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OLD-GROWTH DEFINITIONS FOR BRITISH COLUMBIA INTERIOR FORESTS

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ABSTRACT

A review of the literature concerning old-growth definitions was applied to determining an old-growth definition for the interior forests of British Columbia. The attributes and values of old-growth ecosystems, general and ecosystem-specific definitions and additional factors were examined. The ecological research of Franklin and associates was proposed as a structural framework for definitions specific to each old-growth ecosystem. The ecological data collected by the British Columbia Forest Service in documenting the biogeoclimatic zones, subzones and variants of the of the province provide a starting point for the determination of specific zonal and site-associated old-growth definitions.

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INTRODUCTION

The ecological, social and heritage values of old-growth forests have recently become a focus of attention in British Columbia yet the diversity of forest types in the province have made a comprehensive review difficult. The extent and types of coastal old-growth protected in parks has been documented by Roemer et al. (1988). These authors noted, however, that a complete inventory of remaining old-growth in Britaish Columbia was not possible without a consistent definition of old-growth. This paper provides a review of old-growth literature and definitions relevant to British Columbia's varied forest cover.

Old-growth forests, one stage in the successional continuum, exhibit large variation in characteristics dependant on forest type and disturbance history. Thus the concept of one all-encompassing old-growth definition is unrealistic. Indeed, the definitions of old-growth discussed in the literature are either extremely general (SAF 1984; Thomas et al. 1979) or are specific to one forest type (Achuff 1988; Foote 1983).

Franklin and his associates have led much of the work on the ecological characteristics of old-growth forests in the Pacific Northwest.Their research has focused on features, such as structure and composition, thought to be important or characteristic of a functioning old-growth forest. Their observations of old-growth coastal Douglas-fir forests has provided much of the fundamental information for the discussion of old-growth attributes and characteristics (Franklin et al. 1981: Franklin and Spies 1984).

In British Columbia considerable work by the Ministry of Forests has produced a Biogeoclimatic Ecosystem Classification (BEC) system for the range and forest land of the province which includes hierarchical site, vegetation and zonal classifications incorporating primarily climate, soil and vegetation data (Pojar et al. 1987). The site classification identifies areas which support or have the potential to support ecologically equivalent ecosystems at climax. The vegetation level classification of mature communities is based on floristic similarity of plant communities. Geographic areas experiencing similar climatic conditions are identified using the zonal classification and would be expected to support similar ecosystems (biogeocoenoses) at maturity (Pojar et al. 1987). Because this system was designed as a resource management tool for the organization and communication of ecological information, it can provide a valuable framework for identification of the province's old-growth. As BEC is based on climax ecosystems and their various characteristics, the majoity of old-growth is documented. Thus the next logical step is to determine what constitutes old-growth in each of the zones and site associations.

To assist in determining the specific features of old-growth appropriate to the forest types of the interior, this paper intends to:

1. Examine the attributes and characteristics of old-growth forest ecosystems.
2. Review the old-growth definitions relevant to British Columbia forests described in the literature.
3. Examine some old-growth definitions directly applicable to British Columbia interior forests.
4. Discuss definitional problems.
5. Make recommendations based on the information reviewed.

OLD-GROWTH ATTRIBUTES

Old-growth forests exist as stable communities for the latter years of their existence unless disturbed by traumatic disruptions such as windstorms or fire. The stable environment of an old-growth forest is supportive of some highly specialized and adapted organisms exemplified frequently by cavity nesting birds, canopy dwelling animals and understory saprophytic plants (Juday 1988). An intricately complex structural environment composed of large downed logs, standing snags, leaf and bark detritus is created by endemic levels of tree disease, mortality and decay which in turn support the myriad functions of lower organisms essential to the web of life. The forest canopy, dominated by long-lived seral or shade-tolerant tree species may be deep and layered from extensive, prolonged competition for light under the primary canopy .

