variables, excluding presence/absence measurements (see above). Variables that had low correlations with all others in the dataset were then excluded. Different models, containing different attribute sets were run using SPSS Factor. The final model chosen was (i) that which explained most variation in the data (ii) where the attributes associated with the main axes (PCA1, PCA2 and PCA3 and PCA4) could be linked to biological patterns of old growth development (based on theory and literature review of important old-growth attributes), and iii) where the largest number of variables were included.

Principal component axes 1, 2 and 3 were graphed against mean age of the plot to assess how mean age relates to PCA ordination (Fig. 4). Summary statistics of attribute values for each group are presented on a per hectare basis throughout the analysis and in the scorecard. Thresholds for "old-growthness" are presented and compared to summary statistics for old growth reported in other studies (see discussion).

Where PCA did not appear to produce ecologically relevant groups of plots, an alternative analysis method was taken. In the dry sites, stands were separated into groups based on their measured mean age, and summary statistics were produced for attributes of interest for these groups. Three age-breaks were used to separate potential old growth from younger stands: mean age greater than 120 years, mean age greater than 140 years, and mean age greater than 180 years. We used three different mean ages to separate the data in order to examine the effects of varying age on attribute densities. Commentary on why PCA was not a successful technique in these stands is presented in the results and in the discussion.

## Results

### *1. Age data summary*

Thirty-eight stands were sampled in the MSdk BEC variant, ranging in mean age from approximately 64 to 299 years old, with individual plot mean ages ranging from 59 to 357 years old (plot data are shown in Fig. 2a, b). Based on forest cover (FC) data, stands ranged from age class (AC) 5 to 9 (2.5% AC5, 16% AC6, 16% AC7, 50% AC8, 16% AC9). Forest cover age class data are compared with mean measured age of dominant and co-dominant layers and are compared with average plot data for the wet and dry stands separately (Fig. 2 and 3). Plot data are shown to demonstrate the variation in age between plots within stands.

Calculated mean ages of stands (from tree cores at breast height) differed from the FC typed information. Based on the mean stand age of dominant and co-dominant trees in all three plots (adjusted for growth to breast height), the age class of only 13 out of 38 (34.2%) stands were correctly classified. Forest cover maps underestimated the age of stands in 4 of 38 (10.5%) stands but overestimated the age of the stand in 21 of 38 (55%) stands, including an overestimate by two age classes in 9 of 38 (23.7%) stands. No difference was observed between error rates in the wet and dry stands. In addition to FC errors of those stands sampled, while locating stands we were forced to reject a high proportion of sites because they were typed on Forest Cover maps as being much older than the existing trees. Thus, we believe that forest cover inventory data actually overestimates age class in more than the 55% of stands reported here.

Table 1. Accuracy of Forest Cover Inventory Map Age Designations

| | # Stands | % Stands |
|---|---|---|
| Accurate FC designation | 13 | 34.2% |
| FC Overestimates age | 21 | 55.3% |
| FC Underestimates age | 4 | 10.5% |
| TOTAL | 38 | |

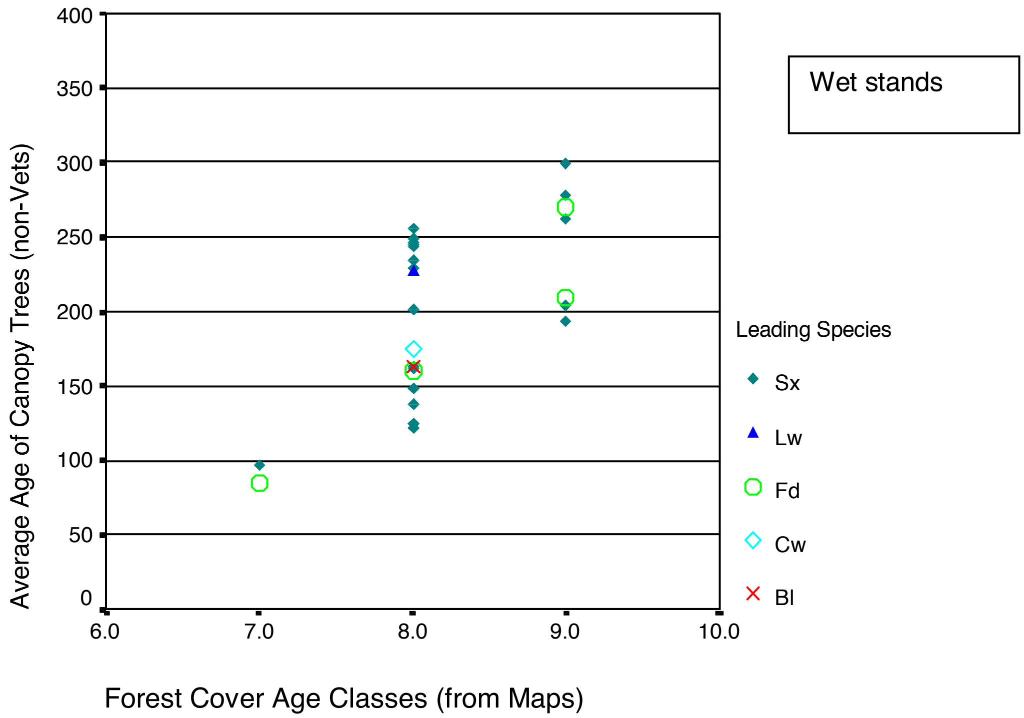



Figure 2. Typed forest cover age classes (from maps) compared with average age of canopy trees for *plots* in wet stands. Leading species of each plot is noted.

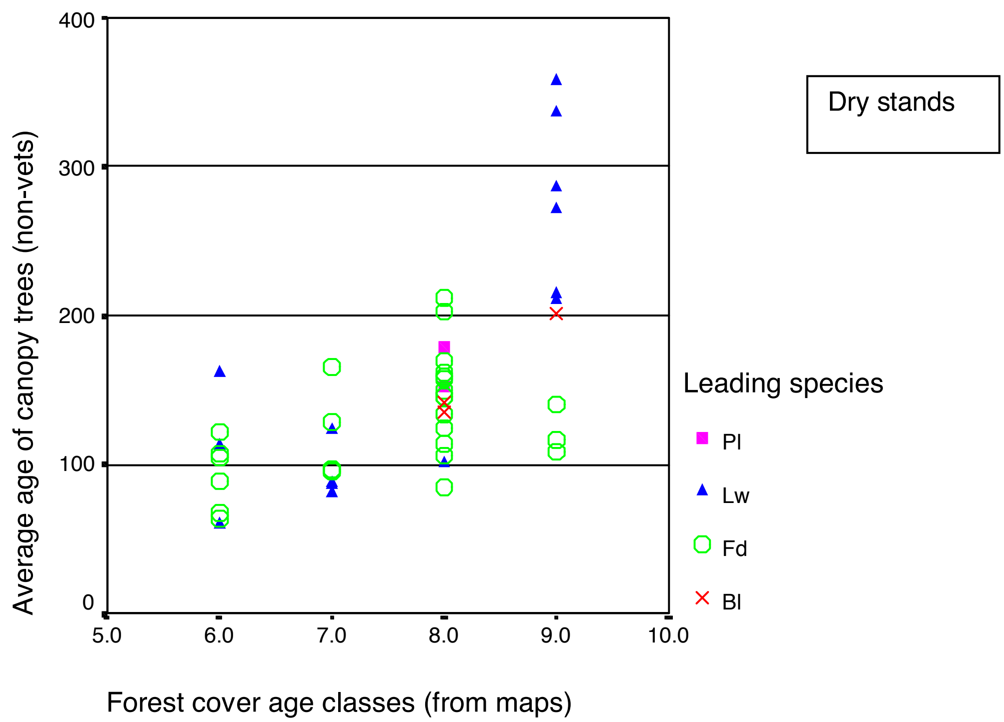



Figure 3. Typed forest cover age classes (from maps) compared with average age of canopy trees for *plots* in dry stands. Leading species of each plot is noted.

## 2. Principal components analysis

### *Sub-Analysis – Wet stands*

67 of 67 possible plots were included in the analysis. The PCA that explained the most variation in the data set, and produced the most biologically meaningful results contained the following attributes (*variable name in analysis shown in italics)*:

- density of large live trees (>40cm dbh) (*trees>40*),
- density trees 25-40 dbh (*trees 25-40*)
- density trees 12.5 – 25 dbh (*trees 12.5-25*)
- density trees <12.5 (transformed: *sqrt trees <12.5*)
- largest tree dbh measured in the plot (*big_dbh*)
- density large snags (>40cm dbh) (*snags>40*)
- largest coarse woody debris piece sampled (diameter at point of intersection; *big_cwd*)
- coarse woody debris stems per hectare (transformed: *sqrt cwd_sph*)
- percent cover layer A (transformed: l*ayer A*)
- percent cover layer B1 (transformed: *layer B1*)
- percent cover layer B2 (transformed: *layer B2*)
- percent cover layer C (transformed: *layer C*)

The first PCA axis (PCA_1) accounted for 30% of the variation in the data set. The second, third and fourth axes (PCA_2, PCA_3 and PCA_4) accounted for a further 18%, 12% and 9% of the variation in the data respectively. Subsequent axes accounted for less variation in the data. Total variance explained by the first four axes was 70% (Table 2).

