DEFINING OLD-GROWTH FORESTS IN THE ICHWK1 BEC VARIANT IN THE NELSON FOREST REGION

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Prepared by:

R.F. Holt, D.J. MacKillop

Veridian Ecological Consulting Ltd.

rholt@netidea.com

and T.F.Braumandl

Ministry of Forests, Nelson Forest Region

Prepared for:

Revelstoke Community Forest Corporation,
Downie Street Sawmills, and Pope and Talbot (Nakusp)
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Executive Summary

Old-growth forests in the wet and very wet Interior Cedar Hemlock biogeoclimatic (BEC) zone are important for the maintenance of biodiversity. A relatively mild and moist climate has led to long intervals between stand-replacing disturbances, which has created a landscape dominated by old forests. Many of these old-growth stands are 'antique' in that they have escaped catastrophic disturbance for longer than the age of the oldest living trees in the forest. Antique forests are considered amongst the most endangered of British Columbia's endangered forests. Old-growth forests are known to be vital for the survival of mountain caribou (*Rangifer tarandus caribou*), a species listed as endangered or threatened in British Columbia, Canada, and the United States. Mountain caribou, antique forests, and other old-growth biodiversity values are important values to consider within timber management plans.

The Ministry of Forests in British Columbia defines old-growth forests solely on Forest Cover age class. There is, however, increasing awareness that age class alone may miss functional attributes of old growth, and may be too coarse and inaccurate a scale for evaluating the biological value of older seral forests. In addition, Forest Cover age classes were found to be accurate in only 53% of stands sampled. In order to optimize the biodiversity retained in old growth management areas, it is important to identify and rank candidate sites based on their distinctive structural features.

This paper examines old growth forests in the Wells Grey wet cool Interior Cedar Hemlock BEC variant (ICHwk1) in the Columbia Mountains. Old-growth forests are evaluated on the basis of stand structure and an index of old-growthness is produced for Wet and Mesic sites. The index is based on a Principal Components Analysis of thirty-eight sites with three plots evaluated in each. PCA uses multiple variables to summarize correlations between attributes and to explain underlying patterns in the data. We interpret the results of PCA based on pre-defined notions of what constitutes biologically relevant old-growth structural attributes. Scorecards are developed which present numerical thresholds for a number of key structural attributes. The scorecards can be used for ranking the 'old-growthness' of individual old-growth forest stands on Mesic and Wet sites in the ICHwk1.

Our structural attribute-based old growth descriptions are compared to habitat needs of mountain caribou. We highlight areas where objectives for conserving mountain caribou and for preserving high quality old forest overlap, and where separate strategies are needed. In addition, the ecology, natural disturbance patterns, and management of ICHwk1 forests are briefly summarized and suggestions for timber harvesting and old growth management planning are presented.

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1.0 Introduction

The area of remaining old-growth forests in British Columbia has declined significantly over the last 50 years predominately due to timber harvesting (MacKinnon 1998). Old-growth ecosystems are unique, and provide habitat assemblages and stand structures that are important for biodiversity. Species associated with old forests tend to rely on inflexible habitat requirements such as large diameter snags and trees or an abundance of coarse woody debris (Bunnell and Kremsater 1991, Marcot 1997, MacKinnon 1998). These attributes are especially important for biodiversity due to the long timeframes required for their development. In general, old-growth structural attributes are not readily available in younger forests or managed stands and are not easily or quickly created (Bunnell and Kremsater 1991). In order to inventory, manage and conserve old-growth forests, a definition that adequately describes key structural attributes is necessary.

Forestry planning in the Columbia Mountains is heavily influenced by management for mountain caribou (*Rangifer tarandus caribou*). British Columbia has three ecotypes of Woodland Caribou – Northern, Boreal and Mountain. All three ecotypes look similar, but have distinctly different behavioral patterns relating to food sources, terrain utilization, snow adaptations and predation (BC Ministry of Environment, Lands and Parks 2000). Changes to the environment from human activities have reduced the amount of available habitat and mountain caribou now occupy approximately 60 percent of their historic range (BC Ministry of Environment, Lands and Parks 2000). There are approximately 2300 individual mountain caribou, all of which are found in British Columbia[1]. Mountain caribou are 'red-listed' in British Columbia and are considered "imperiled provincially because of extreme rarity or because of some factor(s) making (them) especially vulnerable to extinction" (Conservation Data Centre S2 Ranking; in Stevenson et al. 2001). The Committee on the Status of Endangered Wildlife in Canada has classified mountain caribou as "threatened" and environmental groups are calling the caribou North America's most endangered large mammal.

Caribou are broad ranging animals and require large tracts of old-growth forests for forage and cover from predators. Their primary food sources are *Bryoria* spp. and *Alectoria sarmentosa,* lichens that grow on mature and old-growth trees. Immature stands are generally avoided because they lack forage (especially lichen) and provide habitat for moose, deer, elk and their associated predators (Waters and Delong 2001). Mountain caribou habitat needs conflict directly with timber harvesting throughout their ranges. As a result, old-growth management strategies emphasize maintaining forests suitable for caribou (e.g. Ministers Advisory Committee (MAC) Plan 1999, Kootenay Boundary Land Use Plan 1999). Under this approach, mountain caribou are used as an umbrella species and their management is intended to "address the needs of old-growth dependant species… at least until further information about such species allows for more specific management direction to be developed" (MAC Plan 1999).

It is not clear whether the "umbrella species" approach will preserve the full range of biodiversity values in the Columbia Mountains. Old-growth forests in the wet and very wet Interior Cedar Hemlock (ICH) are themselves globally unique and rare (Arsenault and Goward 2000, Goward and Arsenault 2000). Mild, humid, coastal-like climates and long intervals between stand-initiating events have created forests in the wet and very wet ICH where the time since catastrophic disturbance is often greater than the age of the oldest living trees (Arsenault and Goward 2000). These 'antique' inland 'rainforests' are among the "most endangered of the province's endangered ecosystems" (Goward and Arsenault 2000). Inland 'rainforests' are a phenomenon unique to British Columbia. There are no other regions in the world with a similar combination of humidity and climatic continentality (Arsenault and Goward 2000). In these stands, western red cedar (*Thuja plicata* Donn ex D. Don) can grow to over 200cm in diameter at breast height

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[1] Approximately 35 animals from the Southern Selkirk herd reside on both sides of the Canada-US border (Hamilton 1997).

(dbh) and to ages exceeding 900 or 1000 years. Most ancient stands are found topographically on toe slope positions and in gullies where the probability of fire is reduced (Arsenault and Goward 2000). However, these locations also render them easily accessible for harvesting, and vulnerable to disturbance from road construction, and flooding for hydroelectric dams. Remaining antique forests are highly fragmented due to these developments (Goward and Arsenault 2000).

Ancient rainforests are structurally complex and act as reservoirs for biological diversity. Studies of arthropod diversity in tree canopies in coastal British Columbia have found that some species rely on microhabitat features that are only found in intact old growth (Winchester and Ring 1999). Timber harvesting affects fragmentation and alters habitat diversity (Winchester 1997). Without intact canopy habitats, species assemblages will be lost (Winchester and Ring 1999). Although fine-scale biodiversity questions such as arthropods have not been studied in the interior rainforests, antique forests in the ICH have many similarities to coastal old growth (Arsenault and Goward 2000) and may harbour similar levels of biodiversity. Rare lichens have been studied extensively in the ICH and have been explicitly linked to antique, and not just ‘old’, forests (Goward 1993, Goward and Arsenault 2000). Goward and Arsenault (2000) found that antique forests act as ‘ports of entry’ for rare epiphytic cyanolichens. They found at least 16 cyanolichens that would not occur in inland British Columbia in the absence of old-growth forests in the wet and very wet subzones of the ICH. Although hair lichens are vital for caribou survival, cyanolichen diversity is not necessarily correlated with the abundance of *Bryoria* or *Alectoria sarmentosa*. This may indicate problems with the use of mountain caribou as an umbrella species.

This report aims to describe stand-level old-growth characteristics in the Wells Grey wet, cool Interior Cedar Hemlock variant (ICHwk1) of the Columbia Mountains (Braumandl and Curran 1992). In general, definitions of old growth range from simplified descriptions based solely on forest age estimates to definitions that follow broad 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; Kneeshaw and Burton 1998; Wells et al. 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). Quantitative approaches to defining old growth tend to focus on these structural elements since they are easily measured, are often linked to biodiversity and have the potential for manipulation through forest management (Wells et al. 1998).

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 forest most often in this report because it is most commonly used in the scientific literature. In British Columbia, the definition used by forest planners is based on estimated stand age classes determined from forest cover inventory maps and databases. Age class cut-offs for old growth are outlined in the Landscape Unit Planning Guide (B.C. Ministry of Forests and BC Environment 1999) and vary according to Natural Disturbance Type (based on biogeoclimatic units with similar disturbance return intervals), and in some cases, biogeoclimatic ecosystem classification (BEC) zone (B.C. Ministry of Forests and BC Environment 1999). Age-based definitions allow managers and planners to identify old forests based on existing data without the expense of field sampling. However, this simple working definition does not consider stand structural attributes and assumes that Forest Cover age data are correct. Structural attributes provide the unique habitat values and ecosystem functions that confer special importance to old growth, and can vary considerably among stands in the same age class. Defining old growth without an assessment of structure may fail to identify the most biologically important areas of forest.

Ecological definitions of old growth can take the form of minimum criteria or indices. 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). This paper takes a similar conceptual approach, and uses the term *old-growthness* to describe the degree to which a stand is actually 'old-growth forest'.

The Landscape Unit Planning Guidebook (LUPG: BC Ministries of Forests and Environment Lands, and Parks 1999) outlines the process for retention of old-growth forests within landscape units in British Columbia. 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. However, if the landscape unit is to be managed under the low biodiversity emphasis option, only one third of the target has to be met at this time. In the Kootenay-Boundary region, mature forest must also be retained in some circumstances. In mountain caribou ranges, old growth management emphasizes strategies to conserve suitable old growth habitat (MAC Plan 1999).

Forest policy in BC is currently in flux, with movements towards results-based management underway. Although the details are unclear at this time, a results-based code will require some level of old growth management to maintain biodiversity values in the landscape. Certification systems that address management practices are recommending using ecosystem-based management approaches, which also require retention and appropriate management of old and mature seral stages. It will be necessary to make choices for retention of old-growth forest in the landscape, irrespective of the regulatory framework, and where old growth is very rare, younger recruitment forests will have to be designated and managed to maintain old forest values.

This study builds on three previously completed projects where 'indices of old-growthness' were developed for the ICHmw2, ICHdw, ESSFwm and MSdk BEC units (Holt et al. 1999; Holt 2000, Holt et al. 2001). 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. The current study was designed to address similar questions for the ICHwk1, with a special emphasis on relating old-growthness to mountain caribou habitat and other biodiversity needs.

Available sampling effort allowed the study to stratify sampling effort based on 'wet' and 'sub-xeric to mesic[2]' site series groupings; these two subgroups were analysed separately. The objectives of this study were:

1. to determine what easily-assessed structural features are consistently associated with older forests in each of the "Wet" and the "Mesic" 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.
4. to provide recommendations on appropriate management for mountain caribou and other elements of biodiversity.

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[2] Throughout this report, we use the label "Mesic" to refer to plots with sub-xeric to mesic soil moisture regimes (site series 01-04).

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 or horizontal heterogeneity, and size and age of all trees) were not included. We sampled 16 Wet and 22 Mesic stands, with 3 plots 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.

2.0 Ecosystem characteristics

The ICHwk1 is found in the Nelson, Kamloops and Prince George Forest Regions and is characterized by old seral stands of western red cedar and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Hybrid spruce (*Picea engelmannii* Parry ex Engelm x *glauca* (Moench) Voss), Douglas-fir (*Pseudotstuga menziesii* (Mirb.) Franco), western white pine (*Pinus monticola* Dougl. ex D. Don) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) form minor components of some stands. Climatic conditions include warm, wet summers and cool winters with moderate snowfall; most precipitation falls as snow. Falsebox (*Pachistima mirsynites*) and huckleberries (*Vaccinium* spp.) are common understory species on drier sites, while devils club (*Oplopanax horridus*), oak fern (*Gymnocarpium dryopteris*) and one-leaved foamflower (*Tiarella unifoliata*) are prolific on wetter sites (Braumandl and Curran 1992). The ICHwk1 is considered part of the ‘interior wetbelt’ where a unique combination of humidity and continentality result in coastal-like forests within an interior context.

This study focuses on ICHwk1 stands in the Columbia Mountains. Research sites were concentrated along the Revelstoke reservoir, but included areas along the Kinbasket reservoir, in the Trout Lake area, and near the northern end of the Arrow reservoir.

3.0 Methods

3.1 Study site selection

Thirty-eight stands were sampled in the ICHwk1 BEC unit of the Columbia and Arrow Forest Districts. Stands were identified on forest cover maps prior to field sampling. The aim was to sample equal numbers of ‘Wet’ and ‘Mesic’ stands, evenly distributed throughout the age range 100 –500+ (or oldest available) years old. Projected ages from the Forest Inventory database were used to locate older age class 9 sites. Plots within stands were assigned to the ‘Wet’ and ‘Mesic’ moisture groupings based on site series. Site series 05 and 06 (subhygric – hygric) were considered ‘Wet’ while site series 01 and 04 (subxeric – mesic) were classified as ‘Mesic’.

Within this stratification scheme, an effort was made to sample only one stand per drainage, and a minimum stand size 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, 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, creeks, cliffs or selectively harvested portions of a stand were moved a minimum of 50 m along the transect. Three sets of nested plots were sampled per stand. Each included a circular 0.04 ha (11.28 m radius) plot with a second concentric 0.2ha (radius 25.23m) circular plot (see Figure 1). The 25.32m plot was used to count large trees and snags (>50cm dbh), since these relatively rare features are inaccurately assessed using a small plot. The length and diameter (at point of intersection) for each piece of coarse woody debris >20cm in diameter were counted along 2 perpendicular transects of 24m in length that joined in the center of the plot (Figure 1). Seedlings were counted in three 0.0012ha (1.98m radius) plots located at the end of each coarse woody debris transect and at the plot center.

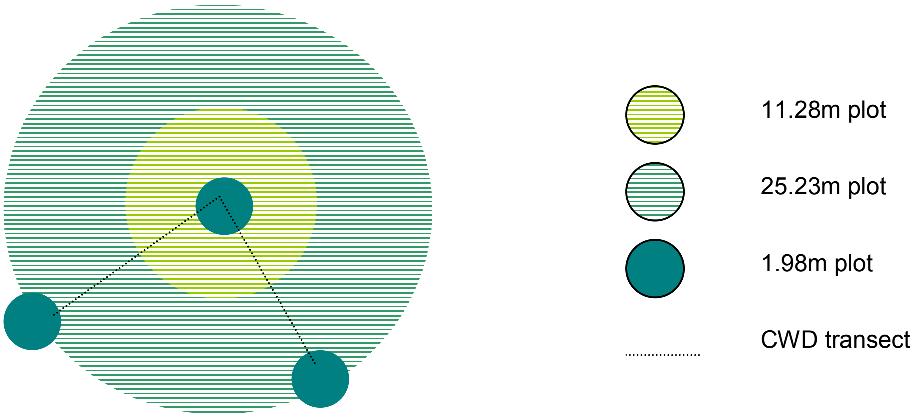

Figure 1. Sampling design

3.2 Variables measured

11.28m radius plot:

- number of live trees in <12.5cm (and >1.3m tall), 12.5-17.5cm, 17.5-30cm. 30-50cm dbh classes
- number and wildlife tree classification[3] of snags in 17.5-30cm and 30-50cm dbh classes
- percent cover of layers A1, A2, A3 – Canopy trees, B1 – Trees and Shrubs (separately; 2-10m), B2 – shrubs(<2m), C –herbs, D – mosses (as per BC Ministry of Environment Lands and Parks 1998)
- arboreal lichen presence below 4.5m above ground height (as per Armleder et al. 1992)
- percent cover *Pachistima myrsinites* (falsebox) in each of the four quarters of the plot

25.23m radius plot:

- number and species of live trees 50-75cm, 75-100cm and >100cm dbh
- number of trees >75cm dbh with pathogen indicators or insect damage[4]
- number of trees >75cm dbh with dead or broken tops
- largest tree diameter and species
- number and wildlife tree classification of snags 50-75cm, 75-100cm and >100cm dbh
- largest diameter snag
- age at breast height measured on dominant and codominant trees of three western red cedar, three western hemlock and two of any other species present; a minimum of five trees were aged.
- arboreal lichen loading in tree tops (average of 6 trees; adapted from Armleder et al. 1992)

1.98m radius plot

- number of seedlings (<1.3m tall)

24m CWD transects (two that intersected at plot center):

- diameter-at-intersection with the transect (if >20cm in diameter)
- approximate length

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

[4] Although most cedar had extensive internal decay, we did not record pathogen indicators unless there was major damage to a tree. Otherwise, pathogen indicators included conks, blind conks, major scars or cracks, large rotten branches, and mistletoe (BC Ministry of Environment, Lands and Parks and BC Ministry of Forests 1998).