The primary attributes of forest ecosystems are composition, structure and function. Composition is defined as the array of plant and animal species and the shifts in their relative abundance. Structure refers to physical arrangements in space and time. Function is indicative of ecological processes and the rates at which they occur (Maser 1988).

Composition

The term "biological desert" has frequently been applied to old-growth forests but recent research has substantiated the presence of a diversity of plants, vertebrate and invertebrate animals within these mature ecosystems (Mannon and Meslow 1984; Meslow et al. undated.; Pike et al. 1975; Raphael 1984; Schoen et al. 1988; Swindel and Grosenbaugh 1988; Thomas 1979). An obvious change in composition occurs between young stands and old-growth forests during succession . In the coastal Douglas-fir area the forest changes from pure or nearly pure Douglas-fir to mixtures of Douglas-fir, western hemlock, western redcedar and other tree species (Franklin et al. 1981). In the British Columbia Interior Cedar-Hemlock Zone the seral tree species western larch, Douglas-fir and western white pine will be replaced by western hemlock and western redcedar as the forest reaches climax (Ketcheson et al. 1983 in Watts).

Few vascular plants appear restricted to old-growth ecosystems but often find suitable habitat therein. Optimal habitat is present for some species such as some of the saprophytic plants in the orchid and heather families which obtain all or part of their energy from decomposition of dead organic matter (Franklin et al. 1981). Difficulties have been encountered in addressing the dependence of non-vascular plants on old-growth forests but it is conjuctured that many species find their optimum habitat in old-growth. Old-growth forests are characterized by a unique combination of plant associations which may be used to categorize the stand as a certain habitat type or in British Columbia as a biogeoclimatic variant (Pojar et al. 1987). Entire tree samples in 450 year Douglas-fir forest in western Oregon yielded 74 species of lichens and 32 species of bryophytes (Pike et al. 1975). Snags in old-growth have a rich flora of lichens while the canopy of old-growth Douglas-fir harbour abundant quantities of the nitrogen-fixing foliose lichen *Lobaria oregana* which is seldom found elsewhere (Franklin et al. 1981).

A great deal more is known about the relationship of vertebrates to old-growth forests than that of other organism groups. Many vertebrates use old-growth forests with some existing mainly in old-growth ecosystems due to optimal breeding or foraging habitat (Franklin et al. 1981). The degree of dependance on old-growth by many of these species is unclear but the survival of a species in other age classes of a forest may not imply that it can survive once the major reservoir of optimum habitat has disappeared (Franklin et al. 1981). Armleder and others (1986) examined the management of winter range of mule deer in B.C. interior Douglas-fir forests. They found that areas of high crown closure, as provided by old-growth stands, were important for shelter values. A multi-layered, uneven-aged stand structure was critical for continuous winter range capabilities for this species (Armleder et al. 1986).

The northern spotted owl *Strix occidentalis* is an important specialist species, requiring old-growth stands for nesting and feeding, in the Pacific Northwest Douglas-fir region. The northern spotted owl is considered an old-growth indicator species. Its habitat requirements are for an area of 400 ha per pair (Meslow et al. undated). As many as 18 bird and mammal species have been identified as finding optimum habitat in Douglas-fir old-growth forests (Franklin et al. 1981). Studies in the mixed conifer forests of the western Sierra Nevada identified 24 species of breeding birds and 5 species of mammals that found optimal conditions in old-growth forests (Verner and Boss 1980 in

Meslow et al. undated). In the U.S. Forest Service Region One, located in Montana, which contains similar ecological zones to those of the British Columbia interior, the pileated woodpecker Dryocopus pileatus is an old-growth indicator species. A minimum of 10 percent old-growth stands within forested areas has been recommended as necessary for this species in northwestern Montana (Yanishevsky 1987). Current research in Colorado has identified the flammulated owl (Otus flammeolus) as a probable indicator species for old-growth ponderosa pine / Douglas-fir stands (Fletcher 1989). Research indicates that these owls prefer to forage and nest almost exclusively in old-growth forests (Fletcher 1989).