The amount of variation explained by each axis is also reflected in the Eigenvalues in Table 2. E-Values represent the amount of variance explained by each component axis. Each variable entered into the analysis contributes an E-Value of 1. Therefore, only those components with an E-Value of >1 contribute more to describing the variation within the data than each individual input variable.

Table 2. Variance explained by each principal component axis 1-4 for wet plots.

**Total Variance Explained**

| | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 3.659 | 30.489 | 30.489 | 3.659 | 30.489 | 30.489 |
| 2 | 2.116 | 17.635 | 48.124 | 2.116 | 17.635 | 48.124 |
| 3 | 1.404 | 11.698 | 59.821 | 1.404 | 11.698 | 59.821 |
| 4 | 1.127 | 9.394 | 69.215 | 1.127 | 9.394 | 69.215 |

Extraction Method: Principal Component Analysis.

The variable loading scores for each significant component (1-4) are shown in the component loading matrix (Table 2). Higher loadings indicate that the variable is more highly correlated with the component and thus more representative of the axis. Scores of greater than 0.71 reflect an excellent correlation between the variable and the component. Scores of 0.63 and 0.55 are considered 'very good' and 'good', respectively. Scores of 0.32 are 'poor' and are at the lower limits of interpretability (Tabachnik and Fidell 1996).

Using the ‘good’ correlation cut-off of 0.63, the following variables are highly associated with PCA-1: largest tree in the plot (*big_dbh*), density of large snags >40cm dbh (*snags>40*), density of large trees >40cm dbh (*trees >40*) and (negatively associated with PCA_1) density of trees 25-40cm (*trees 20-40*). This suggests that PCA_1 describes the ‘old-growthness’ of the stand by summarizing the abundance of large sized structural attributes (as suggested by the literature). PCA_2 is most associated with density of small trees <12.5cm dbh (*sqrt_trees<12.5*) and is perhaps an indicator for gappiness within the stand. PCA_3 is most associated with density and size of coarse woody debris present (*sqrt_cwh_sph* and *big_cwd*).

Table 3. Component matrix for principal component analysis of wet plots in the MSdk.

Attributes highly associated with PCA_1 are indicated by arrows. Full explanations of variables are summarized in the Methods.

**Component Matrix**[a]

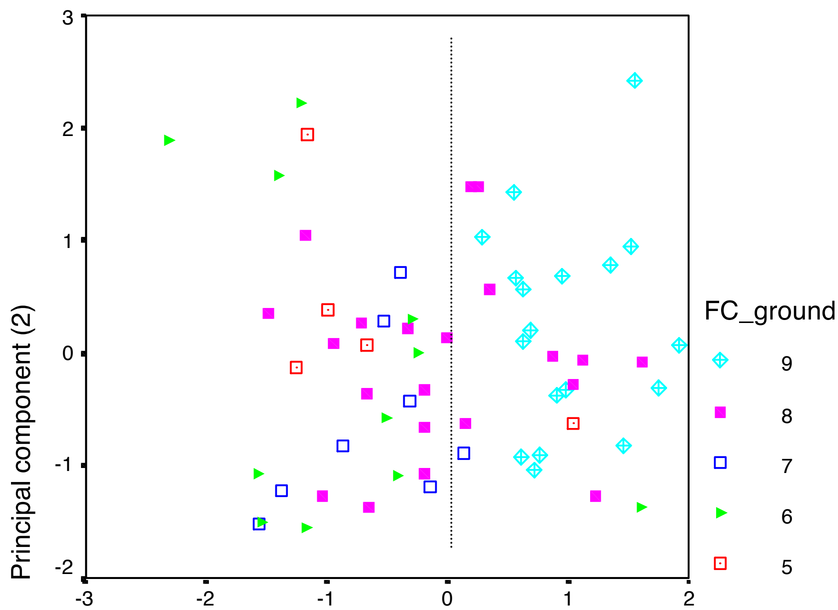
| | | Component | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| | BIG_CWD | .411 | .501 | .543 | .166 |
| | SQRT_CWD_SPH | .338 | .378 | .657 | -9.96E-03 |
| → | BIG_DBH | .767 | -.103 | -3.24E-02 | .277 |
| → | Snags>40 | .638 | 2.727E-02 | .334 | 4.964E-02 |
| | Trees12.5-40 | -.559 | .503 | .290 | -9.19E-03 |
| | SQRT_Trees<12.5 | .165 | .727 | -.273 | -.375 |
| | LAYERA | -.464 | .251 | -8.31E-02 | .768 |
| | LAYERB1 | .460 | .575 | -.362 | -.275 |
| | LAYERB2 | .616 | -.317 | -.125 | .187 |
| | LAYERC | .417 | -.611 | .345 | -.341 |
| → | Trees>40 | .759 | 2.336E-02 | -.207 | .205 |
| → | Trees25-40 | -.695 | -.249 | .301 | -.146 |

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

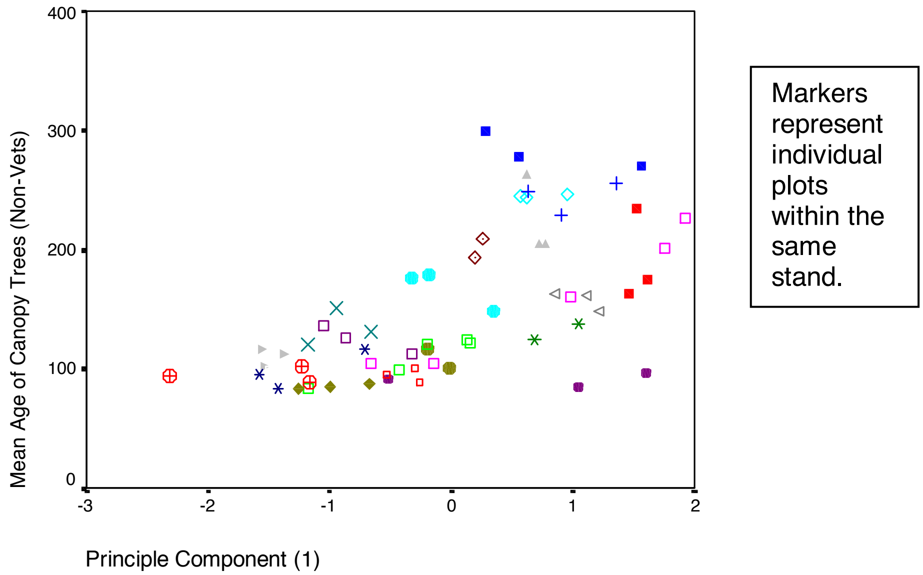
PCA distributes plots along multiple axes in ‘factor space’. A visual assessment of plot groupings (Fig. 4) does not suggest that the data split into obvious and different groupings. However, given that a continuous distribution of stands were sampled, this is unsurprising. In this case, we use PCA=0 to split the plots into two groups, because this means that plots with a positive score are positively correlated with PCA_1 and its associated variables and vice versa.

Figure 4. Principal component 1 versus principal component 2, plots marked by measured age class.



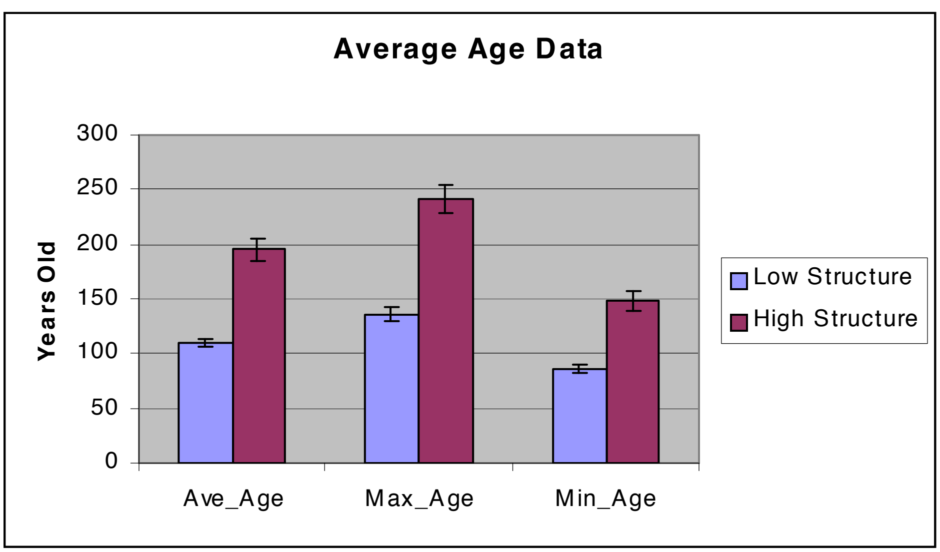

PCA_1 is associated with the abundance of large structural attributes and explains the largest proportion of the explainable variation in the data (30%). PCA_1 was plotted against measured mean age (FC_ground: Figure 3) to examine the relationship between this variable and forest age, in order to assess whether it is a likely measure of 'old-growthness' . A significant correlation was found (Spearman's rho = 0.652, p<0.01). PCA_2 and PCA_3 were not correlated with age (Spearman's rho = 0.213, p<0.0.94 and –0.20, p<0.877), while PCA_3 had an extremely low (negative) correlation with age (Spearman's rho = -0.277, p<0.032). Although the component matrix loadings suggest PCA_2, PCA_3 and PCA_4 are related to stand structure, they are not obviously related to old-growthness as indicated by their low correlations with age.