- decay class (BC Ministry of Environment, Lands and Parks and BC Ministry of Forests 1998)

A walk-through the stand was used to determine:

- presence of veteran trees in the stand (defined as residual trees that are larger in diameter, taller, older and totaling less than 25 stems per hectare[5])
- presence of disturbance indicators (blowdown, fire scars, historic logging, etc.)
- presence of ecologically significant gaps in overstory

In addition, the following biophysical information was taken:

- Site series
- Aspect
- Elevation
- Slope
- Slope position

3.3 Stand age

Stand age was determined from tree cores taken at breast height from a minimum of five dominants and codominants in each plot. Internal decay is extremely prevalent within old-growth stands in the wet ICH so it was necessary to estimate the ages of trees with incomplete cores. Seventy-five percent of the tree cores in this study required extrapolation as a result of being too far from the pith to count actual age. To determine the number of missing rings, we used the average growth rate of the entire intact core and the growth rate of the innermost remaining 50 years (closest to the pith). Because the growth rate slows in most large old trees as they age, we took a very conservative approach and used the lower extrapolation of these two estimates. Bark thickness was subtracted from the tree radius using ratios developed for the PrognosisBC growth and yield model (see Appendix A; Zumwari 2002, pers. comm.).

Our goal in sampling was to obtain a core that represented at least 1/3 of the radius. However, this was not always possible, particularly for very large cedar (>150cm dbh). We found that estimates from shorter cores were much older than those from longer cores from equivalent sized trees. Since it was not possible to eliminate shorter cores without basing stand age on non-dominant species, we used the average growth rate for all trees sampled in this study (7.4 rings per cm) to extrapolate ages from short cores[6]. Estimates using this method may over-estimate the age of trees that had very fast early growth and will under-estimate trees that were suppressed in their earlier years. Because we used the lowest age from our extrapolations, we have taken a conservative approach to estimating ages and consider the ages presented as **MINIMUM** estimates. Although there are many assumptions inherent in this approach, it is reasonable considering the extent of internal decay present.

It is important to note that in several stands the time since the last stand-replacing disturbance is likely much greater than the ages of the oldest trees.

3.4 Coarse Woody Debris (CWD)

CWD volume was calculated using the following formula:

$$V = (\pi^2 / 8L) * \Sigma d^2$$

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[5] 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)

[6] The average growth rate of cedar trees was greater than the overall average for all species since most cores only represented the outer tree rings that had been laid down once trees were very large (>100cm dbh) and older.

where volume is in m^3, L is the length of the transect line in meters, and d is the diameter of pieces at the point of intersection with the transect. The number of pieces of CWD per hectare was calculated using:

$$SPH = (10000*\pi)/2L * \Sigma\ (1/l^{ij})$$

where l refers to the estimated length of each piece[7].

3.5 Caribou Habitat Attributes

Mountain caribou are highly associated with old-growth forests (Servheen and Lyon 1989, Terry et al. 2000, Apps et al. 2001, Stevenson et al. 2001). To assess potential for mountain caribou habitat within each plot, we measured the percent cover of the short woody shrub falsebox (*Pachistima myrsinites*) and the abundance of the two most important arboreal lichens to caribou: *Bryoria* spp. and *Alectoria sarmentosa*. Falsebox is an important food source in early winter. The percent cover of falsebox was estimated in each of the four quarters of the 11.28m radius plots. Lichen abundance on trees up to 4.5m in height was visually assessed and given a ranking as per Armleder et al. (1992). Because lichen abundance below 4.5m is generally low in ICHwk1 stands, we used a modified version of Armleder et al. (1992) to assess the abundance of lichen in the canopy (using binoculars) where it is most prolific. The canopy lichen loadings represent the potential supply within a stand. Caribou can access this source at ground height on litterfall and on windblown branches and trees.

4.0 Data analysis

4.1 Age data summary

Mean ages of dominant and codominant trees, as estimated from tree cores, are presented for each stand and compared to age class categories taken from Forest Cover Inventory information (Figure 2). This information is used to provide a preliminary analysis of the reliability of forest cover data for locating old growth management areas (OGMAs) solely on age. The mean ages of the dominant and codominant trees of *each species* in a stand are compared to the overall mean-age of the stand to provide insight into stand dynamics and species-cohort relationships (Figure 3).

4.2 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 the scientific literature). 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 found 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 to classifying plots on the basis of old-growthness 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.

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[7] www.for.gov.bc.ca/research/deadwood/Dtmes4.htm

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 Variables Measured 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 (SPSS Inc.1999). The final model chosen was (i) that which explained most variation in the data (ii) where the attributes associated with the main axes (PCA_1, PCA_2 and PCA_3 and PCA_4) 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 and 2 were graphed against mean age of the plot to assess how stand age relates to PCA ordination (e.g. Figure 5). 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). We used plot data rather than average stand data for the PCA analysis since rules of pseudo-replication are not in effect in data exploration procedures using PCA.

5.0 Results

5.1 Age Data Summary

The age data analysis included 38 stands in the ICHwk1. Forest Cover data[8] correctly classified the age of 20 of 38 stands (53%; Figure 2; Table 1). In 37% of the stands (14 of 38), forest cover data under-estimated the mean age of the stand. In most of these cases (12 of 14), the forest cover maps labeled stands age class 8, while field sampling suggested stands were actually age class 9. Forest cover data over-estimated the age of four stands (10%) by as many as three age classes. The stands over-estimated correspond to the four youngest forests in our data set.

Stands ranged in age from 81-610[9] years old with considerable variation in ages of plots within stands. Four age class 9 stands had individual plots that are age class 6 or 7 and five age class 9 stands had age class 8 plots. The ages of Wet stands were correctly estimated more often than those of Mesic stands (69% and 41% accuracy, respectively). This is likely because younger stands were mis-typed more often than older stands and because younger wet stands were extremely rare.

Table 1 Accuracy of Forest Cover inventory data.

	Number of Stands	Percentage of Stands
Forest Cover –Accurate	20	53%
Forest Cover – Over-estimates	4	10%
Forest Cover – Under-estimates	14	37%
TOTAL	38	100%

Stand-replacing disturbances are historically rare in the ICHwk1 (BC Ministry of Forests and BC Environment 1995) and as a result it was difficult to locate age class 6, 7 and 8 stands. The majority of forested lands are classified as age class 8 or 9 in the Forest Inventory database. In the Revelstoke TSA, age class 8 and age class 9 each account for 15.5% of the forested landbase (31% total) and in the Golden TSA for 25% and 30% respectively (55% total). In contrast, age class 6 and 7 combined account for 7% of both TSAs (see Table 9). Our data suggest that polygons labeled as age class 8 are actually older than 250 years, which contributed to our difficulty in locating mature stands. We sampled 17

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[8] Forest Cover age classes (AC) are as follows: AC1 = 0-20 years; AC2 = 21-40 years; AC3 = 41-60 years; AC4 = 61-80 years; AC5 = 81-100 years; AC6 = 101-120 years; AC7 = 121-140 years; AC8 = 141-250 years; AC9 = 250+ years.

[9] Note that these ages are considered MINIMUM ages, based on conservative extrapolation (see methods).

polygons that were labeled age class 8 on forest cover maps and only two were correctly classified (12%); three were younger (18%) and 12 were older (71%) than the Forest Cover inventory labels.

Because age class 9 is open-ended, we stratified it into three classes: 9a = 250-400; 9b = 400-500; and 9c = >500 year old. We determined stand ages from the mean age of dominant and codominant trees of the leading species in a stand. However, the ages presented are, in most cases, conservative estimates taken from incomplete (decayed) tree cores and should be considered minimum age estimates (see Methods). The age of the oldest tree encountered in a stand (maximum age) is presented in Figure 2 to show the minimum potential age of each stand (time since disturbance). Our estimates of forest age, including maximum ages, do not consider that many stands are likely older than the age of the oldest living trees. These ‘antique’ forests have likely avoided catastrophic disturbance for very long periods and may have been in existence for several generations of dominant trees.

Small-scale disturbances and gap-phase dynamics (see Oliver and Larson 1996) likely lead to a wide range of ages of canopy trees within old ICHwk1 stands. Differences between mean and maximum ages and variation amongst mean ages of canopy trees by species (Figure 3; Figure 4) suggest that regeneration is continuous and occurs without stand-replacing disturbances. Considering individual species, the western red cedar component of stands is generally older than the mean stand age and older than all other species. Western hemlock is younger than the mean, but older than the spruce, subalpine fir and Douglas-fir components. This difference is especially apparent in wet stands (Figure 3) where hemlock and spruce are much younger than cedars in all but three stands.

The differences in ages of cedar and hemlock do not necessarily suggest that species are invading one after another (i.e. relay floristics; Clements 1916 sensu Oliver and Larson 1996). Ages may be more similar if early suppression of seedlings and saplings are considered. Cedar also have longer average life expectancies than hemlock (Farrar 1997), so it is possible that dominant hemlock trees observed are from a second cohort that established beneath an original cedar-hemlock canopy. In contrast, the pattern for spruce trees appears to follow a relay floristics model. Where spruce were found, many were observed to have established on nurse logs and tree ring data suggests that most are young enough to have developed within cedar-hemlock stands.

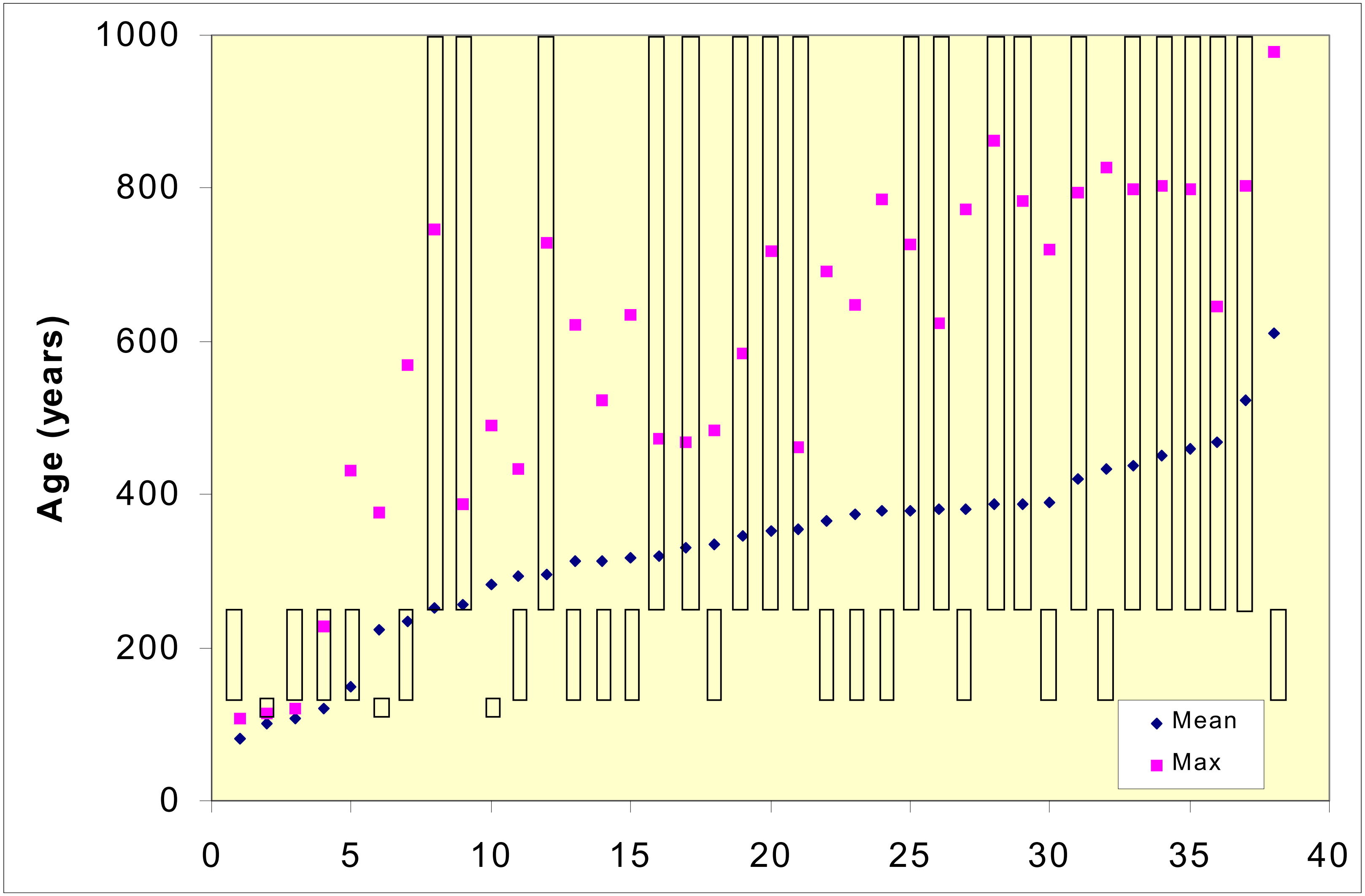

Figure 2. Mean and maximum ages of dominant and codominant trees in each stand[9]. Boxes are forest cover age ranges for that stand.

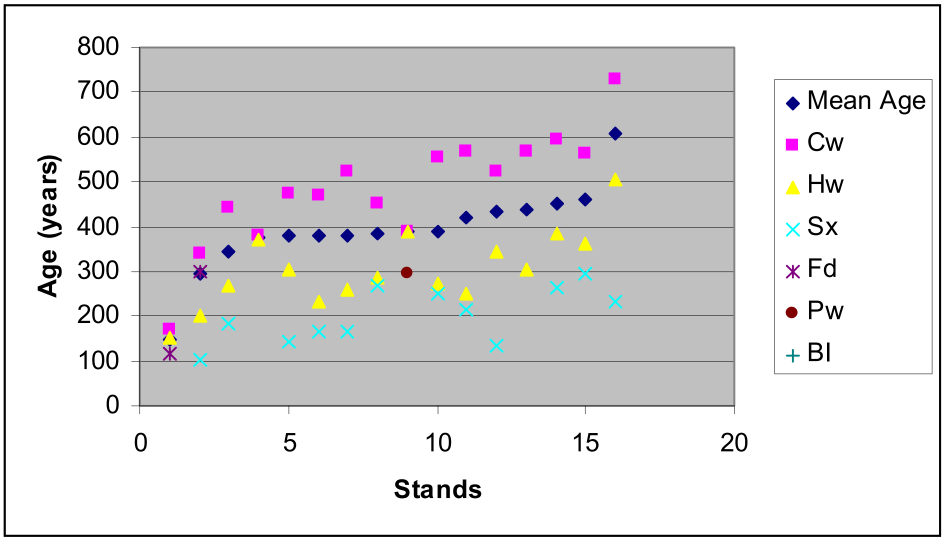

Figure 3. Average age of dominant and codominant trees by species – Wet sites.