The biological richness of the old-growth ecosystem cannot be underestimated. Studies have found 1500 species of invertebrates alone in the canopy of one stand (Franklin 1982). Research continues to document the diversity and inter-relationships of various species in old-growth ecosystems.

Structure and Function

The diverse composition of old-growth forests is largely related to the structural diversity characterized by the presence of large live trees, large snags, and large decomposing logs on land and in streams (Franklin et al. 1981). Although these characteristics are not unique to old-growth ecosystems the combination of all these attributes is highly indicative of an old-growth forest system (Harris 1984). The complexity and variance of nature create a landscape in which no two stands are completely alike and the onset of old-growth features is not a discrete point. The structural components provide important habitat and functional roles which merit a brief examination.

The great height of older trees and the multi-layered canopy created in an uneven-aged stand provides a range of habitats (Spies and Franklin 1988). The large crowns and rough canopy surface trap winter snow allowing herbivore forage beneath on the forest floor, intercept rain, facilitate the interchange of gases and increase dewdrop and fogdrip (Harris 1984). Broken tops, cavities and gnarled branches serve as important nesting sites (Spies and Franklin 1988).

Snags are present throughout succession in a natural ecosystem although the size can be quite variable. Large dead trees are important for cavity dwellers such as the pileated woodpecker and flammulated owl as well as providing important foraging opportunities (Spies and Franklin 1988). Snags are also important in carbon and nutrient cycling (Franklin and Spies 1984), as a perching site for raptors and other birds, as a deadwood medium for arthropods and in providing an opening for light to penetrate to the forest floor (Harris 1984).

Down woody debris in the form of deteriorating logs provide an important source of nutrients, minerals, moisture and humus for the ecosystem (Tollenaar and Power 1982 ; Maser et al. 1988). Downed logs provide important habitat for a continuum of decay organisms and wildlife, sites for nitrogen fixation, nurse logs for succeeding generations and impediments to soil erosion (Franklin and Spies 1984 ; Maser et al. 1988). Downed logs in streams function as components of riparian habitat, dissipators of stream flow, a controlling factor on channel cutting and stream erosion providing streambed stability, sites for nitrogen fixation and as retainers of organic matter such as leaf litter along stream reaches pending utilization by stream organisms (Franklin and Spies 1984).

Gross primary productivity in old-growth forests remains high compared to early stand development with comparable foliage biomasses for coastal and subalpine old-growth types (Franklin et al. 1981). Production of photosynthate is high in old-growth stands but respiration energy demands are also high, nevertheless, substantial growth in the form of wood and other biomass occurs (Franklin et al. 1981). Net wood production reaches a maximum after 90 years and remains high for another 100 years in coastal Douglas-fir forests but wood volume continues to increase after this point on a stand basis (Spies and Franklin 1988). Although old-growth forests may be subject to disease and insect damage productivity remains positive (Franklin et al. 1981). Old-growth forests are thus stable in terms of biomass and board foot accumulations (Franklin and Spies 1981)
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The greatest amount of functional research has involved protective functioning which has demonstrated old-growth ecosystems to be highly nutrient retentive with rapid internal recycling (Franklin and Spies 1984; Sollins et al. 1980).

Values

The aesthetic and spiritual qualities of old-growth forests are important to many people. Just the knowledge that preserved natural areas exist is reassurring to harried urban dwellers and symbolize an important link to the past (Tollenaar and Power 1982). Many old-growth areas provide recreational and educational values, including landscape and scenery enhancement, which are of increasing importance as the tourism industry expands in British Columbia. Wildlife habitat requirements, scientific research opportunities and gene pools are important concerns whose needs extend into the future (Barnes 1989). Old-growth forest ecosystems also demonstrate low soil erosion and high quality water production with great effectiveness at condensing and precipitating moisture and atmospheric particulates (Harr 1982 ; Franklin and Spies 1984) which are of particular importance to watershed areas.