Figure 5. PCA_1 and measured mean age of plots (shown by each stand sampled).




Most young plots have low values for structural attributes. All of the plots greater than 200 years old have scores in the high structure group. However, several younger plots were found to have high PCA_1 scores. These plots generally have higher numbers of large diameter (>40cm dbh) trees and snags. When age data are summarized for each group, there is a clear separation between high and low structural groups. The high structure groups have higher mean, maximum and minimum ages for trees cored (Fig. 6).

Figure 6. Mean values for age data in wet plots. Bars indicate standard error of the mean.




Conducting the PCA analysis with fewer input variables produced relatively similar results. When different groups of variables were used in the analysis, there were 4 plots that were inconsistently grouped between the high and low-structural value groups. These plots were used in the analysis, but were not included in the summary values for groups.

Summary statistics are presented in Appendix A.

### *Sub-Analysis: Dry stands*

47 of 47 possible plots were included in the analysis. The same procedure was used with the dry as with the wet plots to determine how well PCA could separate the data into ecologically meaningful groups of plots.

Interpretability is key to the success of PCA (Tabachnik and Fidell 1996). Patterns must be observed in the data for the analysis to be applicable. With the dry plot data, although PCA could explain approximately 64% of the variation in the data (in 5 axes; Table 4) no clear patterns or splits were observed, and in particular, there were no correlations between PCA axes and measured mean age (see below). As a result, we determined that the results of the PCA were inappropriate to develop an index of oldgrowthness for the dry stands sampled (see below).

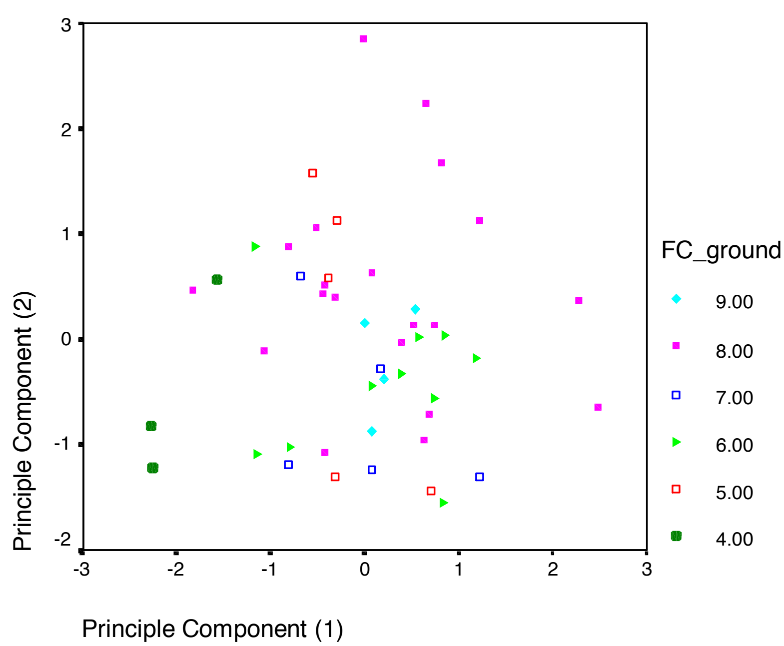
Table 4. Percent of variance explained by each component axis (1-5).

**Total Variance Explained**

| | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.898 | 20.702 | 20.702 | 2.898 | 20.702 | 20.702 |
| 2 | 2.857 | 20.409 | 41.110 | 2.857 | 20.409 | 41.110 |
| 3 | 2.037 | 14.549 | 55.659 | 2.037 | 14.549 | 55.659 |
| 4 | 1.220 | 8.711 | 64.371 | 1.220 | 8.711 | 64.371 |
| 5 | 1.129 | 8.067 | 72.438 | 1.129 | 8.067 | 72.438 |

Extraction Method: Principal Component Analysis.

Figure 7. PCA_1 versus PCA_2 for dry MSdk plots



Component loadings did not show easily interpreted patterns. Using Tabachnik and Fidell's (1996) cut-off of 0.63 as a 'very good' correlation between a variable and a principle component, PCA 1 is most associated with the density of trees 12.5-25cm in diameter (negative correlation). Based on the highest component loading scores, PCA 2 through 5 are associated the size of the largest piece of CWD (BIG_CWD), the percent cover moss (LAYERD), trees 25-40cm dbh, and the percent cover tall shrubs (LAYER B2), respectively (Table 4).

Table 5. Component Loading Scores for principal component analysis of dry plots in the MSdk

**Component Matrix**[a]

| | Component | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| BIG_CWD | .142 | .713 | .257 | 5.063E-02 | -.374 |
| SQRT_CWD_SPH | -2.93E-02 | .621 | -.171 | .188 | -.458 |
| BIG_DBH | .574 | .346 | -.281 | .169 | .150 |
| SNAGS40 | .404 | .599 | .516 | 3.423E-02 | 2.599E-02 |
| BIG_DEAD | .441 | .513 | .401 | -.413 | -5.74E-02 |
| live12.5-25 | -.734 | .308 | .334 | .131 | -.136 |
| SQRT_live<12.5 | -.498 | .473 | -.372 | -.323 | -6.62E-02 |
| LAYERA | -.595 | -9.75E-02 | .430 | -.100 | .337 |
| LAYERB1 | -.437 | .537 | -.444 | -1.53E-02 | .265 |
| LAYERB2 | .266 | -.526 | -.346 | .270 | -.463 |
| LAYERC | .580 | -.263 | .431 | 8.093E-02 | 4.925E-03 |
| LAYERD | .257 | .415 | -.613 | .233 | .201 |
| Total>40 | .619 | .133 | -.217 | -.346 | .377 |
| Total25-40 | -3.32E-02 | .263 | .276 | .772 | .386 |

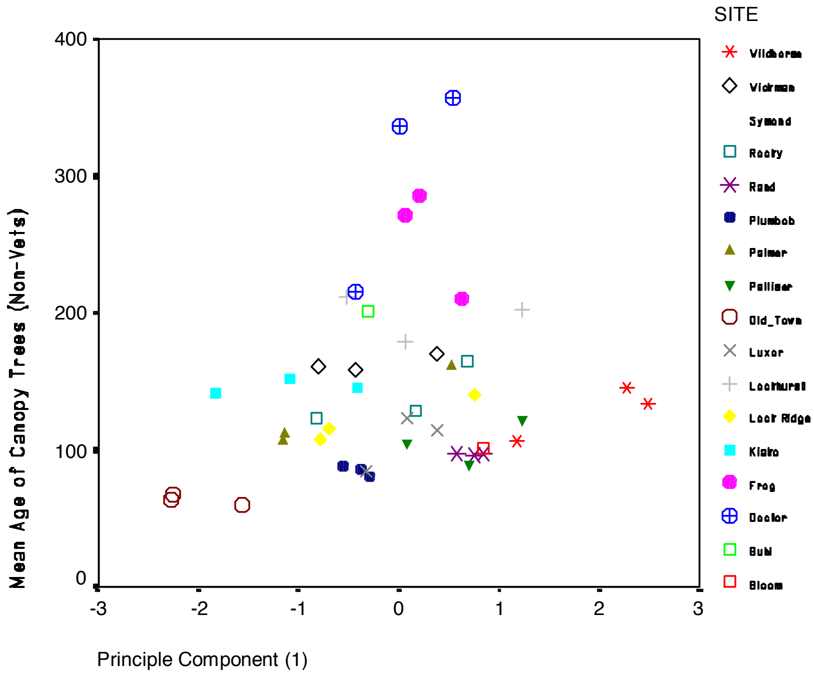
Extraction Method: Principal Component Analysis.

a. 5 components extracted.

In addition, there were no correlations between PCA axes and ages (Figure 8). The lack of coherent patterns between PCA and age suggests that PCA was not grouping plots based on 'old-growthness'.

It may be that PCA is differentiating plots based on 'openness' more than 'old-growthness'. In addition to the density of smaller trees (12.5-25cm dbh), PCA 1 is related to a combination of attributes associated with stand openness: density of large trees (>40cm dbh), herb cover (LAYER C), the diameter of the largest tree and, negatively, with the density of canopy trees (LAYER A; see Table 4). An examination of individual plots also suggests that varying degrees of openness detracted from the correlation between PCA_1 and 'old-growthness. For example, plots from Kiakho, at the low end of PCA_1 had extremely dense patches of small trees, while those in Wildhorse, at the opposite end of the spectrum were very open (Fig. 8). It is likely that the influence of open vs. closed stands played a stronger role in determining PCA axes than old-growthness.