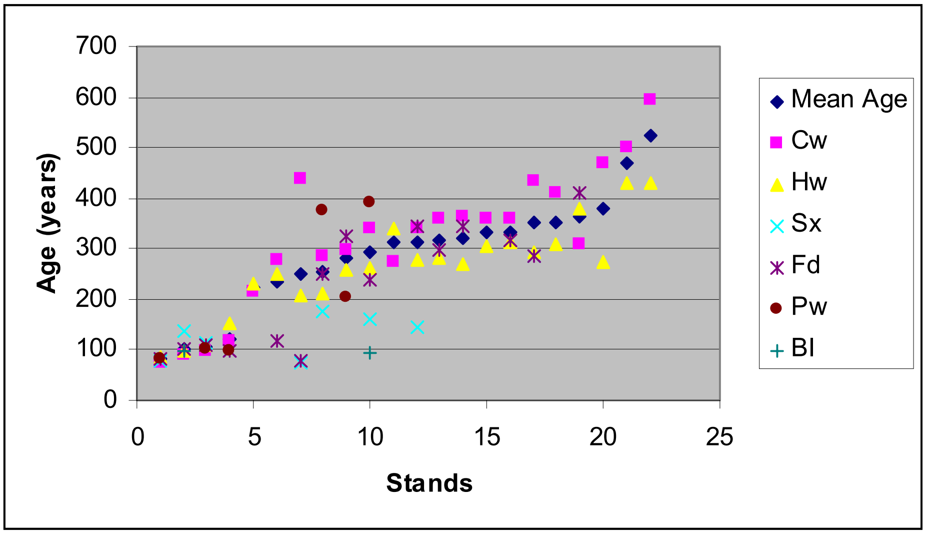

Figure 4. Average age of dominant and codominant trees by species – Mesic sites.

5.1 Principal Components Analysis

The results of Principal Components Analysis are presented separately for each of the Wet and Mesic subgroups of plots.

5.1.1 Sub-analysis: Wet stands

Forty-eight of 48 possible plots were included in the analysis. The first PCA axis (PCA_1) accounts for 26% of the variation in the data. PCA_2 and PCA_3 contributed an additional 13% and 10% of the variation explained. Subsequent axes accounted for less variation and are not presented here. The variable loading scores for each axis are shown in the component loading matrix (Table 2). Larger 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, 0.55, and 0.45 are considered ‘very good’, ‘good’ and ‘fair’, respectively; scores of 0.32 are ‘poor’ and are at the lower limits of interpretability (Tabachnik and Fidell 1996).

Using a cut off of 0.63 (‘very good’ correlation), PCA_1 is positively associated with the largest tree on a plot and the number of trees >100cm dbh, and is negatively correlated with the density of trees and snags 17.5-30cm dbh and trees 50-75cm dbh. PCA_1 also has ‘fair’ to ‘good’ correlations with the largest snag, the percent cover of short shrubs (<2m tall; mostly devil’s club in this study), and the percentage of large trees (>75cm dbh) with dead or broken tops. Strong negative correlations are with canopy closure (%cover layer A), and density of trees and snags 30-50 dbh. PCA_2 is related to CWD and PCA_3 represents the number of trees 75-100cm dbh and the canopy lichen loadings.

Table 2. Component loading matrix for Wet stands. Values reflect the correlations between variables and each axis.

Component Matrix

	PCA Axis		
	1	2	3
%Trees>75 with Dead Tops	.475	-9.71E-02	.390
Lichen Loading*	.227	-.522	.528
Largest CWD	4.416E-02	.710	.303
Largest Snag	.571	4.963E-02	1.899E-02
Largest Tree	.797	.295	-.123
Snags17.5-30	-.678	.134	.119
Snags30-50	-.502	-.159	.261
Snags50-75	-.282	-.598	.106
Snags75-100	.139	-.404	-.185
Snags>100	.433	.123	9.002E-02
Trees30-50	-.621	.359	.246
Trees50-75	-.640	.287	.146
Trees75-100	-.259	-.266	-.565
Trees>100	.777	.317	-.133
CWD Volume	-8.43E-03	.662	.457
%cover layer A: Trees>10m	-.627	.347	-.482
Trees<17.5	-.406	-.361	.510
Trees17.5-30	-.676	3.683E-02	7.948E-02
%cover layer B2:Shrubs and Trees<2m	.518	-.179	.312

*Represents the relative amounts of arboreal lichen in the mid-upper canopy

** See Methods for a complete description of variables.

Instead of separating plots into groups, PCA summarizes patterns of correlation between variables and distributes plots along multiple axes in ‘factor space’. A visual assessment of plot groupings (Figure 5) suggests a split in the data at PCA_1 = -1.5. These younger stands are obviously separate from the remainder. A second split in the data is (less) apparent at PCA_1 = 0. Splitting the data at PCA_1 = 0 has a statistical basis in that plots with a positive score are positively correlated with PCA_1 and its associated variables. Given that a continuous distribution of stands was sampled by age and seral stage development, we are not surprised to find a correspondingly continuous distribution in ‘factor space’.

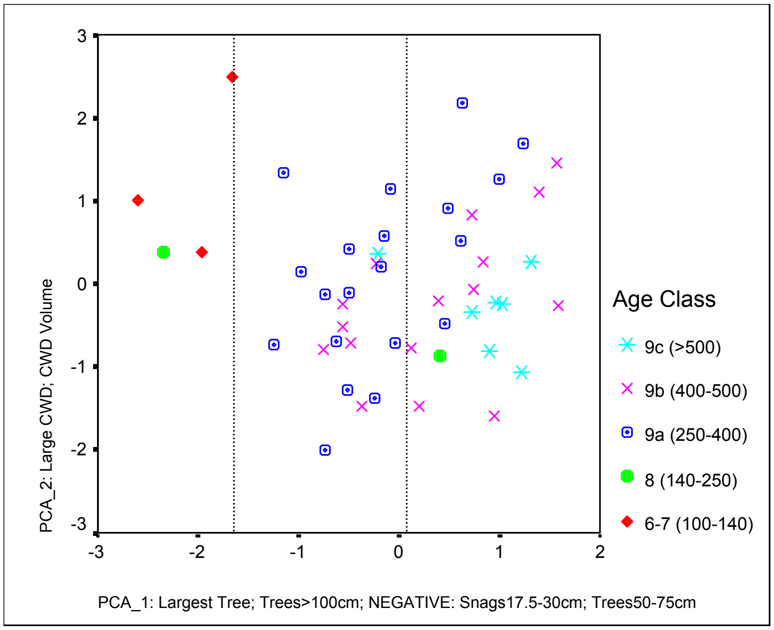

Figure 5. PCA_1 vs. PCA_2 for WET sites. Age classes are based on tree ring data.

Interpretation is key to the success of PCA. Because the patterns in PCA_1 summarize the abundance of large sized structural attributes, and because a significant correlation was found between PCA_1 and age (r=0.680; p>0.01; Figure 6)[10], we have used the three groups identified in PCA_1 to separate plot data into groups of old-growthness (Figure 5). Although virtually all plots have a mean age of >250 years (age class 9), there are differences in the ‘old-growthness’ that are not accounted for by age alone. Structural attributes are necessary to determine the structural and therefore the biodiversity values of old-growth forests in Wet ICHwk1 stands.

PCA_2 and PCA_3 explain lower percentages of the variation in the data and are only weakly associated with most input variables. In addition, there is no correlation between age and PCA_2 or PCA_3 (PCA_2 – r = -0.276; p = 0.057 and PCA_3 – r = 0.72; p = 0.627). For these reasons, our index is based on PCA_1 only.

Based on the correlations between PCA_1 and the stand structural attributes, the three groups derived from the PCA analysis represent Low, High, and Very High Old-Growth Structure (Figure 5). We feel that these categories are appropriate given that many stands in the wet ICHwk1 are likely ‘antique’ and have not experienced catastrophic disturbances for periods longer than the age of the oldest living trees (Goward and Arsenault 2000). Antique stands generally correspond to the Very High structure group, although it is possible that not all Very High structure plots are antique.

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[10] The correlation is significant even when the younger plots were not included in the analysis (r=0.408; p=0.006)

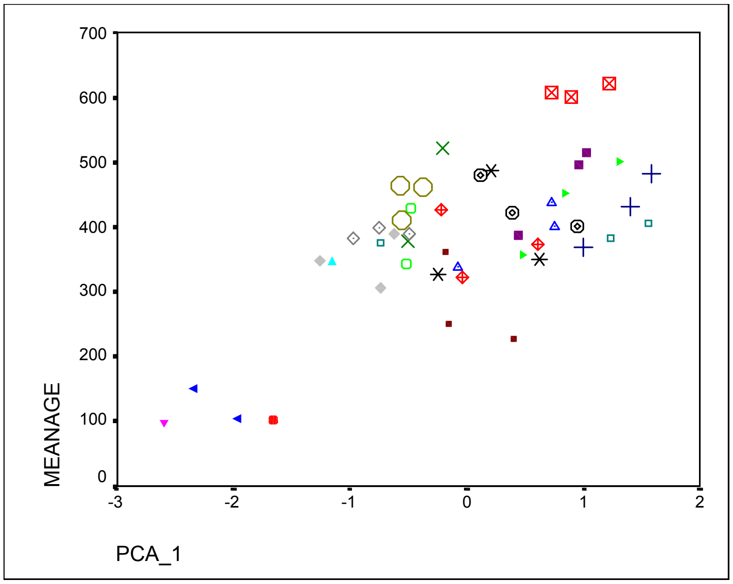

Figure 6. Relationship between PCA_1, the old-growth axis, and mean stand age. Markers indicate plots from the same stand.

Using these splits in the data, the mean values for the following attributes increase with increasing 'old-growthness' (from Low to Very High Structure): Mean age; density of trees >100cm dbh; density of trees >75cm dbh with dead or broken tops, and with pathogen indicators; size of the largest tree and snag; and density of snags >100cm dbh. The following attributes decline with increasing old-growthness: density of trees 17.5-30cm dbh and 50-75cm dbh; density of snags 17-30cm dbh and percent cover trees >10m tall (layer A). The High Structure group has maximum mean values for the number of trees <17.5cm dbh and 75-100cm dbh and for snags 50-75cm dbh. Values for densities of trees <30cm, >50cm and >75cm dbh are presented for comparison with other studies.

Table 3. Summary statistics for Low, High, and Very High old-growth structure on Wet sites.

Structural Attribute	Low Structure				High Structure				Very High Structure			
	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
Sample Size	4				21				23			
MeanAge	**110**	10	98	150	**380**	13	250	522	**443**	19	227	621
Slope	**25**	11	0	52	**28**	5	0	75	**20**	3	0	51
Elevation	**740**	64	500	850	**852**	31	580	1100	**933**	43	580	1290
Trees<17.5cm dbh	**540**	253	75	1525	**618**	113	0	2125	**235**	44	0	950
Trees17.5-30 cm dbh	**200**	60	0	300	**66**	13	0	180	**21**	5	0	75
Trees30-50 cm dbh	**220**	38	100	325	**54**	10	0	140	**40**	9	0	175
Trees50-75 cm dbh	**101**	21	45	160	**60**	5	30	120	**36**	3	10	70
Trees75-100 cm dbh	**17**	5	5	30	**41**	5	10	95	**23**	4	5	80
Trees>100 cm dbh	**6**	4	0	20	**19**	3	0	55	**52**	5	15	100
Trees>50cm dbh with dead or broken tops	**3**	2	0	10	**17**	3	0	70	**45**	5	15	85
Trees>50cm dbh with pathogen indicators	**8**	4	0	20	**18**	3	0	45	**15**	3	0	50
Largest Tree	**97**	7	79	119	**124**	6	81	185	**176**	6	110	232
Largest Snag	**60**	13	22	95	**93**	4	54	123	**115**	6	79	180
Seedlings	**6534**	5539	270	28620	**5850**	1401	0	19170	**1244**	301	0	5940
Snags_17.5-30 cm dbh	**65**	13	25	100	**15**	5	0	75	**1**	1	0	25
Snags_30-50 cm dbh	**30**	9	0	50	**18**	5	0	75	**4**	2	0	25
Snags_50-75 cm dbh	**5**	4	0	20	**19**	3	0	50	**7**	2	0	30
Snags_75-100 cm dbh	**3**	2	0	10	**7**	1	0	15	**8**	2	0	40
Snags_100 cm dbh	**0**	0	0	0	**3**	1	0	15	**7**	1	0	25
Canopy lichen loading	**1.3**	0.2	0.8	2.2	**2.5**	0.2	1.2	4.3	**2.8**	0.3	1.0	4.5
%cover layer A:>10m	**39**	5	25	50	**24**	2	8	45	**15**	1	7	30
%cover layer B1:2-10m	**4**	2	0	10	**8**	1	0	30	**5**	1	1	10
%cover layer B2:<2m (trees and shrubs)	**15**	6	5	35	**24**	2	7	45	**33**	2	15	50
%cover layer C (herbs)	**47**	3	40	55	**44**	3	20	85	**48**	3	20	80
%cover layer D (mosses)	**28**	11	5	60	**28**	4	8	60	**27**	3	8	45
#Tree Species	**4.0**	0.5	2.0	5.0	**2.7**	0.2	2.0	4.0	**2.5**	0.1	2.0	4.0
Largest CWD	**65**	8	45	95	**73**	4	41	123	**71**	4	37	117
CWD Volume	**559**	108	352	969	**494**	60	62	1181	**519**	77	73	1395
CWD pieces per hectare	**507**	144	250	1069	**308**	36	99	686	**248**	33	74	651
Volume of CWD >50cm diameter	**298**	159	0	897	**312**	58	0	957	**380**	71	0	1175
Trees<30 cm dbh	**740**	285	75	1800	**684**	116	40	2150	**257**	46	0	975
Trees>50 cm dbh	**130**	24	75	175	**120**	8	55	190	**112**	6	55	155
Trees>75 cm dbh	**26**	4	15	35	**60**	6	10	125	**75**	6	25	135
Total Live Trees >12.5cm dbh	**630**	20	130	460	**300**	24	95	975	**214**	15	80	350
Total Live Trees >17.5cm dbh	**555**	70	365	700	**240**	17	130	400	**173**	11	80	300
Total Stems (live and dead) 50-75 cm dbh	**106**	24	45	180	**79**	5	40	130	**44**	3	10	75
Total Stems (live and dead) >75cm dbh	**26**	5	10	40	**70**	6	30	135	**90**	5	50	150

5.1.2 Sub-analysis: Mesic sites

Sixty-five of 65 possible plots were used in the analysis. A ‘best-fit’ approach was used to determine the final input variables in PCA. Changing input variables had little effect on the output. However, four plots (Crawford 1, Devil 1 and 2, and Dam 3) had resulting PCA_1 scores of approximately zero regardless of input variables, but were not consistently positive or negative. Because of their ambiguity, they were not included in the final analysis. Removing them did not affect the PCA scores for the remaining 61 plots.

The first PCA axis (PCA_1) accounts for 29% of the variation in the data. PCA_2 and PCA_3 contributed an additional 10% and 8% of the variation explained. Subsequent axes accounted for less variation and are not presented here. The correlation between variables and PCA axes are shown in the component loading matrix (Table 4). Larger 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, 0.55, and 0.45 are considered ‘very good’, ‘good’ and ‘fair’, respectively; scores of 0.32 are ‘poor’ and are at the lower limits of interpretability (Tabachnik and Fidell 1996).

Table 4. Component Loading Matrix for Mesic stands. Values reflect the correlations between variables and each axis.

	PCA Axis		
	1	2	3
%Trees >75 with dead tops	.600	-.426	7.871E-02
%Trees 50-75 with dead tops	.616	-.491	-.131
%Trees >75 with pathogen indicators	.381	-.568	-.163
%Trees 50-75 with pathogen indicators	.394	-.180	-.480
Lichen Loading*	.672	-.176	-.118
Largest CWD	.695	9.085E-02	.316
Largest Snag	.633	.185	.216
Largest Tree	.768	.303	.167
Snags17.5-30	-.461	-.164	.355
Snags30-50	-.617	7.070E-02	.124
Snags50-75	.205	-.119	-.135
Snags>75	.393	.450	.110
Trees<17.5	-5.71E-02	.159	-.418
Trees17.5-30	-.317	-.409	.307
Trees30-50	-.652	-.193	.342
Trees50-75	9.000E-02	.496	-.568
CWD Volume pieces 20-30cm	-.582	.401	-.128
CWD Volume pieces 30-50cm	-.313	.149	-.102
CWD Volume pieces>50cm	.690	.163	.257
Trees75-100	.701	-3.88E-02	-.118
Trees>100	.590	.457	.424

Extraction Method: Principal Component Analysis.