Old-growth forests have been the major source of timber which has allowed the B.C. forest industry to develop into a producer of international importance for lumber and pulp products. The harvesting, extraction and manufacturing of these forest products has provided a great deal of direct and indirect benefits to residents of the province. Wood products obtained from old-growth trees have special values due to their strong, durable, easily worked timber. The straight grain and freedom from knots create a high quality wood which is in great demand.

CURRENT DEFINITIONS

A number of working definitions for old-growth forests have been developed by researchers in western North America. A review of these definitons may assist in determining an appropriate old-growth definition for British Columbia interior forests. The criteria arrived at for these definitons range from age and tree size to complex structural, functional and compositional components reflecting an ecological approach. Many of the definitions are based on floristic classification systems using plant associations and dominant tree species and are specific to the forest ecosystem assessed.

Pacific Northwest Coastal Definitions

The United States Department of Agriculture Forest Service is resposible for much of the public forest land in the U.S. and supports reserch projects addressing the old-growth situation in the Pacific Northwest. Its designation for old-growth stands is defined as any stand of 4 ha or greater generally containing the following characteristics:

1. Mature and overmature trees in the overstory and well into the mature growth stage.

2. A multi-layered canopy and trees of several age classes.

3. Standing dead trees and down material.

4. Evidence of man's activities may be present but do not significantly alter the other characteristics and would be a subordinate factor in a description of such a stand.

(United States Department of Agriculture Forest Service 1981)

The work of Dr. Jerry Franklin and his associates has been fundamental in the examinaton of old-growth forests in the Pacific north-west of the U.S. Their studies have focused on coastal Douglas-fir (Pseudotsuga Menziesii) old-growth ecosystems, their definition, structure and to a lesser extent, their function. The information and depth of comprehension of the intricacies of these ecosystems commends the application of the ecological principals presented by Dr. Franklin to other coniferous ecosystems.

The main characteristics of a Pacific Northwest old-growth Douglas-fir ecosystem are listed in Table 1 (Franklin and Spies 1984). Age alone is considered unsatisfactory. The development of structural features characteristic of old-growth stands develop over different time scales dependent on actual site conditions and stand history. Thus the development from a clearcut will usually be much longer than from a natural disturbance such as fire or wind as their is little retention of the structural components of snags and downed logs (Franklin and Spies 1981).

Given the continuous nature of ecological succession, thinking in terms of an index of structural diversity as the basis for an index of "old-growthness" has been proposed as a reasonable approach for characterizing ecosystems (Spies and Franklin 1988). It would be important to use characteristics which change to the greatest degree during succession and are of the greatest ecological importance to habitat and functional systems. Structural and functional changes take much longer in Douglas-fir ecosystem (Figure 1 and Table 2) than in shorter seres (Spies and Franklin 1988) common to the interior of British Columbia.

The Society of American Foresters published a position paper which was based on the definitional work done by Franklin. They concluded that age related definitions required inclusion of ecological concepts and could not rely on inventory definitions of 200 years of age in Pacific Northwest Douglas-fir forests (SAF 1984).

The United States Department of Agriculture Forest Service established an Old-Growth Definitional Task Group which prepared interim minimum standards for four common Douglas-fir and mixed-conifer habitat types of the Pacific Northwest (Table 3)(Old-Growth Definitional Task Group 1986). Plant community series were used to stratify the definitions. It was felt that the use of multiple factors was required for differentiation between young, mature and old-growth conditions. Minimal stand charecteristic values were used rather than averages to reflect the range of values found among stands. The chosen levels were in the low to very low range to encompass all old-growth stands sampled. Even these ninimum values were considered reliable for excluding most, if not all, young and mature stands from classification as old-growth (Old-Growth Definitional Task Group 1986).

Table 1. Criteria proposed for old-growth definitions.