Figure 8. PCA 1 vs mean plot age



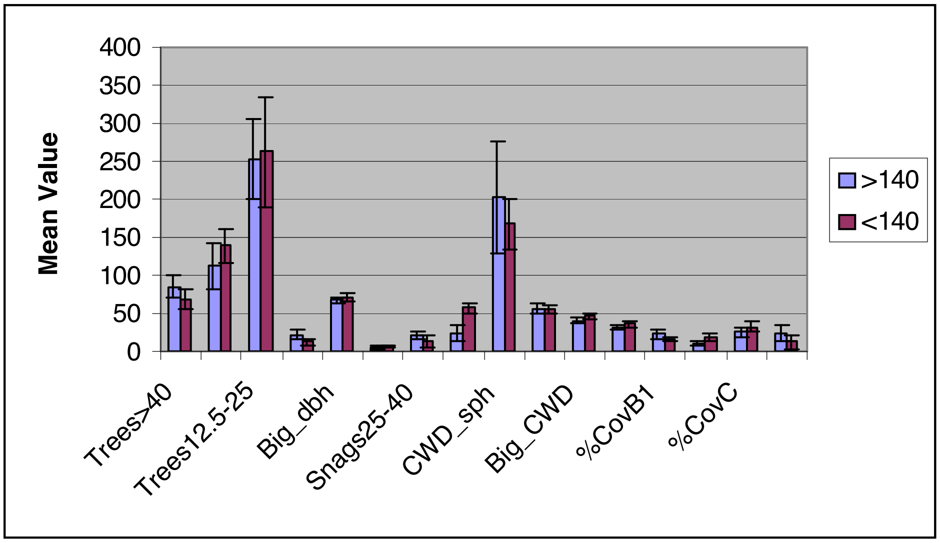

Since obvious splits in the data set based on old-growthness were not evident from PCA and because component loadings were not consistent with patterns of structural development cited in the literature, we decided to summarize the data based on age class separations. Although this is not a preferred approach (see introduction and discussion) the variation in the data prevented any other approach from being used.

In the MSdk, 'old growth' is defined by the Province of BC Ministry of Forests as stands older than 140 years. For simplicity, we used this age class break to separate stands into 'old' and 'not-old' in order to examine the variation in stand structural attributes present. In addition, we also applied different age class breaks to examine the effects on structural attribute patterns of changing age class breaks.

We used *plot* data in the PCA analysis where pseudo-replication was not a concern. However, in presenting data based on age splits, it was necessary to use average *stand* values to avoid pseudoreplication.

Figure 8 summarizes average values for stands based on a split in the data at 140 years. Stands 140 years and greater are grouped and presented in comparison with stands younger than 140 years. Average values are presented in Appendix B. No significant differences were found for any attributes based on these age-class splits (Figure 8).

Figure 9. Attribute Values for Older and Younger Stands - DRY Sites. Mean values + standard error of the mean (Values are shown in Appendix B).




Given this lack of differentiation using the 140 year age break, other age breaks were explored. Mean and standard error values were compared for three age-break scenarios: at 120 years, 140 years and 180 years. However, there was still substantial overlap and no difference between groups of plots for all three scenarios (Fig. 10 and 11).

Figure 10. Mean values of attributes in younger stands - DRY Sites for three age-class breaks: 20, 140 and 180 years. Note small sample size for the >180 group (n=3)

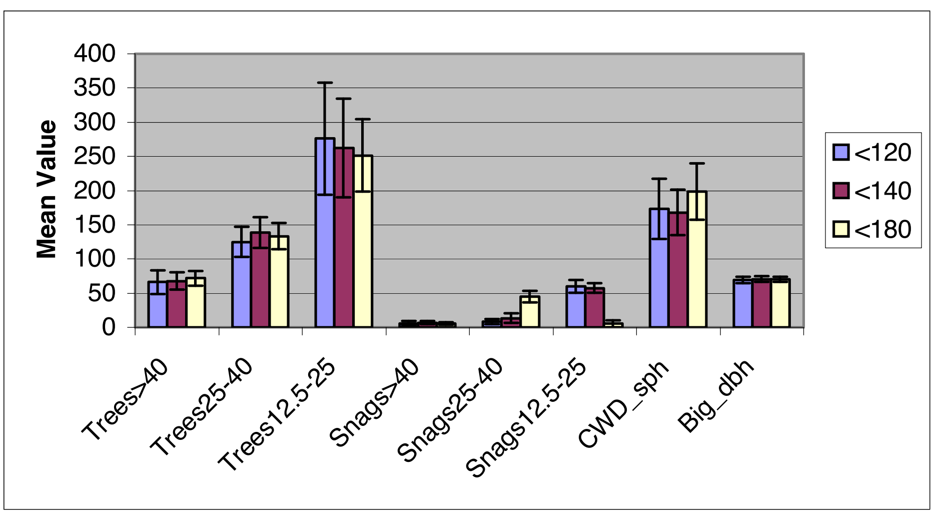
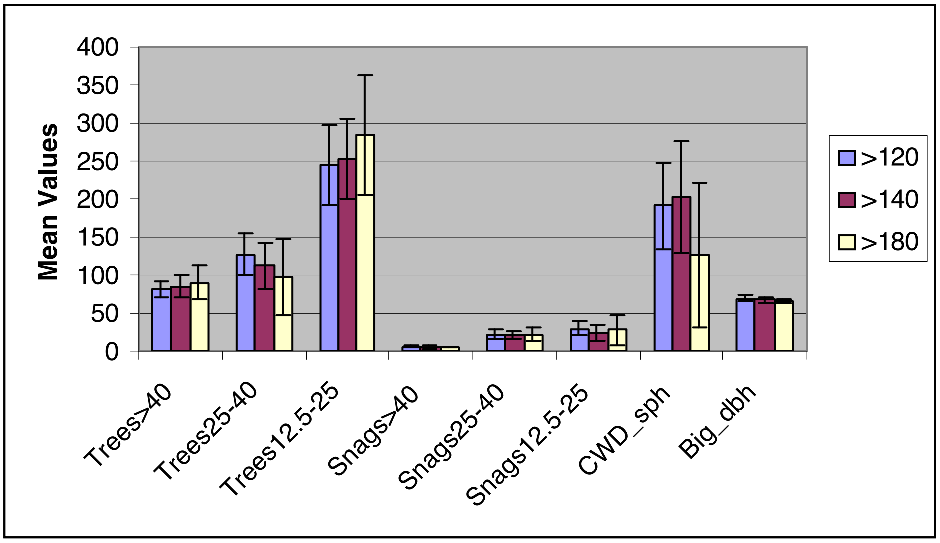


Figure 11. Mean values for attributes in older stands – dry sites for three age-class breaks:120, 140 and 180 years. Note small sample size for the >180 group (n=3)




## 3. An index of old-growthness

The statistical analysis presented in this paper was used to separate forest plots on *wet* sites based on the combinations of structural attributes present; plots with similar structural attributes were located closer together than those with different structural attributes. Principal components analysis does not automatically 'group' or cluster plots, rather it is the researchers' responsibility to determine the lines between groups. In this analysis, it was decided to use the statistical value of PCA_1= zero as the separator. Although this does not result in 'objectively' grouped plots, it still provides a relatively unbiased way to determine splits between groups.

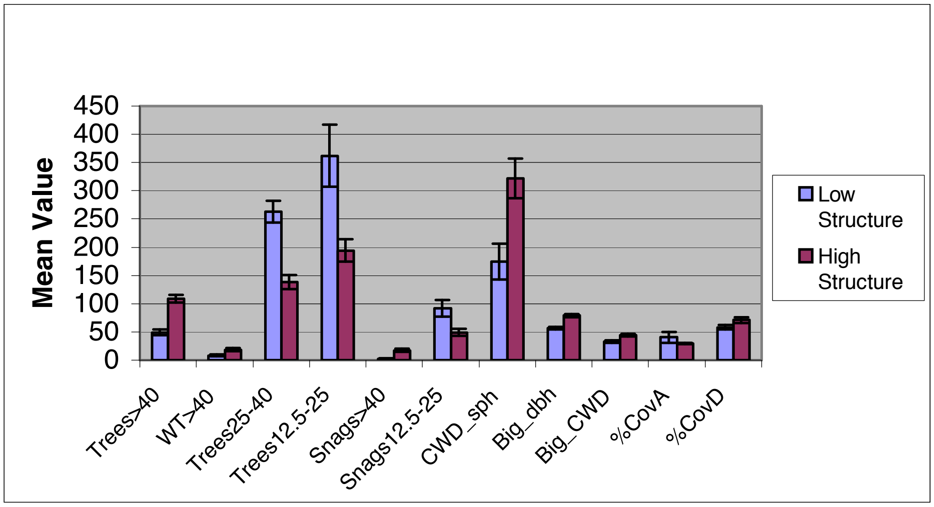
No index is presented for dry MSdk sites since there were no obvious splits in the data. Management recommendations in lieu of an index are provided in the discussion.