*Average lichen loading on the mid-upper canopy.

Using 0.63 as the cut-off for a ‘very good’ correlation, PCA_1 is positively associated with the largest tree, snag and piece of CWD in a plot, the density of trees 75-100cm dbh, arboreal lichen loading in the canopy, volume of CWD pieces >50cm in diameter, and, negatively, with the density of trees 30-50cm dbh. PCA_2 and PCA_3 have ‘good’ negative associations with the percentage of large trees (>75cm dbh) with pathogen indicators and with densities of trees 50-75cm dbh.

PCA_1 is positively associated with numerous large sized stand structural attributes and is negatively correlated with smaller structures. These correlations suggest that PCA_1 is describing the ‘old-growthness’ of plots on the basis of stand structure (as per the literature; see Introduction). PCA_2 and PCA_3 explain lower percentages of the variation in the data and are only weakly associated with most input variables. In addition, there is a strong correlation between the mean age of a stand and its PCA_1 score (r = 0.794; p >0.001; see Figure 8) and no correlation between age and PCA_2 or PCA_3. For these reasons, our index is based on PCA_1 only.

PCA does not separate plots into specific groups, but results multivariate scores for each plot that is distributed along each axis. It is then the researcher’s responsibility to interpret the results. Regardless of input values in this analysis, PCA always grouped the majority of younger and older plots at opposite ends of the axis with stands in the 250-400 year old range spread across the middle. We have separated the data into three groups. The first group represents younger stands with Low old-growth structural value and is split at PCA_1 = -1. The second split, at PCA = 0, separates stands with Moderate and High old-growth structure. Splitting the data at PCA_1 = 0 has a statistical basis in that plots with a positive score are positively correlated with PCA_1 and its associated variables. Given that a continuous distribution of stands was sampled by age and seral stage development, we are not surprised to find a correspondingly continuous distribution in ‘factor space’.

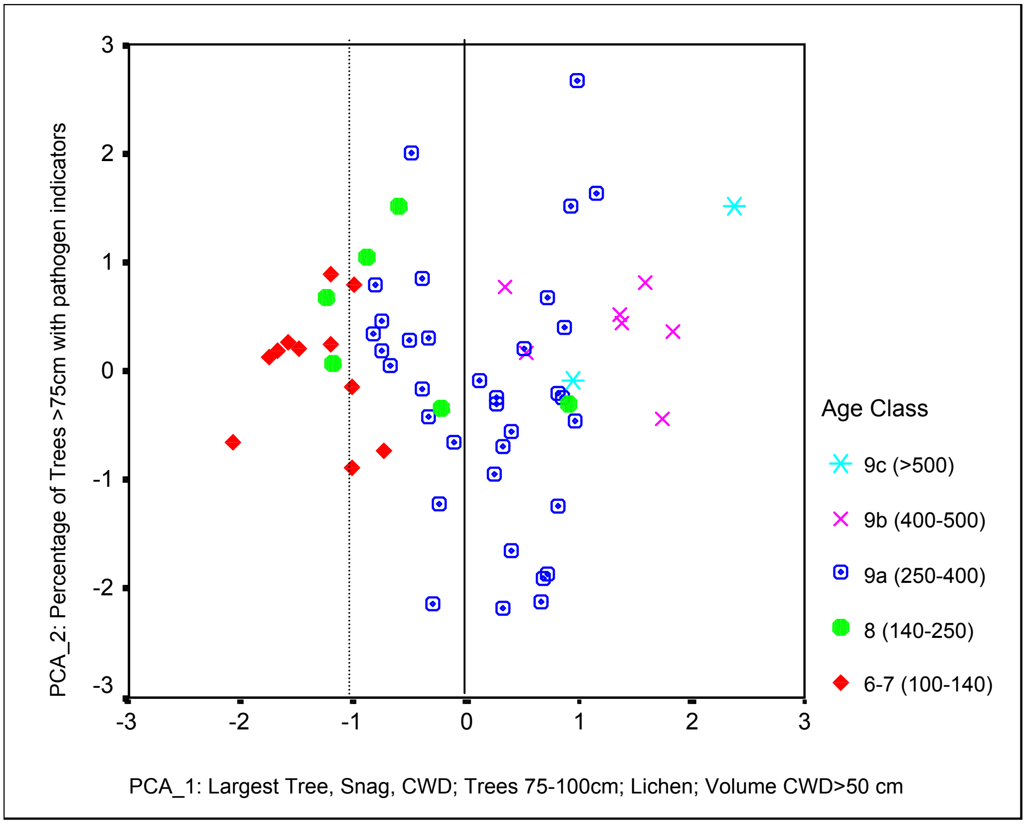

Figure 7. PCA_1 vs PCA_2 for Mesic sites. Age classes are based on tree ring data.

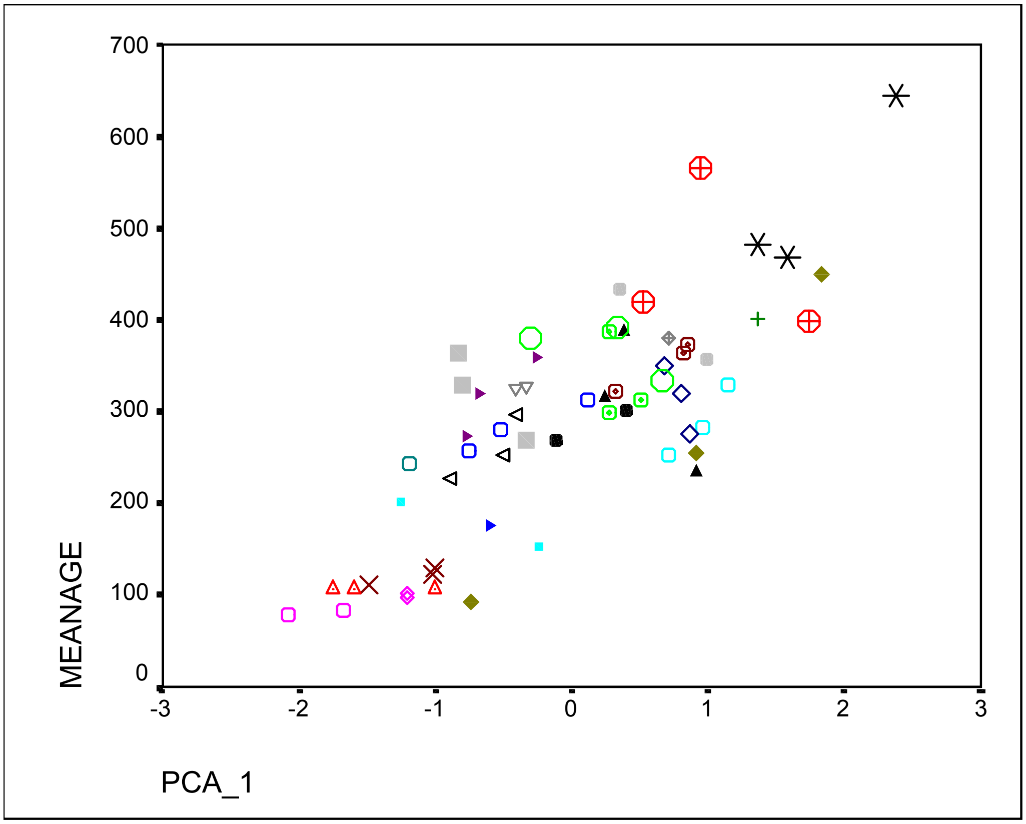

Figure 8. Relationship between PCA_1, the old-growth axis, and mean stand age. Markers indicate plots from the same stand.

Summary statistics for the Low, Moderate and High old growth structural attribute groups show increasing trends for the following attributes (from Low to High; Table 5): mean age; density of trees 75-100cm dbh and trees >100cm dbh; number of trees >75cm dbh with dead and broken tops and with pathogen indicators; the largest tree and snag on a plot; density of snags 75-100cm dbh; and total number of stems (live and dead) >75cm dbh. Declining trends are shown for the density of trees 17.5-30 and 30-50cm dbh, for the number of snags 30-50cm dbh and for the number of pieces of CWD on a plot. Differences were found between the Low and Moderate groups for snag density 17.5-30cm dbh and for the average percent cover of falsebox. The High structure group had larger CWD pieces and higher volumes than the Moderate structure group. Stands with Moderate old-growth structure had peak levels of seedlings, trees <17.5cm dbh and trees 50-75cm dbh.

Table 5. Summary statistics for Low, Moderate and High old-growth structure on Mesic sites.

Structural Attribute	Low Structural Value				Moderate Structural Value				High Structural Value			
	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
Sample Size	12				18				31			
MeanAge	**124**	14	79	242	**275**	18	93	379	**368**	16	233	645
Slope	**41**	3	21	55	**48**	4	0	68	**50**	2	27	73
Elevation	**828**	55	550	1085	**826**	42	500	1055	**910**	44	500	1370
Trees<17.5 cm dbh	**639**	135	100	1575	**1079**	200	275	3550	**898**	111	175	2825
Trees17.5-30 cm dbh	**202**	18	75	300	**163**	27	25	425	**123**	19	0	400
Trees30-50 cm dbh	**217**	28	80	375	**172**	19	25	275	**89**	11	0	250
Trees50-75 cm dbh	**48**	8	0	90	**81**	8	20	130	**67**	5	15	150
Trees75-100 cm dbh	**1**	1	0	10	**9**	2	0	25	**31**	3	5	85
Trees>100 cm dbh	**0**	0	0	0	**1**	0	0	5	**7**	2	0	35
#Trees>75cm with dead or bt	**0**	0	0	0	**2**	1	0	15	**19**	3	0	60
#Trees>75cm dbh w/ pathogen	**0**	0	0	5	**4**	1	0	20	**16**	2	0	40
Largest Tree	**69**	3	48	89	**85**	3	65	108	**108**	4	82	177
Largest Snag	**64**	6	46	120	**67**	3	40	85	**88**	3	50	124
Seedlings	**2295**	756	0	8370	**8655**	2343	0	32400	**3205**	702	0	16740
Snags 17.5-30 cm dbh	**65**	16	0	200	**10**	4	0	50	**10**	4	0	75
Snags 30-50 cm dbh	**60**	8	25	100	**15**	4	0	50	**8**	4	0	80
Snags 50-75 cm dbh	**11**	3	0	35	**14**	3	0	50	**16**	2	0	40
Snags 75-100 cm dbh	**2**	1	0	10	**4**	1	0	15	**8**	1	0	25
Snags >100 cm dbh	**1**	1	0	5	**0**	0	0	0	**3**	1	0	35
%cover Falsebox	**1.7**	0.6	0.0	6.3	**4.4**	1.5	0.0	21.8	**4.9**	1.1	0.0	29.3
Canopy lichen loading	**2**	0	1	3	**2**	0	1	4	**3**	0	2	5
%cover layer A:>10m	**37**	3	25	50	**31**	3	15	55	**28**	2	10	50
%cover layer B1:2-10m	**2**	1	0	10	**12**	3	1	40	**11**	1	1	30
%cover layer B2:<2m (shrubs)	**9**	2	1	20	**18**	3	1	40	**18**	2	3	45
%cover layer C (herbs)	**21**	6	1	60	**16**	3	1	50	**25**	2	1	50
%cover layer D (mosses)	**38**	7	4	70	**53**	5	12	100	**43**	3	5	75
#Tree Species	**3.9**	0.3	2.0	5.0	**3.4**	0.2	2.0	5.0	**2.6**	0.2	2.0	5.0
Largest CWD piece	**48**	2	40	60	**48**	2	38	60	**64**	3	28	110
CWD Volume	**369**	40	179	661	**302**	36	67	628	**412**	41	44	1007
CWD pieces per hectare	**483**	41	318	765	**387**	58	12	843	**293**	23	136	623
CWD Volume >50cm diameter	**41**	17	0	162	**40**	12	0	150	**225**	37	0	887
Trees<30 cm dbh	**841**	137	325	1775	**1241**	197	420	3650	**1021**	114	250	2850
Trees>50 cm dbh	**50**	8	0	100	**90**	9	25	145	**105**	6	40	190
Trees>75 cm dbh	**1**	1	0	10	**9**	2	0	30	**38**	4	10	90
Snags>75 cm dbh	**3**	1	0	10	**4**	1	0	15	**11**	2	0	60
Total Live Trees >12.5cm dbh	**654**	44	440	875	**537**	45	290	975	**427**	31	95	840
Total Live Trees >17.5cm dbh	**468**	25	360	580	**425**	27	265	625	**317**	21	95	680
Total Stems 50-75 cm dbh	**59**	8	5	100	**94**	8	25	150	**83**	5	20	150
Total Stems >75cm	**5**	1	0	10	**14**	2	0	30	**49**	4	20	95

5.2 Differences between Wet and Mesic sites

Wet sites have larger sized structures than Mesic stands and are dominated by trees of a full size class larger than those on Mesic sites. For example, Very High structural value stands on Wet sites have many trees >100cm dbh while High structure Mesic stands are comprised of trees 75-100cm dbh. The largest trees on Mesic sites ranged from 48cm dbh to 177cm dbh. On Wet sites, the range was 79cm dbh to 232cm dbh with an average on Very High structure Wet sites of 176cm dbh.

Species composition of large trees also differed between Wet and Mesic sites. The average species composition of trees >75cm across all Mesic sites was 33% cedar, 55% hemlock and 12% other species (Douglas-fir and western white pine). On Wet sites, the species composition of trees >75cm dbh favoured cedar with 73%, versus 25% hemlock and 2% spruce. Summaries of relative species abundance by size class for structural value groups are presented in Appendix C.

The difference between Wet and Mesic stands is substantial enough that management for old growth must conserve representative stands across the range of dominant site series. Old growth management that does not include the High and Very High old-growth structure stands on Wet sites will fail to maintain certain stand characteristics, and will therefore result in increased risk to biodiversity in the ICHwk1.

5.3 Mountain caribou habitat

Mountain caribou are highly associated with old-growth forests and require large tracts of land for their foraging and other survival needs (Hamilton 1997, Stevenson et al. 2001). In the Columbia Mountains, caribou have wide seasonal ranges and move between low elevation ICH stands and high elevation ESSF, parkland and alpine tundra (AT) areas as snow depth shifts. In the Early Winter (late October – mid January), caribou survive on falsebox and on lichen on litterfall and windthrown trees in the ICH and lower ESSF zone. Late winter (mid January to April) is spent in the subalpine parkland in the ESSF zone with occasional use of the AT, where foraging on arboreal lichens is made available by litterfall and by snowpack depth in some situations. In the spring, mountain caribou return to snow-free elevations in the lower ESSF and ICH, or remain in snow-covered portions of the ESSF. As the snow melts at higher elevations, the caribou return to the upper ESSF and AT for the summer and fall (June through late October; Stevenson et al. 2001).

Early winter habitat is found in the ICH and is critical to mountain caribou survival (Servheen and Lyon 1989, Hamilton 1997, Stevenson et al. 2001). During this season, winter snowpacks have not yet consolidated at higher elevations making energy expenditures associated with travel very high. Food availability is greater at lower elevations where snow interception and warmer temperatures extend the availability of green forage such as falsebox (*Pachistima myrsinites*), and where hair lichen on litterfall and windblown trees is more accessible. Research into stand selection in the early winter has shown that caribou prefer highly productive stands with gentle terrain, high lichen abundance, large old trees, and closed canopies (>50%; Servheen and Lyon 1989; Apps et al. 2001).

Falsebox

Falsebox is an important early winter food source for mountain caribou although they also browse on huckleberry leaves (*Vaccinium* spp.), wintergreen (*Pyrola* spp.) and Sitka valerian (*Valeriana sitchensis*; Hamilton 1997). Falsebox is an indicator species on mesic to sub-xeric sites (site series 01 and 04) and is rare or absent in wetter areas (Braumandl and Curran 1992). Falsebox is not an indicator of old-growthness and was not included in PCA. However, due to its importance to mountain caribou, we sampled falsebox cover in plots, and can assess the relationship between falsebox and old growthness.