### *(a) Wet stands in the MSdk*

The two groups produced from this methodology are used to produce a table of look-up threshold values for each attribute. Mean values and standard errors of the mean were calculated for all variables and compared between the low structure and the high structural value groups (based on the PCA1 > or < zero). Attributes were not included in the index of old-growthness when a) there was an overlap between each group mean, plus or minus one standard error, or b) where there was no biologically meaningful correlation between a variable and age.

This resulted in the following variables being removed from the index: i) 25-40cm dbh snags (due to overlap between the high and low structural value groups), ii) saplings (trees <12.5cm dbh) due to no biologically relevant correlation with age, iii) largest diameter snag due to no biologically relevant correlation with age and iv) vegetation layers B1, B2 and C (tall and short shrubs, and herbs) due to no biologically relevant correlation with age. In addition, percent cover of A and D layers were removed from the scorecard due to our consideration of the difficulties of distinguishing these small differences ocularly. The mean and standard errors of all remaining attributes included in the index of old-growthness are shown in Fig. 12 and Table 5.

Figure 12. Mean values for low and high structural value stands - WET sites. Standard error of the mean is shown by error bars.




In order to minimize potential overlap between "old" and "not-old" sites, we used both means and the standard errors to determine thresholds. The threshold values presented in Table 6 for the index of old-growthness were calculated based on the midpoint between the mean of each group +/- its standard error of the mean.

Table 6. Summary statistics and threshold values for index variables – Wet Sites

| Attribute | Low Structural Value | | High Structural Value | | Index Threshold (minimum value) |
|---|---|---|---|---|---|
| | Mean | Standard Error | Mean | Standard Error | |
| Trees >40cm dbh | 49.2 | 4.7 | 108.8 | 6.75 | 78 sph |
| Wildlife Tree Class 2 >40cm dbh | 8.5 | 1.73 | 18.7 | 2.94 | 13 sph |
| Trees 25-40cm dbh | 262.9 | 19.56 | 138.3 | 12.9 | 197 sph |
| Trees 12.5-25cm dbh | 362.1 | 54.47 | 194.2 | 19.83 | 261 sph |
| Snags >40cm dbh | 2.7 | 0.9 | 17.2 | 2.83 | 9 sph |
| Snags 12.5-25 dbh | 91.7 | 14.86 | 49.17 | 6.62 | 66 sph |
| Number of pieces CWD | 174.5 | 32.0 | 322.1 | 35.3 | 247 sph |
| Largest dbh (cm) | 56.4 | 2.0 | 79 | 2.86 | 67 cm |
| Largest piece of CWD (cm) | 33.2 | 2.2 | 44.6 | 2.23 | 39 cm |
| Mean age | 110 | 4.2 | 195 | 10.5 | 145 |
| Max age | 136 | 6.6 | 241 | 12.5 | 181 |

Threshold values are meant to be used in a scorecard of old-growthness (Fig. 13), which allows attributes for each stand to be recorded systematically, and allows practitioners to determine where a stand fits within the range of natural variation of attributes (see discussion). Note that the values for mean age are not intended to revise the current age criteria for old growth in this variant.

### *Application*

The scorecard developed in this paper can be used to assess wet MSdk stands to determine their old-growthness based on structural attributes, and to determine where individual stands fit across the range of natural variation. Data were collected only in the wet MSdk. If extrapolating these data to other subzones beware that although patterns may (or may not) be expected to be similar, the thresholds themselves would be expected to be different, and attribute cut-offs may themselves be different

Figure 13. An example Scorecard for the wet MSdk

| **MSdk**<br>Stand _____________ | Size: __________ | Site series: __________<br>FC Age:_________ | Aspect: __________<br>Slope: __________ | |
|---|---|---|---|---|
| | Measured Value | 'Old' Threshold | "Old" | "Not Old" |
| Trees >40cm dbh | | >78 sph | | |
| Wildlife Tree Class 2 >40cm dbh | | >13 sph | | |
| Trees 25-40cm dbh | | <197 sph | | |
| Trees 12.5-25cm dbh | | <261 sph | | |
| Snags >40cm dbh | | >9 sph | | |
| Snags 12.5-25 dbh | | <66 sph | | |
| Number of pieces CWD | | >247 sph | | |
| Largest dbh (cm) | | >67 cm | | |
| Largest piece of CWD (cm) | | >39 cm | | |
| **TOTAL SCORE** | | | Sum x 2 | Sum |
| ***Landscape Considerations:*** | | | | |
| ***Additional Information*** | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

The thresholds developed here obviously relate to assessing the stand level values of a particular area of potential old growth forest. However, the scorecard should also contain information regarding the landscape context in order for a full assessment to be made.

Although the location of the majority of OGMAs in the MS will be determined on the basis of policy constraints, the scorecard presented here will allow (i) judicious decisions where flexibility is allowed and (ii) will allow the OGMA budget in landscape units to be assessed in terms of representation of larger and biologically important structural attributes (see discussion). Some stands will fail to meet the criteria even though they are old in age, however, this work builds on that of others (Quesnel 1996; Roovers and Rebertus 1993) who have assumed that large attributes are particularly important to the maintenance of biodiversity values. Because large attributes are targeted by harvesting, they are relatively rare at a landscape level or will become so with continuous harvesting. To maintain important biodiversity values into the future, large attributes should be well represented in OGMAs.

The scorecard should be used as follows:

1. stratify the stand and determine the best transect route to cover the variation within the stand, using air photos
2. Locate the transect and sample attributes in the scorecard using a minimum of three 0.04 (11.28m) plots per stand, and using a 0.2ha (25.23m radius) plot for trees and snags >40cm dbh. At each plot, select a random bearing and run two 25m coarse woody debris transects at 90 degrees to one another. Note intersections of >20cm pieces of CWD and the largest diameter encountered.
3. Fill in the scorecard, with data from the stand. Tick the appropriate box depending on whether the measured data is greater or less than the threshold.
4. Identify the number of attributes that meet the 'old/ high structure' target and the number that meet the 'younger/ low structure' target.
5. Compare with other stands, including the costs and benefits of landscape level parameters.

For further details on use, see Holt et al. (1999).

### *Stand versus landscape level considerations*

The methodology we present for an index of 'old-growthness' is a stand level structural attribute ranking procedure only. It does not include other stand and landscape level variables that 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 rare features within the patch. At the landscape level, additional considerations include: the size of the patch, 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 says 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 areas (BC Ministries of Forests and Environment, Lands, and Parks 1999). However, there will be scenarios where OGMAs must be designated within the THLB. In such cases, it will be possible to consider the variables outlined above without having any further impact on timber supply. It 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.

**(b) Dry stands in the MSdk**

No quantitative index of old-growthness could be constructed from our data. Suggestions for identifying important old growth on dry sites in the MSdk are given in the discussion and conclusions.

## Discussion

This project was initiated as the provincial policy on maintenance of biodiversity – the Landscape Unit Planning Guide (LUPG) - was released, and biological information gaps were identified. The aim of the LUPG is to identify the biologically most appropriate areas of forest to set aside as Old Growth Management Areas, within the framework of a rules-based approach designed to minimise timber impact. Old growth by BEC unit is currently defined in Provincial policy based on forest cover age class. However, it is acknowledged that structural attributes provide a more biologically meaningful approach to describing the biological value of old growth stands. The LUPG provides direction that stand structural attributes may be used to guide location of OGMAs where data are available. This, and two preceding projects (Holt et al. 1999; Holt 2000) aimed to provide more guidance around the question of what constitutes appropriate structural attributes in individual biogeoclimatic variants of the Nelson Forest Region, and in particular, to determine if there are thresholds for different attributes that can be used to rank candidate OGMAs at the stand level.

This project focused on mid elevation montane forests of the MSdk (dry cool) subzone. The dry cool Montane Spruce biogeoclimatic subzone (MSdk) is one of the major Biogeoclimatic Ecosystem Classification units in the East Kootenay. It is classified as a natural disturbance type (NDT) 3 ecosystem – dominated by frequent, large size, severe fires (BC Ministry of Forests and BC Environment 1995). It is found from elevations of about 1200 to 1600 metres, in general between the IDFdm1 and the ESSFdk. This location means it is situated between the Natural Disturbance Type (NDT) 4 fire-maintained IDF and the NDT 3 frequent large fire ESSFdk. However, in some areas, it is the lowest elevation subzone, and in these areas, natural disturbance frequencies may be expected to be different than in areas adjacent to NDT4 forest types.

In MSdk portions of both the Cranbrook and Invermere Forest Districts, there is insufficient old growth remaining in many landscape units to meet the retention targets specified by the LUPG (A. Neal pers. comm.).

This project attempted to develop indices of old-growthness for wet and dry sites in the MSdk. The subzone was stratified by moisture regime into ‘wet’ and ‘dry’ stands, and the analyses performed separately on these two groups. The two groups were treated separately due to distinct successional pathways and site productivities expected. We recognise that further stratification of stands based on combinations of slope aspect and site series may have enabled higher explanation of the variation in the data, however, given the extent of sampling possible we decided against stratification which would reduce the sample size in individual groups further.

The approach used to develop the index aims to identify natural differences between stands of different ages based on combinations of their structural attributes. The approach was quite successful for the ‘wet’ stands but was unsuccessful for the dry stands sampled. We suggest that these differences in patterns observed between the stands from different moisture regimes result from a number of factors.

### *i) Attribute development and successional pathways:*

Observations within the range of the subzone suggest that there are significantly different dominant natural disturbance types occurring on wet and dry sites, and likely in different areas of the MSdk (irrespective of moisture regime). Many of the dry sites we encountered were clearly subject to variable regimes of low to moderate intensity fire which result in mixes of relatively open forest type with multi-aged stands and interspersed with thickets, and with numerous trees showing evidence of having survived fire. (Note that these veteran trees were usually present at too high a density to be classified as ‘veterans’ using the definition of less than 25 trees/ hectare[6]). In addition, although the entire subzone is classified as NDT3, stands in higher elevation valleys are likely to have considerably different fire regimes than dry stands in the lower trench area where the MS is adjacent to ecosystems with frequent stand-maintaining fires in the IDF.

The portions of the MSdk subject to large severe fires tend to be dominated by lodgepole pine and were not sampled in this study. However, a few of the stands sampled appeared to be even-aged stands, and were primarily the youngest stands in the dataset. There were also even-aged plots found within stands that had a wider range of tree ages (though it is recognised that the size of sampling plots makes it difficult to assess the cohorts present at that spatial scale).

The wide variability in intensities and return intervals of the fires in the MSdk on the type of non-riparian dry sites sampled leads to very high variability in structural attributes present, and poor correlation of structure with forest inventory age. In western Montana, Fischer and Bradley (1987) note that succession in forests akin to the dry sites of the MSdk is the most complex of any in that area.

Variation in site productivity, and site conditions following different intensities of fire also create variation in the rate at which stands reach stages in successional pathways, which makes analysis of patterns of structural attribute development with age difficult. It was noted that there were a number of sites with large-sized, young trees that scored highly on the structural attribute rankings, but were not 'old' (as determined from tree cores). Although we know some stands can attain larger structural attributes at younger ages, we felt it was important to maintain the link between principal components and actual age of the stand, since age may be linked to attributes not captured in the sampling (e.g. presence of age-related lichens in some ecosystems, development of old seral plant communities, etc). The importance of this is demonstrated by the trends observed in the dry data, where it appears that PCA actually may have distinguished between 'open' and 'closed' stands rather than 'old' and 'not-old stands'. This was only indicated through examination of the correlations between PCA and the mean age of the stands.

In addition, although the largest trees on each plot were measured, the general measure for density of 'large' trees was defined as trees >40cmdbh. The data for dry stands demonstrates that in fact most stands contained at least one very large 'veteran' tree, and hence the largest sized tree present does not distinguish between stands of different overall ages. Machmer (M. Machmer pers. comm.) noted, when developing a habitat supply model for northern goshawk in the MSdk, that the density of trees >50cm dbh was superior for to using density of trees >40cm dbh for differentiating between stands. It may be that density of trees >40cm dbh fails to distinguish between different aged stands and between key aspects of 'old-growthness', and we suspect that it would have been more useful to use an additional higher size range cut-off (e.g. density of trees >60cm dbh) which may have been more useful in distinguishing between stands of different ages and successional stages.

### *ii) Historic harvesting patterns*

Forest cover information suggests that about 15% of the MSdk was harvested over the last 40 years (Pollack et al. 1997). However, it is clear that an extensive area of the MSdk has seen historic harvesting prior to forest inventory. Two major lumbering centres, Lumberton and Bull River, had extensive operations in the MSdk in the early part of the 20$^{th}$ century (Steve Byford, pers. comm.). Extensive historic harvest of the MSdk and IDFdm2 occurred in the early part of the 20th century as a result of logging for railway ties. In addition, spruce-leading stands have also been targeted for logging due to the high value of their timber and easy access.

In a previous study based on old growth stands in the MSdk, it was extremely difficult to find appropriate study sites in old growth forest in the MSdk (C. Steeger pers. comm.). In the current study, likely old growth stands were initially identified from forest cover maps, and then viewed on the ground prior to sampling. Although exact records were not kept, approximately 25% of stands that were considered for sampling based on forest cover data, were either logged or were a significantly different age class than as typed on the forest cover map.

Although forest cover inventory data suggests old growth in the MSdk is still relatively abundant, it is clear from this and other studies that in reality, unharvested old forest (not lodgepole pine leading) in the MSdk is rare.

The lack of un-logged, old forest in the stands sampled may also partly explain the lack of patterns observed particularly in the dry stands. It was noted in some areas of the MSdk that stands with large stumps were found, but that few similar stands with remaining trees of similar size were observed and sampled. We believe that we failed to sample 'good' old-growth sites particularly in the dry sample (except for two stands – 'Frog' and 'Doctor'). As a result, the data did not contain sufficient 'high attribute' old forest and so could not clearly distinguish it in the analysis.

As a result of a previous study, one member of this team sampled extensively in three mesic / wet upland MSdk sites in this region (Quesnel et al. 1997). These three sites contained high densities of large-sized trees and snags, and represented closed-canopy forests with a well developed moss understory. None of the sites sampled during the current study appeared comparable in development of old growth attributes. However, these sites have now been partially harvested and were unavailable for further sampling (R.F.Holt pers. obs. ).

### *iii) Stand Age*

Even though forest inventory suggests 13% of the MSdk is age class 8 or older, we often found that FC typed older stands were younger than typed (see figures 2 and 3, and Table 1), or had seen partial harvesting not noted on forest cover data. In general, forest cover data did not provide a good indication of the actual age of the stand. From our sampling and ground-checking of ages, FC predicted correct age only 34% of time, and forest cover over-estimated the age of stands for 55 % of stands, and for 24 % of stands the overestimation was by 2 age classes (e.g. AC 9 to 7). Although our samples were relatively limited, an analysis of forest cover inventory audit data for the Invermere and Cranbrook Forest Districts showed a remarkably similar pattern to that observed in our study (Table 7).

Table 7. Accuracy of Forest Cover Inventory Map Age Designations Using the Forest Cover Inventory Audit Data for the Invermere and Cranbrook Forest Districts. Our percentages shown for comparison.

| | # audit plots | % Stands | % in our study |
|---|---|---|---|
| Accurate FC designation | 16 | 31% | 34% |
| FC Overestimates age | 27 | 53% | 55% |
| FC Underestimates age | 8 | 16% | 11% |
| TOTAL | 51 | | |

Although inaccuracies in forest cover data are well known, and have been observed in other biogeoclimatic zones (Holt et al.1999, Holt 2000), the inaccuracies appear to be more frequent in the MSdk. Moderate intensity and often numerous fires during stand development in these stands have led to difficulty in assigning a meaningful stand age to dry sites and has led to extremely variable stand structure. Fires in some stands were of mixed intensity leading to different age structure that further complicated assessment of stand age. Detailed observation of mean stand and plot ages for the dry stands sampled show a combination of even-aged, and multi-aged stands with different numbers of cohorts present in different plots within some stands (though the plots were too small to assess cohorts; this study, unpublished data).

### *iv) Comparison with other data for the MS*

Two other studies that present old growth structural definitions for similar sites are Quesnel (1996) and Green et al. (1992; Table 8). 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). 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.

Table 8. Comparison of present study to other definitions of old growth based on density of large trees

| Site series or variant/old growth category | number of stands | mean stand age | Threshold .>40 cm DBH Density / hectare |
|---|---|---|---|
| MSdk wet: | | | |
| Old - our data | 23 | 195 | 78 |
| Old – Quesnel 96 MSdk/01 | 13 | 167 | 41 |
| Old – Quesnel 96 MSdk/05 | 3 | 167 | 123 |
| Old – Quesnel 96 MSdk/06 | 3 | 165 | 6 |
| Old – Green et al 92[1] | 13,867 | 180[2] | 25[3] |
| MSdk – dry | | | |
| Old - our data | | >140yrs | 85 ± 14 |
| Old - Quesnel 96 MSdk/01 | 13 | 167 | 41 |
| Old - Quesnel 96 MSdk/03 | 6 | 195 | 59 |
| Old - Quesnel 96 MSdk/04 | 3 | 160 | 76 |
| Old – Green et al 92[4] | 2,505 | 170[2] | 25[3] |

[1] Western Montana Zone Old Growth Type Code 4 Engelmann Spruce-subalpine fir, western redcedar, grand fir, Douglas-fir, western larch forest types on cool, moist to wet environments
[2] Minimum age criterion
[3] greater than 53 cm DBH
[4] Western Montana Zone Old Growth Type Code 2 Douglas-fir and western larch forest types on moderately cool, dry environments

Data in Quesnel (1996) for large tree density on wet sites reveals considerable variation (Quesnel's standards range from 6 to 123 stems based on site series splits) that may be due to a combination of the small sample sizes in Quesnel's data, plus natural high variability. In Green et al. (1992), the density of large trees is considerably lower (25 compared to 78 per hectare for our data), though large trees are defined as >53cm dbh and, as has been noted previously, the approach used to define old growth in that paper uses conservative minimum criteria.