Falsebox abundance was low on most sites (Figure 9) and appeared patchily distributed in the field. On Mesic sites, there were no correlations between falsebox (measured as percent cover) and mean age or old-growthness (PCA_1). Weak relationships were observed between falsebox cover and lichen abundance (r=0.368; p>0.003) and falsebox and density of trees >100cm dbh (r=0.257; p>0.039). Average values for the groups produced in the PCA analysis suggest minimal levels of falsebox occurring on Low structure sites, but no difference in abundance between Moderate and High structure groups.

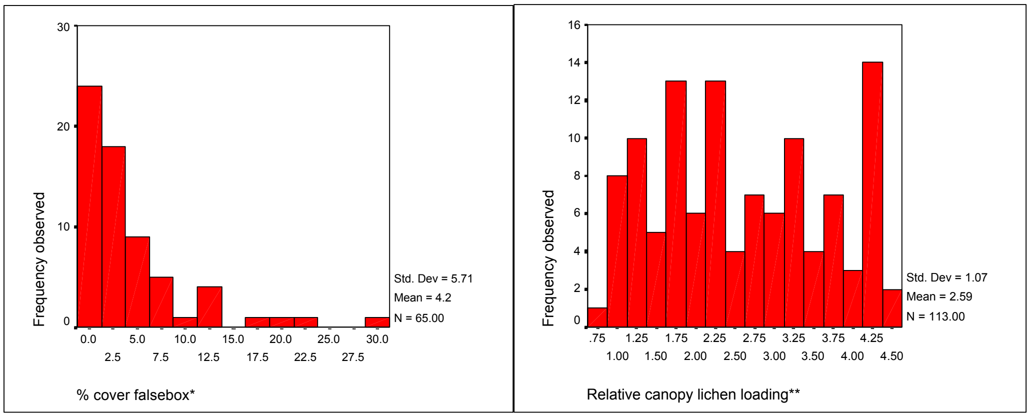

Figure 9. (a) Mean % cover falsebox for Mesic sites and (b) canopy lichen loading for all sites.

Lichen

The abundance of hair lichens (*Bryoria* spp. and *Alectoria sarmentosa*) within 4.5m of the ground was very low or virtually absent in 99 of 113 plots in this study[11] and *Alectoria sarmentosa* was far more prevalent than *Bryoria* spp. at all canopy heights. Most hair lichen in the ICHwk1 is found in the upper canopy and is made accessible to caribou through litterfall and windthrow events. The average lichen abundance in the upper canopy (based on a visual assessment of six trees; adapted from Armleder et al. 1992) ranged from virtually absent (0.833 on a 5 point scale) to very high (4.5; Figure 9). On Wet sites, lichen abundance was positively correlated with mean stand age (r=0.480; p>0.001) and the density of hemlock trees >75cm dbh (r=0.370; p>0.01), and negatively associated with crown closure (% cover layer A: -0.436; p>0.002). Canopy complexity in terms of number of branchings likely increases with age (S. Steventon pers. comm.), and may explain why lichen loadings were linked to age in high structure forest. Lichen abundance on Mesic sites was significantly correlated with old-growthness (as per PCA_1; r=0.672; p<.001). Other correlations between lichen and the following variables on Mesic sites were significant to the 0.01 level: mean stand age (r=0.499); and size of the largest snag (r=0.383) and tree (r=0.427). Correlations were significant at the 0.05 level for crown closure (% layer A; r=-0.277); shrub cover (%B1 r=0.245; %B2 r=0.363), and the density of snags >75cm dbh (r=0.259) and trees >75cm dbh (r=0.303).

Although significantly correlated with measured mean ages and crown closure, lichen abundance in both the Wet and Mesic groups was NOT correlated with estimated Forest Cover age classes or with the crown closure class codes from inventory maps (see Apps et. al. 2001). Amongst Wet sites, lichen abundance was NOT correlated with PCA_1 (r=0.211; p>0.149) nor was it correlated with the primary variables defining PCA_1 – density of trees >100cm dbh and the largest tree on a plot. While arboreal cyanolichens are clearly linked to ancient forests (Goward and Arsenault 2000), which correspond to the Very High structure plots in this study, hair lichens are not always a good indicator of ‘old-growthness’. High hair lichen will be found in younger, nutrient poor sites and very old open sites (Goward pers. comm.).

Old Growth Management Area selection and harvesting retention strategies designed to maintain caribou food sources might be compatible with retention of other biodiversity values associated with old-growth

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[11] Lichen loadings were ‘Low’ (2) in the remaining 14 plots.

forests on *Mesic* sites. However, Wet sites with Very High old-growth structure are not correlated with lichen or falsebox abundance. Conservation of these globally rare and endangered forests (Goward and Arsenault 2000) must be addressed separate from the mountain caribou context.

6.0 Discussion

6.1 An Index of Old-Growthness

An index of old-growthness was created for Wet and Mesic sites in the ICHwk1. The indices are derived from the Principal Components Analysis of stand level structural attributes and can be used in a scorecard to rank potential old growth stands. Thresholds between levels of ‘old-growthness’ are provided for a range of attributes and scorecards are presented for Wet (site series 05 and 06) and Mesic (site series 01 and 04; Braumandl and Curran 1992) sites. In order to minimize potential overlap between structural value groups, thresholds for the index of old-growthness were calculated by using the midpoint between the mean of each group plus or minus its standard error of the mean. Attributes were not included in the index of old-growthness when a) there was an overlap between group means, plus or minus one standard error, b) where there was no biologically meaningful correlation between a variable and age, or c) when the attribute followed an inverted-u or u-shaped development curve.

The scorecards for old-growthness are a tool for managers to use in systematically evaluating stand-level structural attributes associated with old-growth forests. The use of multiple attributes ensures that stands are evaluated using suites of variables and are not rejected as ‘old growth’ on the basis of any single parameter. Threshold values are presented in Table 6 and Table 7. Refer to Table 3 and Table 5 for minimum and maximum values for each attribute.

Table 6. Thresholds for old-growthness on Wet sites.

Structural Attribute	Low Structure		**Threshold for High Structure**		High Structure		**Threshold for Very High Structure**		Very High Structure	
	Mean	SE			Mean	SE			Mean	SE
Mean Stand Age	110	10	>	**243**	380	13	>	**408**	443	19
Trees17.5-30 (sph)	200	60	<	**109**	66	13	<	**40**	21	5
Trees30-50 (sph)	220	38	<	**123**	54	10		**N/A**	40	9
Trees50-75 (sph)	101	21	<	**72**	60	5	<	**47**	36	3
Trees>100 (sph)	6	4	>	**13**	19	3	>	**35**	52	5
Number of Trees>75cm with Dead or Broken Tops (sph)	3	2	>	**9**	17	3	>	**31**	45	5
Largest Tree (cm)	97	7	>	**111**	124	6	>	**150**	176	6
Largest Snag (cm)	60	13	>	**81**	93	4	>	**103**	115	6
Snags_17.5-30 (sph)	65	13	<	**36**	15	5	<	**6**	1	1
Snags_30-50 (sph)	30	9	<	**21**	18	5	<	**9**	4	2
Snags_75-100 (sph)	3	2	>	**6**	7	1		**N/A**	8	2
Snags_100 (sph)	0	0		**N/A**	3	1	>	**5**	7	1
Average Canopy Lichen Loading**	1.3	0.2	>	**1.9**	2.5	0.2		**N/A**	2.8	0.3
%cover layer A: trees >10m tall	39	5	<	**30**	24	2	<	**19**	15	1

** Based on visual assessments of hair lichens in the canopy (0 = no lichen; 5 = very high lichen) - modified from Armleder et al. (1992).

Thresholds are not provided for percent cover of shrubs, herbs and mosses because where differences between groups existed, they were too small to accurately distinguish in the field. For the Wet group of plots, no values are presented for density of trees 75-100cm dbh because values were lower in the Low and Very High structure groups, and higher for High structure sites. On Mesic sites, thresholds are not provided for densities of seedlings (<1.3m), trees <17.5cm dbh or for trees 50-75 cm dbh because peak values were observed in the Moderate structure group. CWD volume followed a u-shaped pattern on both Wet and Mesic sites (as expected from literature MoF 1998).

The scorecards developed in this report can be used to assess *Wet* or *Mesic* stands in the ICHwk1 to rank candidate old-growth stands on the basis of structural attributes, and to evaluate where individual stands fit within the range of natural variation. If extrapolating these data to other subzones or site types beware that although patterns may (or may not) be similar, the thresholds themselves are expected to be different, and attribute cut-offs may themselves be very different.

The thresholds developed here relate to assessing the stand level values of a particular area of potential old growth forest. However, when applied, scorecards should also contain information regarding the landscape context in order for a full assessment to be made. Additional considerations include: high use caribou areas, the size of the patch, position in relation to other OGMAs within the landscape unit and with adjacent landscape units, general 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, powerlines or housing), and other special management zone or biodiversity values in the landscape.

Table 7. Thresholds for old-growthness on Mesic sites.

Structural Attribute	Low Structural Value		Threshold for Moderate Structure		Moderate Structural Value		Threshold for High Structure		High Structural Value	
	Mean	SE			Mean	SE			Mean	SE
Mean Stand Age	124	14	>	**198**	275	18	>	**322**	368	16
Trees17.5-30 (sph)	202	18	<	**187**	163	27	<	**139**	123	19
Trees30-50 (sph)	217	28	<	**189**	172	19	<	**126**	89	11
Trees75-100 (sph)	1	1	>	**4**	9	2	>	**19**	31	3
Trees>100 (sph)	0	0	>	**0**	1	0	>	**3**	7	2
Number of Trees>75cm with Dead or Broken Tops (sph)	0	0	>	**0**	2	1	>	**10**	19	3
Number of Trees>75cm dbh with Pathogen Indicators (sph)	0	0	>	**2**	4	1	>	**10**	16	2
Largest Tree (cm)	69	3	>	**77**	85	3	>	**96**	108	4
Largest Snag (cm)	64	6	>	**N/A**	67	3	>	**78**	88	3
Snags 17.5-30 (sph)	65	16	<	**31**	10	4	<		10	4
Snags 30-50 (sph)	60	8	<	**35**	15	4	<	**12**	8	4
Snags 75-100 (sph)	2	1	>	**3**	4	1	>	**6**	8	1
Average Canopy Lichen Loading**	1.6	0.2	>	**1.9**	2.2	0.2	>	**2.7**	3.3	0.2
%cover Layer B2: shrubs and trees <2m	9	2	>	**12**	18	3	>	**N/A**	18	2
Largest CWD piece (diameter in cm)	48	2	>	**N/A**	48	2	>	**55**	64	3
Number of CWD pieces per hectare	483	41	<	**443**	387	58	<	**323**	293	23
Volume of CWD pieces >50cm diameter (per hectare)	41	17	>	**N/A**	40	12	>	**120**	225	37

** Based on visual assessments of hair lichens in the canopy (0 = no lichen; 5 = very high lichen) - modified from Armleder et al. (1992).

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 presented in the scorecard using a minimum of three nested plots per stand (main plot - 0.04ha (11.28m radius) and large plot - 0.2ha (25.23m radius) for trees and snags >50cm dbh). At each plot, select a random bearing and run two 24m coarse woody debris transects at 90 degrees to one another. Note intersections of pieces of CWD with a diameter >20cm and the largest diameter encountered. Compile CWD and age data.
3. Fill in the scorecard (see Figure 10 or Figure 11 for an example) with data from the stand. Tick the appropriate box depending on whether the measured data are greater or less than the threshold.
4. Identify the number of attributes that meet each of the target thresholds. Multiply the score for 'High structure' on Wet sites or 'Moderate structure' in Mesic stands by 2 to weight attributes. Multiply scores for the 'Very High' and 'High' structure groups in Wet and Mesic sites, respectively, by 3.
5. Compare with other stands, including the costs and benefits of landscape level parameters.

ICHwk1 – Wet Stands (Site Series 05-06)

Site Series________ Slope________Aspect ________ Elevation ________ Size (ha) _________

Stand Name _______________ Polygon ______ Map Sheet _________ FC Age _____________

Structural Attribute	Measured Value	Threshold for Moderate Structure	Threshold for High Structure	Score = 0 for Low; 1 for High; 2 for Very High
Mean Stand Age		>243	>408	
Trees17.5-30		<109	<40	
Trees30-50		<123	N/A	
Trees50-75		<72	<47	
Trees>100		>13	>35	
DT_75+		>9	>31	
Largest Tree		>111	>150	
Largest Snag		>81	>103	
Snags_17.5-30		<36	<6	
Snags_30-50		<21	<9	
Snags_75-100		>6	>N/A	
Snags_100		N/A	>5	
Average Canopy Lichen Loading		>1.9	N/A	
%cover layer A:>10m		<30	<19	

Sum:

Landscape Considerations/ notes

Figure 10. An example scorecard for old-growthness on Wet Sites in the ICHwk1.

For example, if measured value for ‘largest snag’ is 92cm, dbh – stand receives a ‘2’ in the last column, because the value is in the moderate structure class (i.e. greater than the threshold for moderate, but lower than threshold for high). Totaling up the last column will provide an overall ranking for the stand.

ICHwk1 – Mesic Stands (Site Series 01-04)

Site Series________ Slope_________Aspect _________ Elevation _________ Size (ha) __________

Stand Name ________________ Polygon ______ Map Sheet __________ FC Age ______________

Structural Attribute	Measured Value	Threshold for Moderate Structure	Threshold for High Structure	Score = 0 for Low; 1 for Moderate; 2 for High
Mean Stand Age		>198 years	>322 years	
Trees17.5-30		<187 sph	<139 sph	
Trees30-50		<189 sph	<126 sph	
Trees75-100		>4 sph	>19 sph	
Trees>100		N/A	>3 sph	
Number of Trees>75cm with dead or broken tops		N/A	>10 sph	
Number of Trees>75cm dbh with pathogen indicators		>2 sph	>10 sph	
Largest Tree		>77 cm	>96 cm	
Largest Snag		N/A	>78 cm	
Snags 17.5-30		<31 sph	N/A	
Snags 30-50		<35 sph	<12 sph	
Snags 75-100		>3 sph	>6 sph	
Average Canopy Lichen Loading		>1.9	>2.7	
%cover Layer B2:<2m (shrubs)		>12%	N/A	
Largest CWD piece		N/A	>55 cm	
CWD SPH		<443 sph	<323 sph	
CWD Volume >50cm diameter		N/A	>120 m^3	
				Sum:
Landscape Considerations/ notes				

Figure 11. An example scorecard for old-growthness on Mesic Sites in the ICHwk1.

6.2 Natural disturbance patterns

The Biodiversity Guidebook classifies the ICHwk1 as Natural Disturbance Type 1 (NDT1) where stand-initiating events are rare and forest ecosystems were historically uneven-aged or multi-storied even-aged (Ministry of Environment and Ministry of Forests 1995). The ICHwk1 has a cool wet climate that is not conducive to large-scale natural fires. Although fire return intervals have not been reported for the wet ICH, data from preliminary studies suggests that several centuries may separate stand-replacing events (Arsenault, pers. comm. 2002). The oldest stands in this study had average ages of at least 500-600 years and potentially older[12]. Individual trees were estimated to be as old as 900 to 1000 years, which is consistent with other data collected in the ICHwk1 (A. Arsenault, pers. comm. 2002). These are likely ‘antique’ forests that have “escaped catastrophic disturbance for a period longer than the age of the oldest living trees within the forest” (Arsenault and Goward 2000). Antique stands in this study were generally found on wet sites located on benches, lower toe slopes and in gullies. Arsenault and Goward (2000) reported similar locations for antique stands. Fires are especially rare on these highly productive wet sites due to low fine fuel loading and moisture conditions. Wet sites sampled had high coverage of devils club (*Oplopanax horridus*) and, by definition, do not experience any periods of water deficit throughout the year (Klinka et al. 1989).