Although there appears to be little other published research on the Montane Spruce zone, highly variable stand structure has been seen elsewhere, and has prevented meaningful analysis of stand structure patterns (W. Klenner, pers. comm. 2001). Leavell (D. Leavell, pers. comm. 2001) of the Kootenai (northwestern Montana) and Idaho Panhandle National Forests has found a similar lack of coherent patterns in dry Douglas-fir and western larch forests in comparable ecosystems. Mixed severity fires, for which they have evidence of 2000 years of occurrence, are the likely source of ambiguous structural patterns. In northwestern Montana, highly variable stand structures in mixed severity fire regime stands are also seen (Doug Berglund, pers. comm.). In northwestern Montana old growth reserves are not located in mixed severity fire regime areas, instead, if any harvest is carried out in stands that meet local old-growth definitions, sufficient amounts of large live and dead must be maintained to meet old definitions while attempting to reduce crown fire potential. For areas similar to wet MSdk in northwestern Montana, no harvest is allowed in stands that meet old definitions, as harvest is likely to reduce old structure in these fire refugia. Since mid-seral stands are thought to be present in greater amounts than naturally expected, harvest in these stands are designed to enhance development of later successional composition and structure.

## Conclusions

1. We developed a scorecard for ranking stands on wet sites (lower slope 01,05,06 site series) in the MSdk for 'old-growthness' based on a multiple structural attribute definition. This scorecard should provide assistance to managers looking for a more detailed definition of old growth in this portion of the MSdk.

2. A scorecard for assessing the old-growthness of dry sites in the MSdk could not be constructed using our data. We feel this is due to the high degree of structural variability and difficulty in assigning stand age for stands subject to moderate and mixed severity fires on a frequent return rate. For these stands, stand level ranking should be based on the presence of large and rare attributes. As noted earlier, the presence of >50 cm trees was an important attribute in determining goshawk habitat (Machmer, pers. comm.). Stands with large, old trees (e.g.>250 years) are rare, plus large snags are a rare element and their presence would convey value to the stand. Due to the relative rarity of these structures, silviculture systems employed outside of OGMAs should strive to maintain as much large structure as feasible.

3. The thresholds provided in the scorecard for each attribute should not be considered in isolation as 'absolute' values. The field sampling possible during this study was relatively limited, and determining cut-off points between groups is relatively arbitrary. However, it should also be noted that these data provide the first attempt to provide a definition of old growth based on multiple stand structural attributes, and based on field data designed for the purpose. As a result, it is felt that the scorecard provides the manager with the ability to make a more informed decision about the biological 'old-growthness' of a stand than would be possible using age, or any other single attribute.

4. Since there is high variability in the stand structural attributes present in stands of widely differing ages, it is important to assess those attributes prior to locating OGMAs. An effort should be made to include a variety of stand types (open stands, and stands with higher levels of canopy closure), since this range was likely present naturally. However all old growth stands should include high densities of large trees since it is clear from a combination of sampling, and presence of stumps throughout this landscape that the density of stands containing large trees has decreased over the last 100 years.

5. Forest cover inventory information may be particularly misleading in the MSdk, due to the mixed and variable intensity fire frequencies observed in this ecosystem. In both this study, and in an analysis of audit plot data, forest cover accurately predicted average age of stands only 34% of the time. Age was overestimated more than 50% of the time in these stands. We suspect this is a result of having veteran layers in stands that suggests stand age is higher than it actually is.

## General Recommendations

1. Forest cover information is inadequate for assessing the potential 'old-growthness' of stands in the MS. This results from (i) forest cover mapping tends to overestimate age of stands in this subzone and (ii) that age alone does not give a good indication of structural attributes present in a stand. Aerial surveys and ground surveys must be used to ensure appropriate stands are chosen as OGMAs.

2. Current policy does not allow representation of OGMAs below variant level – i.e. that OGMA delineation cannot consider variation by site series, unless there is no timber impact (LUPG 1999). However, exploratory data analysis in this work (not presented) and from review of literature clearly demonstrates that factors such as successional pathways, fire regime and site productivity below variant level impact development of forest structures in this forest type, and so will obviously impact the biological value of forest stands designated as OGMAs.

3. The importance of maintaining the natural range of variability of ecosystems is becoming recognised. Forest types with large-sized attributes have tended to be targeted for removal from the landscape, and so are, or will become relatively rare in future. Forests with large-sized attributes should therefore be well represented in OGMAs, since the LUPG policy aims to maintain important biodiversity values into the future. Harvesting outside of OGMAs should strive to maintain large trees and snags as is currently done in similar forests in Montana.

4. This work presents a stand level basis for ranking candidate OGMAs, but landscape level attributes such as connectivity, surrounding landscape condition and patch size are at least equally important, and must factor heavily in choosing OGMAs.

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## Appendix A:

### *Summary statistics for 'wet' groups*

Tables 1-3. Summary statistics for the two groups separated on the basis of PCA_1. Data for the 'high structural attribute' group is shown first followed by that for the 'low structural attribute' group (a=mean ages, b= stems per hectare data, c= layer data)

Table 1a. Mean ages for 'high structural attribute' group

**Stand Ages, High Structural Value**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| AVE_AGE | 30 | 214.00 | 85.00 | 299.00 | 195.4000 | 10.4702 | 57.3475 |
| AGE_MAX | 30 | 247.00 | 96.00 | 343.00 | 241.4667 | 12.4791 | 68.3509 |
| AGE_MIN | 30 | 178.00 | 72.00 | 250.00 | 141.6667 | 9.2107 | 50.4492 |
| FC_MAP | 30 | 2 | 7 | 9 | 8.20 | .10 | .55 |
| FC_ground | 30 | 4 | 5 | 9 | 8.03 | .17 | .93 |
| Valid N (listwise) | 30 | | | | | | |

Table 1b. Mean ages for 'low structural attribute' group

**Stand Ages, Low Structural Value**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| AVE_AGE | 33 | 96.00 | 83.00 | 179.00 | 109.9394 | 4.1898 | 24.0688 |
| AGE_MAX | 33 | 135.00 | 93.00 | 228.00 | 136.0303 | 6.5799 | 37.7984 |
| AGE_MIN | 33 | 69.00 | 57.00 | 126.00 | 86.3939 | 3.4306 | 19.7071 |
| FC_MAP | 33 | 3 | 5 | 8 | 7.06 | .18 | 1.06 |
| FC_ground | 33 | 3 | 5 | 8 | 6.21 | .16 | .93 |
| Valid N (listwise) | 33 | | | | | | |

Table 2a. Live and dead tree stems per hectare for the 'high structural attribute' group

**Stems per Hectare, Live and Dead Trees - High Structural Value**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| Trees>40 | 30 | 155.00 | 45.00 | 200.00 | 108.8333 | 6.7538 | 36.9922 |
| WT_40 | 30 | 55 | 0 | 55 | 18.67 | 2.94 | 16.08 |
| Trees25-40 | 30 | 325.00 | 25.00 | 350.00 | 138.3333 | 12.8951 | 70.6294 |
| Trees12.5-25 | 30 | 475 | 50 | 525 | 194.17 | 19.83 | 108.61 |
| Trees<12.5 | 30 | 2250.00 | 75.00 | 2325.00 | 1013.3333 | 113.9528 | 624.1454 |
| Snags>40 | 30 | 85 | 0 | 85 | 17.17 | 2.83 | 15.52 |
| Snag25-40 | 30 | 150 | 0 | 150 | 44.17 | 6.96 | 38.10 |
| Snag12.5-25 | 30 | 125 | 0 | 125 | 49.17 | 6.62 | 36.25 |
| CWD_SPH | 30 | 855.64 | 85.45 | 941.09 | 322.0954 | 35.2994 | 193.3430 |
| BIG_DBH | 30 | 69.0 | 46.0 | 115.0 | 79.023 | 2.856 | 15.643 |
| BIG_DEAD | 30 | 102.0 | 18.0 | 120.0 | 59.573 | 4.168 | 22.827 |
| BIG_CWD | 30 | 48.5 | 29.0 | 77.5 | 44.617 | 2.232 | 12.223 |
| Valid N (listwise) | 30 | | | | | | |

Table 2b. Live and dead tree stems per hectare for the 'low structural attribute' group

**Stems per Hectare, Live and Dead Trees - Low Structural Value**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| Trees>40 | 33 | 110.00 | .00 | 110.00 | 49.2424 | 4.6979 | 26.9873 |
| WT_40 | 33 | 35 | 0 | 35 | 8.48 | 1.73 | 9.96 |
| Trees25-40 | 33 | 525.00 | 75.00 | 600.00 | 262.8788 | 19.5572 | 112.3473 |
| Trees12.5-25 | 33 | 1200 | 25 | 1225 | 362.12 | 54.47 | 312.88 |
| Trees<12.5 | 33 | 2400.00 | 125.00 | 2525.00 | 668.1818 | 95.2859 | 547.3756 |
| Snags>40 | 33 | 20 | 0 | 20 | 2.73 | .90 | 5.17 |
| Snags25-40 | 33 | 125 | 0 | 125 | 32.58 | 6.01 | 34.51 |
| Snag12.5-25 | 33 | 325 | 0 | 325 | 91.67 | 14.86 | 85.39 |
| CWD_SPH | 33 | 692.68 | .00 | 692.68 | 174.4689 | 31.9631 | 183.6139 |
| BIG_DBH | 33 | 45.0 | 30.0 | 75.0 | 56.367 | 1.954 | 11.225 |
| BIG_DEAD | 33 | 60.0 | 15.0 | 75.0 | 35.718 | 2.605 | 14.966 |
| BIG_CWD | 33 | 50.0 | 14.0 | 64.0 | 33.233 | 2.198 | 12.628 |
| Valid N (listwise) | 33 | | | | | | |

Table 3a. Percent cover data by layer for the 'high structural attribute' group

**% Cover by Layer - High Structural Value**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| %layerA | 30 | 25.00 | 20.00 | 45.00 | 29.6667 | 1.2208 | 6.6868 |
| %layerB1 | 30 | 52.00 | 3.00 | 55.00 | 21.0000 | 2.5547 | 13.9926 |
| %layerB2 | 30 | 53.00 | 7.00 | 60.00 | 29.7333 | 2.5824 | 14.1444 |
| %layerC | 30 | 68.00 | 7.00 | 75.00 | 37.8000 | 3.7344 | 20.4542 |
| %layerD | 30 | 88.00 | 7.00 | 95.00 | 70.9000 | 5.2735 | 28.8843 |
| Valid N (listwise) | 30 | | | | | | |

Table 3b. Percent cover data by layer for the 'low structural attribute' group

**% Cover by Layer - Low Structural Value**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| %layerA | 33 | 35.00 | 20.00 | 55.00 | 40.6061 | 1.6537 | 9.4998 |
| %layerB1 | 33 | 29.00 | 1.00 | 30.00 | 10.8485 | 1.2440 | 7.1463 |
| %layerB2 | 33 | 58.00 | 2.00 | 60.00 | 17.5152 | 2.3549 | 13.5280 |
| %layerC | 33 | 52.00 | 3.00 | 55.00 | 21.7576 | 2.5305 | 14.5367 |
| %layerD | 33 | 80.00 | 5.00 | 85.00 | 57.8788 | 4.0419 | 23.2187 |
| Valid N (listwise) | 33 | | | | | | |

### *Summary statistics for 'dry' groups*

Tables 4 – 6 show the summary statistics for plots greater than or equal to 140 years old and younger than 140 years old. Summary statistics for the two groups are separated on the basis of an age cut-off at 140 years. Data for the older group are shown first followed by that for the younger group (a=mean ages, b= stems per hectare data, c= layer data.)

Table 4a. Age data for stands with average age >140 years.

**Average Stand Ages - Stands 140yrs+**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| AVE_AGE | 7 | 158 | 140 | 298 | 192.99 | 23.61 | 62.48 |
| MAX_AGE | 7 | 381 | 176 | 557 | 293.43 | 51.84 | 137.16 |
| fc_ground | 7 | 1.00 | 8.00 | 9.00 | 8.2857 | .1844 | .4880 |
| FC_MAP | 7 | 2.00 | 7.00 | 9.00 | 8.2857 | .2857 | .7559 |
| Valid N (listwise) | 7 | | | | | | |

Table 4b. Age data for stands with average age <140 years.

**Average Stand Ages - Stands <140**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| AVE_AGE | 8 | 64 | 64 | 128 | 104.06 | 7.72 | 21.83 |
| MAX_AGE | 8 | 158 | 73 | 231 | 147.38 | 20.02 | 56.63 |
| fc_ground | 8 | 3.00 | 4.00 | 7.00 | 5.8750 | .3981 | 1.1260 |
| FC_MAP | 8 | 2.00 | 6.00 | 8.00 | 7.0000 | .3273 | .9258 |
| Valid N (listwise) | 8 | | | | | | |

Table 5a. Attribute values for stands with average age >140 years.

**Average Stems per Hectare, Live and Dead Trees - Stands 140yrs+**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| Trees>40_ave | 7 | 105 | 27 | 132 | 84.71 | 14.29 | 37.80 |
| WT40_ave | 7 | 55 | 0 | 55 | 22.14 | 7.01 | 18.55 |
| Trees25-40_ave | 7 | 209 | 8 | 217 | 112.00 | 29.67 | 78.50 |
| Trees12-25_ave | 7 | 359 | 83 | 442 | 252.29 | 53.26 | 140.92 |
| Trees<12_ave | 7 | 2375 | 692 | 3067 | 1490.57 | 302.18 | 799.50 |
| snags40_ave | 7 | 15 | 0 | 15 | 5.00 | 1.94 | 5.13 |
| snags25-40_ave | 7 | 33.33 | 8.33 | 41.67 | 20.2381 | 5.0973 | 13.4862 |
| snags12.5-25_ave | 7 | 67 | 0 | 67 | 23.81 | 11.27 | 29.83 |
| CWD_AVE | 7 | 546.97 | 4.36 | 551.33 | 202.6253 | 72.7717 | 192.5357 |
| Max_bigdbh | 7 | 37.0 | 54.0 | 91.0 | 67.457 | 4.375 | 11.575 |
| Max_bigdead | 7 | 49.0 | 38.0 | 87.0 | 56.500 | 6.584 | 17.419 |
| Max_bigCWD | 7 | 29.0 | 31.0 | 60.0 | 40.214 | 3.635 | 9.617 |
| Valid N (listwise) | 7 | | | | | | |

Table 5b. Attribute values for stands with average age <140 years.

**Averages Stems per Hectare, Live and Dead Trees - Stands <140 years old**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| Trees>40_ave | 8 | 114 | 13 | 127 | 67.75 | 12.94 | 36.61 |
| WT40_ave | 8 | 28 | 0 | 28 | 12.29 | 3.52 | 9.96 |
| Trees25-40_ave | 8 | 200 | 50 | 250 | 138.50 | 22.70 | 64.21 |
| Trees12-25_ave | 8 | 516 | 17 | 533 | 262.38 | 71.89 | 203.35 |
| Trees<12_ave | 8 | 1625 | 58 | 1683 | 773.00 | 191.06 | 540.39 |
| snags40_ave | 8 | 18 | 0 | 18 | 6.75 | 2.35 | 6.65 |
| snags25-40_ave | 8 | 58.33 | .00 | 58.33 | 13.5417 | 7.0319 | 19.8893 |
| snags12.5-25_ave | 8 | 58 | 25 | 83 | 57.29 | 7.12 | 20.14 |
| CWD_AVE | 8 | 328.85 | 24.76 | 353.61 | 167.9081 | 33.2888 | 94.1549 |
| Max_bigdbh | 8 | 32.5 | 57.5 | 90.0 | 70.713 | 4.533 | 12.821 |
| Max_bigdead | 8 | 43.3 | 31.7 | 75.0 | 54.475 | 5.173 | 14.630 |
| Max_bigCWD | 8 | 36.0 | 28.0 | 64.0 | 46.712 | 4.375 | 12.374 |
| Valid N (listwise) | 8 | | | | | | |

Table 6a. Percent cover data for stands >140 years

**Average % Cover by Layer - Stands 140yrs+**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| %covA_ave | 7 | 23 | 20 | 43 | 31.67 | 3.04 | 8.05 |
| %covB1_ave | 7 | 48 | 12 | 60 | 23.29 | 6.47 | 17.12 |
| %covB2_ave | 7 | 20.67 | 1.00 | 21.67 | 9.7143 | 2.5619 | 6.7780 |
| %covC_ave | 7 | 40 | 8 | 48 | 25.29 | 6.66 | 17.62 |
| %covD_ave | 7 | 69.00 | 1.00 | 70.00 | 24.8571 | 10.4941 | 27.7648 |
| Valid N (listwise) | 7 | | | | | | |

Table 6b. Percent cover data for stands <140 years

**Average % Cover by Layer - Stands <140yrs**

| | N | Range | Minimum | Maximum | Mean | | Std. |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| %covA_ave | 8 | 42 | 15 | 57 | 35.83 | 4.76 | 13.45 |
| %covB1_ave | 8 | 35 | 2 | 37 | 15.96 | 3.52 | 9.94 |
| %covB2_ave | 8 | 37.67 | 4.00 | 41.67 | 19.0833 | 4.9300 | 13.9440 |
| %covC_ave | 8 | 68 | 5 | 73 | 32.29 | 7.11 | 20.12 |
| %covD_ave | 8 | 69.67 | .33 | 70.00 | 11.9167 | 8.3696 | 23.6729 |
| Valid N (listwise) | 8 | | | | | | |