If forest management is to mimic natural disturbance, the patterns outlined here can help guide the scale of harvesting activities. Although large stand-replacing fires are rare across most of the ICHwk1, wind, insects, avalanches, and landslides shape stands at smaller scales. Windthrow, on the scale of one or a few trees, was very common in the stands sampled. We also encountered evidence (both recent and historic) of small-scale rock movement and debris flows. Stand replacing wind damage and soil slumping are rare in wet ICH subzones (Hoggett 2001). Instead, these disturbances contribute to gap or small patch replacement.

The western hemlock looper (WHL; *Lambdina fiscellaria lugubrosa* (Hulst)) has defoliated and killed substantial forested areas in the Columbia Mountains and surrounding regions since before European settlement (Hoggett 2002). Detailed studies of WHL defoliation in the Robson Valley concluded that stand modifying disturbances are significantly more common than stand replacing disturbances (Hoggett 2001). Within outbreak areas, Hogget (2001, 2002) found that hemlock and subalpine fir are more prone to mortality from WHL than cedar or spruce and that smaller trees are killed during outbreaks more often than larger trees. In his study area, trees greater than 50cm dbh experienced the lowest mortality, while the smallest diameter classes (10-29.9cm dbh) had the highest mortality (Hoggett 2001). The higher resilience of cedar often maintains a live canopy influence during periods of re-establishment, but after severe defoliations, some stands may experience a period of non-tree dominance in the understory.

6.3 Regeneration

Seedling distribution within our plots was non-random with a considerable majority of regeneration found on decayed CWD. There were no patterns between seedling density and stand age, CWD volume, CWD by decay class, or old-growthness. In the ICHwk1, understory growth rates are high on most sites and brush control is listed as a post-harvest concern (Braumandl and Curran 1992). Regeneration is particularly limited on wet sites where seasonal surface water and high cover of ferns and devil’s club leave little room for seedling establishment except on elevated microsites. Although we did not measure the distribution, seedlings on the forest floor were rare on both Wet and Mesic sites. Regeneration on nurse logs was very prolific and dominant and codominant trees often showed evidence of establishment on nurse logs (CWD).

Seedling and sapling release within canopy gaps appears to be the dominant regeneration mode in the absence of large-scale disturbance. The dominant species in the ICHwk1 are cedar, hemlock, and to a lesser extent, spruce, Douglas-fir and western white pine. Studies in the ICH in the Prince George Forest Region show that cedar and hemlock are very shade tolerant and can survive in a slow growing state for long periods before an opportunity to release arises (Wright et al. 2000).

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[12] Due to the high incidence of internal decay in large-diameter cedar and hemlock, it is not possible to determine actual tree ages. Estimates were derived using very conservative extrapolation techniques. Stand ages could be greater than 850 years based on less conservative estimates.

6.4 Forest Cover data

The Forest Cover inventory data were only able to correctly identify age classes 53% of the time. Misclassified stands were generally labeled age class 8 on Forest Cover maps. Tree ring data suggested that three stands labeled age class 8 on Forest Cover maps were actually younger than the map estimates, while 12 were older (see Figure 2). In the ICHwk3 in the Robson Valley, Harrison and DeLong (2000) found a similar trend towards under-estimating the age of age class 8 stands. Four of 15 stands in their sample were classed as age class 8 on maps, but were 9 on the ground. However, when age class 8 polygons were *over*-estimated on Forest Cover maps in our study, it was by as much as three age classes (and stands were really as young as 80-100 years old). The level of inaccuracy is unsurprising given that ages are generally from air-photo interpretations.

Even when age classes are correctly identified on Forest Cover maps, the Forest Cover *system* of age classes does not account for the full range of ages present in the ICHwk1. The mean age of stands in this study ranged from 81 to at least 610 years old. Forest cover age class 9 includes all stands over 250 years old and encompasses 31 of 38 stands sampled in this project. The broad scale of the Forest Cover classification system does not accurately account for very old forests (i.e. >400 years old). Forest Cover data does include estimated actual ages of polygons[13] (in addition to Forest Cover age classes), however, in this study they were no more accurate than Forest Cover age classes. We used estimated ages in the Revelstoke TSA, but data were not available for the TFLs, the Golden TSA, Arrow District, or Revelstoke National Park. Seventeen out of 38 of the stands we sampled had detailed Forest Cover age estimates. Nine of these stands were age class 9 and Forest Cover ages were under-estimated on 7 (78%; i.e. stand age was estimated as 305 years, but tree ring data suggested a minimum age of 450). Five of eight age class 8 stands with age estimates were under-estimated. There were no apparent patterns between estimated age and old-growthness.

Although many age class 8 stands are actually older than mapped, this does not indicate that structural attributes will be the same in all age class 8 and 9 stands. Using Forest Cover data to locate old growth stands will NOT differentiate between old and antique or between high and low structure old-growth stands.

6.5 Comparisons with other studies

Harrison and DeLong sampled stands in the ICHwk3 in the Robson Valley in a study designed to describe old-growth characteristics and to determine whether there are differences between age class 8 and 9 stands[14]. Although they used Principal Components Analysis, the list of input variables was based on a 'best-fit model' developed from a Discriminant Function Analysis that was designed to identify variables that best distinguish between age class 8 and 9 stands. The final set of attributes used included: live tree basal area, number of trees with cracks, loose or deeply furrowed bark, total number of trees with pathogens, number of trees with cavities, number of stubs (short snags), height of gold dust lichen, number of CWD pieces in decay classes 1-3, number of trees >50cm dbh and density of trees >75cm dbh. The discriminant functions produced are presented in Appendix B. Their PCA analysis led to the development of thresholds for old-growthness, however, there are no stratifications into moisture class or site series. Comparisons with our data must acknowledge that we found differences between thresholds for Mesic and Wet groups, particularly for the number of large trees (>75cm dbh).

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[13] There are estimates of the actual age for each polygon in the Forest Cover Inventory data, projected to 2001. These ages are photo-interpreted and, in younger age classes, would be used to determine when a stand has 'grown' into the next age class (i.e. the stand was estimated to be 98 years old (age class 5) at the time of air photo interpretation, and 35 years later it would have 'grown' to be 133 years old (age class 7). These estimates also exist for age class 9 stands, but were not accurate when compared to tree ring data.

[14] Age classes in Harrison and DeLong (2001) are based on ages from tree ring data, not Forest Cover maps.

Table 8. A comparison of thresholds and means for ‘old-growthness’ from other studies relevant to the ICHwk1. Thresholds are presented with means in brackets.

Study	BEC Variant / Site Series or Group	Structural Attribute Category	Sample Size	Mean Age	Density of Trees >50cm[a] dbh	Density of Trees >75cm[a] dbh	Total Number of Live Trees[c]
ICHwk1 WET Sites							
Current Study	ICHwk1 Wet Sites (05/06)	Very High	23 plots	443 (408)	N/A (112)	72 (75)	N/A (214)
		High	21 plots	380 (243)	N/A (120)	42 (60)	N/A (300)
Quesnel 1996	ICHwk1 05	Old Growth	12	163 (170)	145 (167)		276 (312)
	ICHwk1 06	Old Growth	2	173 (182)	N/A (60)		217 (361)
ICHwk1 MESIC Sites							
Current Study	ICHwk1 Mesic – subxeric (01/04)	High	31	322 (368)	99 (105)	23 (38)	N/A (427)
		Moderate	18	198 (275)	70 (90)	5 (9)	N/A (537)
Quesnel 1996	ICHwk1 01	Old Growth	15	171 (178)	128 (138)		521 (661)
	ICHkw1 04	Old Growth	18	171 (181)	98 (112)		552 (735)
ICHwk1 Sites – no differentiation by site type							
Harrison and Delong 2001	ICHwk3	Old Growth	45 plots		132[b]	39[b]	
McLellan and Terry (unpublished)	ICH mw3, wk1, vk	Stands used by mountain caribou			(83)		(503)

a. **Thresholds** for these diameter classes are presented for comparison purposes with mean values in brackets. The diameter classes reported in the index of old-growthness are preferable and are based on size classes with more discriminatory power.

b. No mean values are presented in this study.

c. Minimum tree size is 7.5cm dbh in Quesnel (1996), 7cm dbh in McLellan and Terry (unpublished), 10cm dbh in Hoggett 2002, and 12.5cm in the current study.

Principal Components Analysis in our study resulted in clearer splits in the data and higher percentages of variation explained if several diameter classes were used to summarize large trees. In both the Wet and Mesic analyses, we used densities of trees 50-75cm, 75-100cm and >100cm. On Wet sites, adding a fourth diameter class for trees >150cm may have improved the analysis because many sites had more trees >100cm dbh than any other class (except trees <12.5cm dbh). Alternatively, trees >100cm dbh were relatively rare on Mesic sites. Comparisons with other studies are difficult because most authors do not report densities for size classes with a minimum diameter greater than 50cm or 75 cm dbh. We found that the number of trees 50-75cm dbh peaked in Moderate structure plots on Mesic sites while densities of trees 75-100 cm dbh were highest on High structure plots on Wet sites (Table 3 and Table 5). Conversely, densities of trees 50-75cm dbh declined on Wet sites with increasing old-growthness and were negatively correlated with the number of trees >100cm dbh. Comparisons with Quesnel’s data are particularly inappropriate for Wet sites because all trees >50cm dbh are combined. Studies of old growth in wet variants of the ICH must include larger diameter classes.

Harrison and DeLong (2001) used >50cm and >75cm diameter classes and found increasing densities of both with age. We could not create thresholds for all trees >50cm dbh on Wet sites due to overlapping means and standard errors between groups. However, comparisons with Harrison and DeLong show that our thresholds for trees >75cm dbh are higher for Wet sites and lower for Mesic sites (based on the mean and SE from Table 3 and Table 5). Sites sampled by McLellan and Terry in the ICHmw3, wk1 and vk are likely more akin to our Mesic plots, although note the range in BEC units. The average value they present for tree density >50cm dbh is between our thresholds for the Moderate and High structure groups in our study.

Although mean values are not presented, Hoggett (1998 and 2002) found reverse-J curve diameter distributions for old growth stands on mesic to sub-mesic sites in the ICHwk3 in the Robson Valley. As in our study, that project found an increase in the relative abundance of western red cedar in increasing diameter classes (see Appendix C). Mesic stands were dominated by western red cedar with hemlock and subalpine fir as secondary species. Our mesic sites generally had higher numbers of western hemlock than cedar at all but the largest diameter class (see Appendix C). Hoggett (2002) found 63 snags per hectare <30cm dbh and 20 larger snags (>30cm dbh). The density of small snags corresponds to Low structure Mesic plots; the measure of larger snags is not comparable considering the range of size classes in our study. CWD volumes of 501 m^3/ha were reported in Hoggett (2002), which is comparable to High structural value Mesic sites and all Wet sites in our study (Table 3 and Table 5).

6.6 Past development in the ICHwk1

Forestry is the dominant extractive resource use in the ICHwk1 and most harvesting has occurred in the past 30 years (Stevenson et al. 2001, Waters and Delong 2001). The natural age class distribution for this ecosystem (before human intervention) was heavily skewed towards older stands. We used the current age class distribution in Table 9 to estimate the percentage of the landbase that would have been old growth in the absence of harvesting. Under 'natural' conditions (i.e. pre-logging), the rate of stand replacing disturbance should be relatively similar during the past 20 years as compared to previous 20-year periods. Thus, in the absence of harvesting, the distribution of age classes 1 through 7 should be *relatively* equal across the TSAs[15]. Using the numbers in Table 9, each of the age classes from 2 through 7 contains, on average, approximately 5% of the total landbase. However, due to harvesting, age class 1 currently contains approximately 30% of the TSA. If these lands had not been logged and were still age class 8 or 9, the percentage of forested lands in age class 8 and 9 (combined) would be approximately 67% across both TSAs and 60% in the Revelstoke TSA (see Table 9)[16]. These percentages are similar to those predicted using the exponential equation[17] from the Biodiversity Guidebook. Predicted percent of old forest is 54% - 61% assuming age of old = 250 years, and stand replacing disturbance rate of 400 or 500 years respectively.

Extensive harvesting has shifted the age class distribution from 2/3 of the total forested landbase as age class 8 and 9 to 1/3 of the landbase in age class 1 (0-20 years old), 1/3 in age classes 2-7 (21-140 years old) and 1/3 in age classes 8-9 (>140 years old; Table 9; note: numbers are similar to the total landbase for operable and inoperable lands[18]). When the tendency towards under-estimating age class 8 stands is factored in (see above), it is likely that, in the absence of forest management, most of the landbase would consist of stands greater than 250 years old.

Undocumented harvesting has also occurred throughout the ICHwk1. We found evidence of past logging on 11 of 38 sites not shown on Forest Cover maps. Impacts ranged from pole-sized cedar stumps to the remains of shake blocks and even old 'cat' trails. Plots were located away from stumps where possible and six stands were abandoned completely because past harvesting had significantly altered stand

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[15] Natural and human-caused fires have contributed to the development of age class 1 stands (V. Beard, pers. comm. 2002), although harvesting has impacted a larger area.

[16] We have essentially, 'stood' the harvested stands 'back up' to recalculate age class distributions. These figures do not include TFL and private lands.

[17] See Appendix 4 Biodiversity Guidebook

[18] The high percentage of age class 1 stands in the inoperable is due to recent changes to the operability lines that considerably reduced the operable area.

structures. Structural attribute assessments of potential Old Growth Management Areas are particularly important considering that this information is not present in the Forest Cover Inventory.

Timber extraction is not the only activity to heavily impact ICHwk1 forests. Hydroelectric development between the 1960s and 1980s flooded considerable low elevation areas throughout the Columbia River valley and around the Duncan Reservoir. Many high quality old growth stands were flooded during this period (G. Utzig, pers. comm.). In this study, most very old wet stands were located on benches both within and separate from flooded valleys and zones adjacent to the reservoirs tended to be steep (>60% slopes).

Table 9. Current age class distribution for forested stands in the Revelstoke and Golden Timber Supply Areas.

	Age Class 1	Age Class 2	Age Class 3	Age Class 4	Age Class 5	Age Class 6	Age Class 7	Age Class 8	Age Class 9
Revelstoke TSA and Golden TSA – Combined									
Total	29.1	7.9	2.9	5.8	5.3	4.0	3.1	19.9	22.1
Operable	29.8	10.5	2.5	4.9	4.4	3.2	3.3	18.4	23.0
Inoperable	28.1	4.3	3.4	7.1	6.4	5.0	2.7	22.0	20.9
Revelstoke TSA									
Total	33.6	8.7	5.0	7.3	8.1	4.5	2.0	15.5	15.4
Operable	28.3	13.4	4.7	5.0	7.2	4.5	2.0	16.3	18.5
Inoperable	40.0	2.9	5.4	10.1	9.1	4.4	1.8	14.5	11.6

** Based on the 2000 Forest Inventory with stand ages projected to 2001.

7 Biodiversity values in the ICHwk1

Old growth planning in the ICHwk1 is driven by mountain caribou early winter habitat needs (MAC Plan 1999). Studies in the Columbia Mountains have found that mountain caribou select stands with gentle terrain, high productivity, and high canopy cover during early winter. Finer-scale preferences have been shown for hemlock and cedar stands and southerly aspects (Apps et al. 2001). We found significant correlations between lichen loading and old-growthness ($r=0.672$; $p<0.01$) and lichen and mean stand age ($r=0.499$; $p<0.01$) on our Mesic sites, which indicates that retention of caribou habitat and other stand structural values are compatible on these site types. In their caribou tracking study, McLellan and Terry collected stand-level data at foraging areas. Although the range of variation in attributes is not shown, comparisons between their data and mean values for tree densities on Mesic sites suggests that our Moderate and High structure groups are consistent with caribou habitat requirements.

McLellan and Terry (unpublished) developed recommendations for caribou habitat that include maintaining a multi-storied canopy with a large range of tree species, ages and sizes and a reverse-J shaped diameter distribution. They suggest managing young forests to obtain approximately 300 sph by the time the stand reaches 140 years old. Retention strategies include maintaining a minimum 30 snags per hectare with 10/ha over 50cm dbh, a diverse understory including falsebox for caribou forage, and heavy hair lichen loadings directly on retention trees, as litterfall or on wind blown trees.

Table 10. Average caribou habitat variables in comparison to structural attribute groups on Mesic sites.

	McLellan and Terry	Low Structure - Mesic	Moderate Structure - Mesic	High Structure - Mesic
Live tree density >7cm dbh[a]	503	468	425	317
Snag density	97	139	43	45
%Western hemlock	44	78	86	88
%Western red cedar	25	16	13	12
%Other	26	6	1	0
%Slope	35	41	48	50
Total stems >19cm dbh	319	421	355	254
Total stems >50cm dbh	102	64	108	132
Trees >19cm dbh	272	283	312	208
Trees >50cm dbh	83	50	90	105
Snags >19cm dbh	47	139	43	45
Snags >50cm dbh	19	14	18	27

*Data from McLellan and Terry are from ICH mw3, wk1 and vk stands.
a. Minimum tree size for the present study is 12.5cm dbh.

Under current guidelines, 30% of the operable landbase in the ICH is to be retained as age class 8 and 10% as age class 9 for mountain caribou (MAC Plan 1999). From our analysis, old growth forests in the ICHwk1 are generally much older than 250 years. On Wet sites, average ages of Very High structural value stands are 443 years and 380 years on High structural value stands. On Mesic sites, High structure stands had a mean age of 368 while Moderate structure stands were, on average, 275 years old. The average ages presented in this report are based on very conservative methodologies. Regardless, natural disturbance patterns have created a landscape that is historically dominated by stands older than 250 years (see Table 9 and associated discussion). The guidelines for caribou habitat retention significantly deviate from the natural age class distribution across the landscape and are likely to have a considerable risk to biodiversity if they are not implemented in such a way to as to maintain sufficient stands with a range of ‘old-growthness’.

Old-growth forests provide unique habitats for a range of species in addition to caribou. It is on the wet sites where the very large cedar trees associated with antique forests and rare cyanolichens are found. Our assessment of old growth in the ICHwk1 suggests that antique stands overlap considerably with the Very High structural value group produced from PCA. Much like the mountain caribou, these forests are considered highly endangered (see Introduction) and should be considered in old growth management strategies.

6.8 Management Recommendations

We recommend using the indices of old-growthness produced in this report to evaluate and select old growth retention zones in Wet and Mesic stands in the ICHwk1. Very clear differences were found between structural attributes on higher and lower quality old-growth sites and between Wet and Mesic site series groups. Higher quality (structural value) old growth stands had more large trees and snags with larger overall diameters and Wet stands had larger structures than Mesic sites. Although most age class 8 stands (based on Forest Cover maps) were actually age class 9 on the ground, trade-offs should not be made between potential sites without an evaluation of the stand structural attributes. *From a biodiversity perspective, most 200 year-old stands will not provide the same values as a 500 year-old stand.* Planning for old growth retention across the landscape must have a basis in stand structure and must include high structure old-growth forests (as defined in the Index of Old-Growthness presented above).

The MAC plan requires that 40% of the operable landbase, within defined caribou management zones[19], be maintained in the ICH as age class 8 or older with one quarter of this area in age class 9 (MAC Plan 1999). Harvesting is not permitted in these zones. Regardless of the percentage retained as old and mature forest, management activities on the remainder of the operable landbase have a higher probability of maintaining mountain caribou and other biodiversity elements if "managed forests are made to resemble those forests created by the activities of natural disturbance agents such as fire, wind, insects, and disease" (B.C. Ministries of Forests and Environment, Lands and Parks 1995). Within the ICHwk1, natural disturbance agents work at fine scales with small areas affected by single disturbances.

Immature and early mature stands

Mountain caribou depend on old growth forests for their survival and avoid immature and early mature stands because they lack suitable forage and provide habitat for moose, deer and associated predators (Waters and Delong 2001). At a landscape scale, younger, dense stands create barriers to mountain caribou movement and increases in immature forests in the Wells Grey area have been linked to declines in the local mountain caribou population (Kinley and Apps 1999). Most harvesting in the Revelstoke TSA has occurred in recent decades. As these stands reach the dense stem exclusion stage of stand development (Oliver and Larson 1996), they will become an increased obstacle to mountain caribou movement between remaining old growth areas (Waters and Delong 2001).

Immature managed stands have also been shown to reduce habitat for species other than caribou. A study of small mammals in the Pacific Northwest found that although species composition was similar between managed, naturally young, and old-growth forests, old growth supports 1.5 times more individuals and biomass than managed forests (Carey and Johnson 1995). Immature stands on southwestern Vancouver Island had considerably lower understory plant diversity when compared to old growth (Qian et al. 1997). The decline in plant diversity was attributed to the lack of old-growth structural features in immature stands. Size of old-growth retention areas can also impact biodiversity. A study of bird distribution in various sized old growth patches in northern Sweden found that small fragments (<5ha) only provide habitat for generalist species, while larger patches (>10ha) have more rare species (Edenius and Sjoberg 1997). Because old forests are the norm in the ICHwk1, maintaining more of the landscape in a state that is (or closely resembles) old growth will decrease the risk to biodiversity.

Where immature forest plantations exist, restoration may be required. In a study of silviculture treatments to recruit caribou habitat, Waters and Delong (2001) recommended pre-commercial and commercial thinning to accelerate the development of potentially suitable habitat (Figure 12). Thinning will maintain large crown ratios and rapid growth rates, increase within-stand sight lines for caribou, and potentially reduce habitat connectivity problems. Where Armillaria is a concern, planting at wider spacings and lowered stocking levels may reduce the number of thinning entries required while maintaining other objectives. It was suggested that xeric to mesic sites could be prioritized for restoration activities because of falsebox and lichen ecology. However, note that Waters and Delong (1997) conclude that it is more efficient and cost-effective to use partial cutting (in areas outside of old growth retention zones) than to clearcut and attempt rehabilitation.

Stand Management Strategies for Immature Stands (From Waters and Delong 2001)

1. Conserve large tree legacies at harvest (snags, live trees, coarse woody debris)
2. Minimize site preparation, plant widely spaced trees (400-500 sph) and allow natural regeneration of western hemlock, western red cedar and deciduous trees.
3. Create snags.
4. Use pre-commercial thinnings to bypass the competitive exclusion stage. Early thinnings are preferred (<40 years).

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[19] These zones are based on radio-collar locations of mountain caribou and reflect where the caribou are *now*, and not their historic range (Waters and Delong 2001).

5. Use a combination of pre-commercial thinnings and commercial thinnings.
6. Create heterogeneity with less uniform spacing (use a range of densities on the landscape).
7. Favour shade tolerant advanced regeneration.

Figure 12. Recommendations for restoration of caribou habitat on immature sites.

Harvesting in mature and old forest

Within the ICH, harvesting is not permitted within old growth retention areas (MAC Plan 1999). Where harvesting is to occur outside of these areas, partial cutting with long cutting cycles (80 years between entries) should be considered. Partial cutting has been recommended for maintaining forests in a state that more closely follows natural processes and is suitable for caribou use continuously through time (Stevenson et al. 2001). Several recommendations have been put forth outlining specific strategies and rationales for partial cutting in mountain caribou habitat (Stevenson 1986, Hamilton 1997, Stevenson et al. 2001, Waters and Delong 2001). Studies of western hemlock looper and its influence on stand dynamics have also resulted in recommendations for partial-cutting and variable retention silviculture as a means of conducting ecosystem management (Hoggett 2000). Despite these suggestions, very little partial cutting is occurring in the ICHwk1 in the Arrow and Columbia Forest Districts.

Most experience with partial cutting in the interior wet belt has occurred in the ESSF. There is some history of partial cutting in the ICH, but operational experience is limited. When utilization standards changed and processing capacity increased in the 1960s, most partial cutting was abandoned in favour of the more economical practice of clearcut logging (Stevenson et al. 2001). Several on-going studies were established in the 1990s in the ICHwk1 and ICHwk3 to examine partial cutting and interim conclusions have resulted in favourable assessments. Increased windthrow was a considerable concern when projects were initiated, however, it is not as large of a problem as was forecast in the Date Creek study (Coates et al. 1997), at Fleet Creek (Jull et al. 1999) or at the Keystone (in the Revelstoke Community Forest) where there was no statistical difference between blowdown in partially cut and unmanaged stands (Waters and Quesnel 2001). Interim results from the Keystone site conclude that small patch cuts (1-2ha) do not result in increased windthrow, that windthrow varies from year to year and that dead trees are more susceptible to windthrow than live trees. In general windthrow increases when removal has been heavy (>50% by volume or basal area) or when openings exceed the length of two tree heights (Stevenson et al. 2001). Concern regarding increased damage and mortality from Armillaria has also been expressed. However, a study of two sites in the ICH (Ice Creek, ICHmw2; Mount Seven, ICHmk1) found that after three years, mortality and growth of seedlings were not affected in a shelterwood prescription with push-over logging (DeLong et al. 2000).

Other research into the success of partial cutting in the ICH has shown that planted seedlings of many conifer species are performing well in a variety of opening sizes. Rogers and Jull (2000) found no differences in 5-year survival and growth of planted cedar, spruce or Douglas-fir in 0.25ha openings in the ICHwk3. Based on studies in the ICHmc in the Date Creek project, tree species need to be carefully matched to the range of light levels found in partial cuts. For example, at low light levels (<40% full sunlight) cedar performed better than all other species sampled (including hemlock and subalpine fir; Coates and Burton 1999). A similar study in the ICHmw2 near Burton also found that cedar outperformed other species at low light levels, but height growth of all species was highest in areas that received the most light (DeLong et al. 2000). In the high light areas, birch (*Betula papyrifera* Marsh.) had the highest growth.

With shade tolerant species, Wright et al. (2000) found no effect from previous periods of suppression on growth rates when saplings were exposed to light. This means that under natural forest conditions, cedar, hemlock, and spruce, to a lesser extent, respond positively to openings in the canopy even after long periods of suppression and that suppression does not cause shade-tolerant species to lose their ability to respond to release following partial cutting (Wright et al. 2000). Concerns have been raised regarding the quality of advanced regeneration, but most of the cedar regeneration in a retrospective study in the Nelson Forest Region was from layering, was of ‘good form and vigour’, and released well after harvesting in the ICHwk1, ICHmw2 and ICHmw1 (DeLong 1997).

Public concern over ‘inland rainforests’ and the ‘endangered mountain caribou’ is likely to increase in coming years. Similar public pressure on the coast has already led to changes in silviculture practices (see below). Given that age class distributions within the ICHwk1 have already significantly deviated from historic patterns (see above), and that it is not clear whether old growth retention for mountain caribou will adequately address all biodiversity needs, some partial cutting (single tree and group selection) should be implemented ***outside*** the 40% old and mature retention areas in the ICH.

While operational experience is limited in the ICH, many of the elements of successful partial cutting prescriptions from the ESSF should apply to the ICH (Stevenson et al 2001). Table 11 provides a summary of partial cutting guidelines developed in the ESSF. The management objective for partial cuts should be to maintain most of the stand in a late seral state. This will involve long cutting cycles (re-entry only after 60-80 years) and low harvest removals (maximum 30%; Stevenson et al. 2001). Group selection has gained more favour in the ICH than single tree selection because of worker safety issues, ease of harvesting, and difficulties in regenerating mixed-species stands (Stevenson et al. 2001). However, many of the stands referred to as ‘group selection’ are technically small clearcuts or ‘patch cuts’. Smaller openings (i.e. one to two tree heights) are better for preserving the full range of biodiversity values and should be considered. Smaller openings may also facilitate maintenance of lichen. Waters and Quesnel (2001) found a significant inverse relationship between lichen establishment in patch cut openings and distance from mature forests. However, studies in Sweden found that old growth had six times more lichen mass than selectively harvested stands (Esseen and Renhorn 1996).

Table 11. Recommendations for partial cutting in ESSF(adapted from Stevenson et al. 2001)

Stand management goals: **To maintain a stand that is suitable for caribou use continuously through time.** **To maintain most of the stand in a late seral state.**	
Silviculture Systems	▪ Single tree and group selection with low removal (maximum 30% by area, volume or basal area including skid trails) and infrequent entries (e.g. every 80 years) ▪ Use designated skid trails to improve harvesting efficiency and reduce damage to residual trees.
	▪ On slopes <45%: use partial cutting by hand-felling and ground skidding or feller-bunchers.
	▪ On slopes >45%: use cable or helicopter selection harvesting. Strip selection is less preferable to single tree or group selection and poses higher risks to caribou.
Opening Sizes	▪ For group selection, openings should be 0.1ha to 1ha with a mean of 0.5ha or smaller. Varied sizes and shapes of openings are desirable. Smaller openings benefit a broader range of species.
Stand Structure	▪ Maintain the existing range of species and diameter classes found. Avoid highgrading and use a mixture of shorter- and longer-lived shade-tolerant conifer species.
Regeneration	▪ Retain advanced regeneration and residual trees where feasible.
	▪ Traditional stocking standards will likely need to be reduced to create more open (natural) stands. Increased or modified spacing is recommended for planted seedlings.
Rotations	▪ Rotations must be longer than conventionally expected to provide time for lichen levels to recover and for large stems to develop. 250-year rotations are recommended.

The studies referred to above involved patch cuts ranging in size from <1ha to 2 ha in size. Single tree selection was successfully applied within a second growth ICHwk1 stand in the Revelstoke Community Forest in the winter of 2000 (Waters 2001). Despite higher costs, the operation was profitable due to reduced stumpage, high value logs, and low pulp volumes. Although experience is very limited with single tree selection in the ICHwk1, similar prescriptions have been successfully implemented on comparable stands in coastal BC. . Single tree selection may also maintain habitat for many animals, especially if a variety of opening sizes were used at the small end of the range (<0.5ha), including very small openings (<0.1ha; Stevenson et al. 2001). All partial cutting prescriptions should retain large old trees, snags, wildlife trees, CWD and an intact forest floor and understory community. While group selection silviculture has met with success in the ICHwk1, a variety of options should be explored including single-tree selection, small group selection and commercial thinning. From a biodiversity and adaptive management perspective, it is better to implement a variety of management operations than to apply the same practices everywhere on the landscape.

Variable retention silviculture may be a desirable option for achieving ecosystem management in the ICH (Hoggett 2000). Variable retention was developed in the 1990s as an alternative to clearcutting (Franklin et al. 1997). Variable retention, or the 'retention silviculture system', is defined under the Forest Practices Code as "a silviculture system that is designed to

(a) retain individual trees or groups of trees to maintain structural diversity over the area of the cutblock for at least one rotation, and
(b) leave more than half the total area of the cutblock within one tree height from the base of a tree or group of trees, whether or not the tree or group of trees is inside the cutblock" (Forest Practices Code Operational Planning Regulations, March 1999).

Retention refers to both group and dispersed patterns.

The goals of variable retention are:

(a) To maintain 'lifeboats; for species and processes immediately after logging and before forest cover is re-established;
(b) To enrich re-established stands with structural features that would otherwise be absent;
(c) To enhance connectivity across the managed landscape (Franklin et al. 1997).

The expected outcomes involve leaving a biological legacy of older-forest attributes well distributed across the landscape to maintain biodiversity and to establish cutblocks that will be viewed by the public as an example of forest stewardship using a non-clearcut approach.

When first initiated in British Columbia by MacMillan Bloedel's Coastal Division, variable retention was met with considerable skepticism. Cost, terrain, worker safety and regeneration were all cited as reasons for imminent failure. MB, and later Weyerhaeuser, persevered and variable retention has been implemented within an adaptive management framework in their entire coastal division. Variable retention may be particularly applicable to stands in the wet and very wet ICH due to the similarities between inland 'wet belt' and coastal forests. Aggregated and dispersed retention both have potential value and utility in the ICHwk1 and would compliment partial cutting plans as recommended in the caribou management guidelines. Variable retention encompasses many partial cutting objectives, but differs in that long-term reserves are established as opposed to selection systems where harvesting cycles through a stand and, over the course of one rotation, removes the entire area (Franklin et al. 1997). The type of long-term reserves associated with variable retention silviculture may be necessary in the ICH since maintaining caribou habitat may be compromised by multiple harvesting passes (Waters and Quesnel 2001).

Using the range of natural variation (RONV)

The basic premise underlying RONV is that deviations from natural distributions will increase the risk to biodiversity. Although quantifying risk is beyond the scope of this project, larger deviations from natural ranges will result in risks to biological values (MoELP 2000.). If retention levels and harvesting patterns are intended to maintain biodiversity and functioning, representative old-growth into the future, they should be compatible with the range of natural variation. Management practices that deviate widely from RONV significantly increase the risk to biodiversity values. Age class distributions provide one example of the RONV concept: As discussed in relation to Table 9, age classes in the ICHwk1 were traditionally skewed towards older end of the range. Forest management that converts mature and old-growth forests to age class 1 plantations on a broad scale deviates from this distribution and does not fit within the range of natural variation.

The range of natural variation can also be applied to stand level variables. Figure 13 provides an example of the distribution of large trees (>100cm dbh) in High structural value Wet stands. Most High structure stands have the *average* density of approximately 20 stems per hectare. However, other stands are found at the extreme high and low end of the curve. Managing within the range of natural variation would mean ensuring that high numbers of large trees (50-60 stems per hectare) are maintained on some stands, while others would be left with fewer. Harvesting to result in low risk to ecological values should maintain the mean plus or minus the standard error for key attributes.

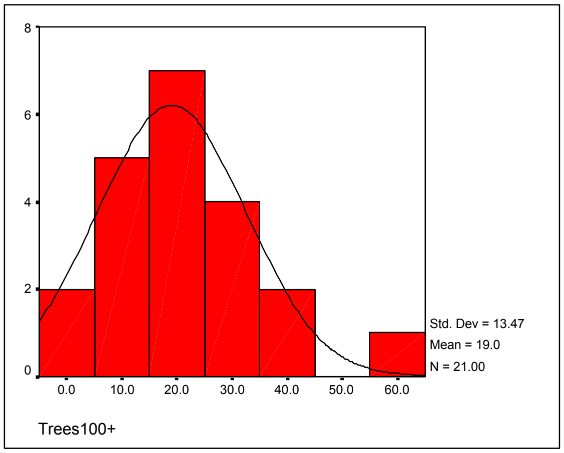

Figure 13. Distribution of trees>100cm dbh on High structure Wet sites as an example of RONV.

Using this framework, the ICHwk1 landscape is already quite significantly different than expected naturally. Prior to harvesting, age class 8 and 9 stands would have been expected to comprise 60-70% of the landscape, but currently occupy approximately one half of that area (see above). However, there remain significant opportunities to limit further deviation in future: partial cutting and variable retention silviculture can reduce the risks to biodiversity by creating stands and landscapes closer to the range of natural variability. These approaches can be successfully used to maintain old-growth attributes and caribou habitat in this exceptional landscape.

7.0 Conclusions

1. Old-growth forests in the ICHwk1 contain trees >200cm dbh and as old as 900-1000 years. Many stands, particularly those on benches, in gullies and on toe slopes, have avoided catastrophic disturbance for longer than the age of the oldest living trees in the stand. These ‘antique’ forests are important reservoirs for biodiversity.
2. Forest Cover inventory data does not provide adequate information for selecting old growth management areas. Forest Cover maps correctly classified the age class of 53% of the stands sampled. Stands labeled as age class 9 were always correctly classified, whereas stands labeled age class 8 were older in 71% of the stands sampled. Where stands labeled as age class 8 were actually younger, Forest Cover data over-estimated by as many as 3 age classes.
3. Indices of old-growthness were developed for Wet (subhygric/hygric) and Mesic (mesic and submesic) stands in the ICHwk1 using Principal Components Analysis. The indices are based on stand level structural attributes and use scorecards for ranking and evaluating the biodiversity value of old growth structure in individual stands.

4. The index of old-growthness produced for Wet stands uses three categories of old-growthness – Low, High and Very High structural value. Thresholds are provided for densities of trees and snags by size class, size of the largest trees and snags, stand age, and arboreal lichen abundance.
5. The index of old-growthness produced for Mesic stands includes Low, Moderate and High structural value old growth and includes thresholds for coarse woody debris as well as the attributes listed for Wet stands.
6. Old growthness was significantly correlated with stand age on both Wet and Mesic stands. Other research has concluded that rare cyanolichens, including those that are only found in the wet and very wet ICH variants, are associated with antique and not just old forests. Thus, 200 year old stands are not likely to contain the same biodiversity value as stands >400 years old.
7. Wet stands have larger structural attributes than Mesic stands. Very High structural value Wet stands are dominated by trees >100cm dbh and have an average of 52 stems per hectare in this size class. High structure Mesic stands have an average of 7 stems per hectare greater than 100cm dbh and 31 stems per hectare 75-100cm dbh. The difference between Wet and Mesic stands is substantial enough that management for old growth must conserve representative stands in both moisture groupings. Old growth management that does not include the High and Very High old-growth structure stands on Wet sites will increase the risk to biodiversity in the ICHwk1.
8. Both Wet and Mesic sites regularly contain very large structures. Stand-level studies must use large diameter classes (e.g. trees >100cm dbh or larger for Wet sites) to account for the range of attributes present.
9. Old growth on Mesic sites is correlated with the abundance of *Bryoria* and *Alectoria* lichens and the falsebox abundance was greater on Moderate and High structural value sites than on Low structure (mature) sites. Thus, old growth management strategies designed to maintain mountain caribou habitat should be compatible with retention of other biodiversity values on *Mesic* sites. However, Wet sites with Very High old-growth structure are not correlated with lichen or falsebox abundance and conservation of these globally rare and endangered forests must be addressed separate from the mountain caribou context.
10. Management guidelines for mountain caribou (i.e. the MAC Plan) recommend retaining 40% of the ICHwk1 as forests >140 years old with ¼ >250 years old. The average age of Very High structure Wet sites was 443 and 368 years old for High structure Mesic sites. Stands >250 years old, including those greater than 500 years old should make up a higher percentage of old growth management areas. The current emphasis on conserving age class 8 stands significantly deviates from the natural age class distribution and is likely to have a considerable risk to biodiversity
11. The historic age class distribution has changed dramatically due to timber harvesting. In the absence of logging, stands greater than (at least) 140 years would be expected to occupy 2/3 of the landbase. Current age class distributions show that age class 8 and 9 stands cover approximately 1/3 of the landbase, while age class 1 occupies another third. However, our assessment of stand ages suggests that most stands (including many labeled as age class 8 on Forest Cover maps) are much older than 250 years.

8.0 Recommendations

1. Use the indices of old-growthness provided in this report to guide selection of old growth management areas with High and Very High structural value. Consider landscape level attributes in the final selection.
2. Conduct pre-commercial and commercial thinning in existing immature stands to accelerate the development of habitat diversity and to reduce barriers to connectivity.
3. Where harvesting is to occur in mature and old growth (outside of retention areas), use partial cutting and variable retention prescriptions to maintain much of the stand in an old seral state.

Rotations must be long enough that large-sized structural attributes and abundant lichen populations can develop. Permanent retention areas should be incorporated into stand level planning.

4. Use an adaptive management framework to implement and monitor the success of single-tree selection in mature and old-growth stands outside of the 40% retention zones.
5. Use the ranges of natural variation presented in this study to guide retention levels at the stand and landscape level.
6. Ensure that field staff are familiar with the thresholds in the index of old-growthness and are able to identify high and low structural value old growth. At the planning stage, be prepared to modify reserves to include higher value stands where feasible.
7. Clearcutting on conventional short rotations will not maintain old growth attributes and therefore the associated biodiversity in the ICHwk1. Studies have concluded that partial cutting may be a viable option in the ICHwk1 (outside of the 40% retention areas) and sustainable forest management strategies should move in this direction.

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Appendix A: Double Bark Thickness ratios from PrognosisBC (Zumwari, pers. com. 2001).

Sx	0.956
Bl	0.937
Lw	0.851
Fd	0.867
Pl	0.969
Pw	0.964
Hw	0.934
Cw	0.950
Other	0.934

Appendix B: Discriminant Functions for ICHwk3 old growthness from Harrison and DeLong (2001)

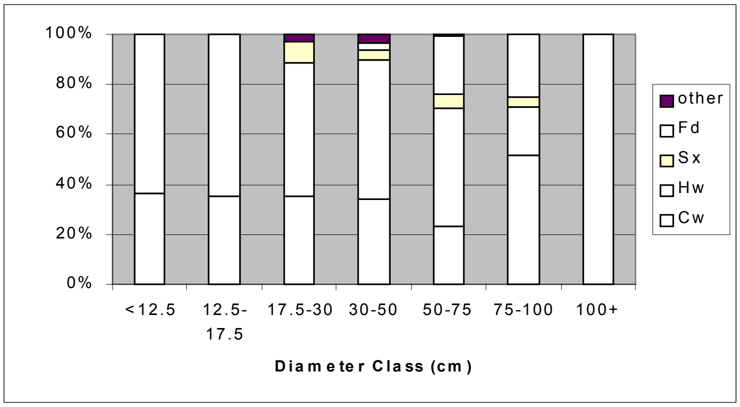
Stand age	Function
< 250 years	$0.663_{x1} + 0.110_{x2} - 0.176_{x3} + 0.390_{x4} + 0.303_{x5} + 0.087_{x6} + 0.400_{x7} + 0.003_{x8} - .017_{x9} - 26.128$
> 251 years	$0.574_{x1} - 0.043_{x2} - 0.373_{x3} + 0.514_{x4} + 0.499_{x5} + 0.090_{x6} + 0.148_{x7} + 0.040_{x8} + .039_{x9} - 31.788$

where x_1 = live tree basal area; x_2 = # of trees with excavated cavities (WLT-3,4 and 5); x_3 = # of trees assessed as WLT-6; x_4 = sum of trees for each pathogen type; x_5 = # of trees assessed as WTC 6 or 7; x_6 = mean height of gold-dust lichens; x_7 = # of trees assessed as CWD types 1,2 or 3; x_8 = tree density >50 cm dbh in sph; x_9 = tree density >75 dbh in sph.

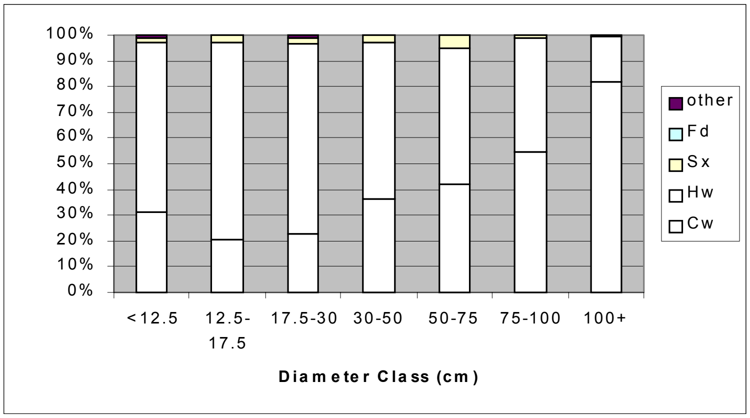
To use these functions, measure the stand level attributes and enter the resulting values in both of the above equations. The stand fits into the category that results in the highest function score.

Appendix C: Relative species abundance by size class for structural value groups in Wet (a) and Mesic (b) stands

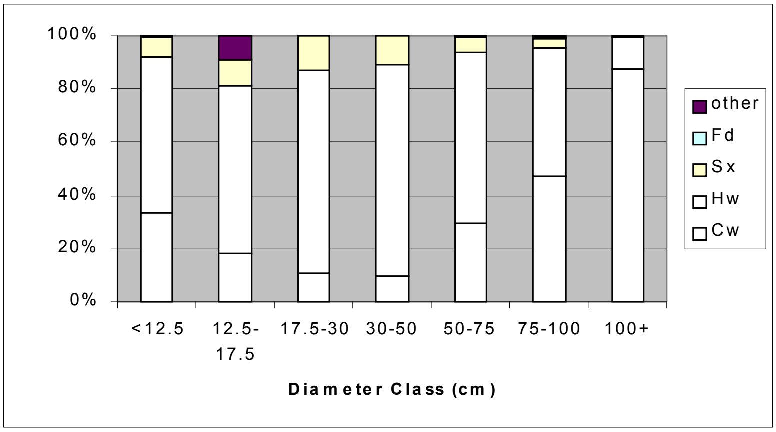
(a) Wet Sites



Low Structure

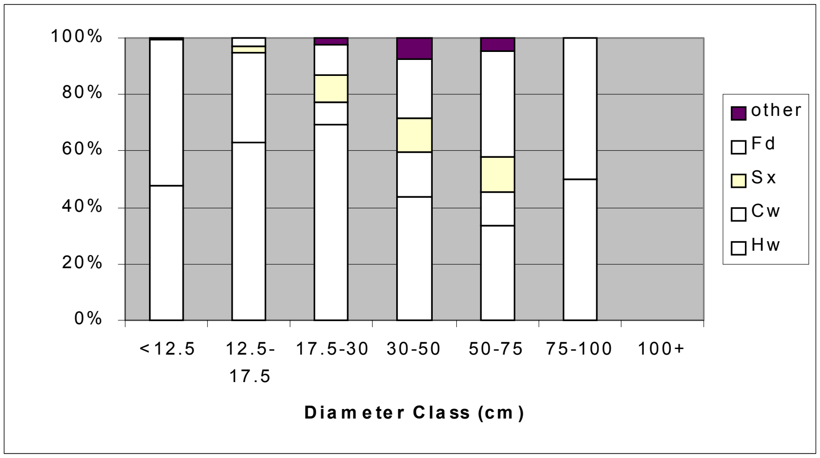


High Structure

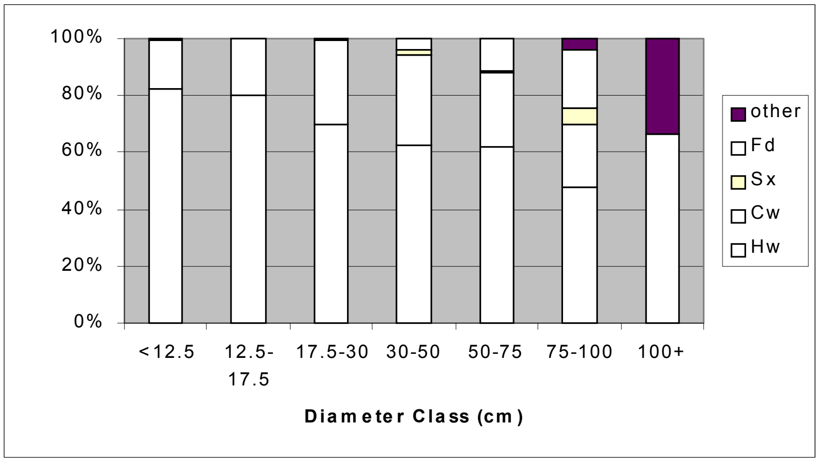


Very High Structure

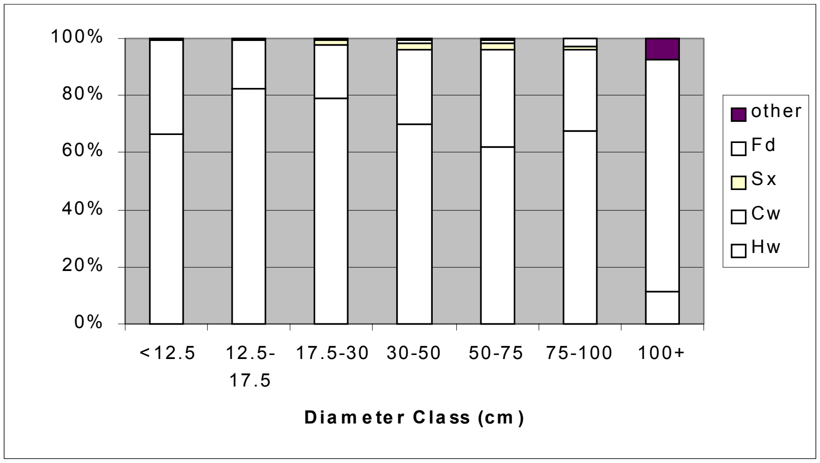
(b) Mesic Sites



Low Structure



Moderate Structure



High Structure