Author	Thomas	Franklin	Habeck
Date	1979	1981	1988
Area	OR. & WA.	Or.& WA.	Montana
Age-years	>160	>250±50	-
Live trees	37/ha	>25/ha	37/ha
size-dbh	>53 cm	>1.0 m or	>50 cm
age-yrs	-	>200	-
Snags	1.2/ha	>25/ha	yes
size-dbh	>53 cm	-	-
-ht	-	>6 m	-
Down logs	-	-	>37 tons/ha
size-dbh	-	>60 cm	-
-ht	-	>15 m	-
Canopy levels	2 or more	multi	multi
closure			
-overstory	10-40%	-	-
-shrubs	>40%	-	-
-total	>70%	-	-
Other Character-istics	Heartrot Decadence Logs on ground	Long lived seral dominant Shade tolerant associate Plant, animal diversity	Min. size 12 ha Decadent Fully stocked canopy

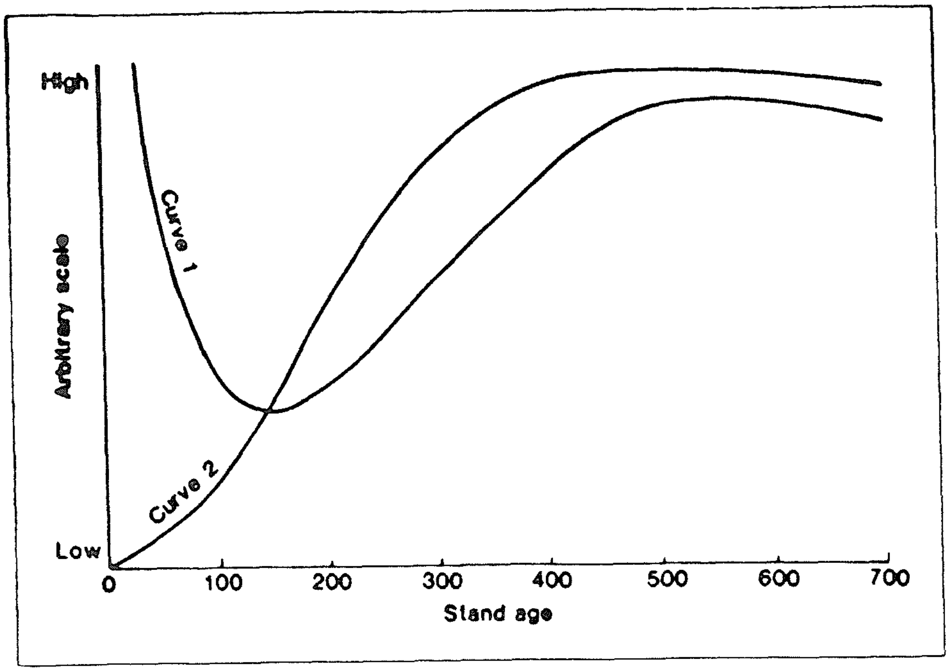

Figure 1. Generalized curves of change in ecosystem attributes with long recovery periods after disturbance in old-growth Douglas-fir forests.

TABLE 2. Classification of ecosystem characteristics according to their expected pattern of change (Figure 3) during succession in Douglas-fir forests.

Characteristics following a "U-shaped" curve (Curve 1)	Characteristics following an "S-shaped" curve (Curve 2)
Amount of coarse woody debris	Average tree size
Number of large snags	Diversity of tree sizes
CWD as percentage of total ecosystem biomass	Incidence of broken tops
Heterogeneity of understory	Forest floor depth
Plant species diversity	Surface area of boles and branches
Mammal diversity	Wood biomass

Adapted From: Spies and Franklin 1988

Table 3. **Interim minimum standards for old-growth Douglas-fir and mixed conifer forests in western Washington and Oregon and in California* (from Old-Growth Definition Task Group 1986).**

Stand Characteristic	Douglas-fir on western hemlock sites (western hemlock, Pacific silver fir)	Douglas-fir on mixed conifer sites (white fir, Douglas-fir)	Douglas-fir on mixed evergreen sites (tanoak, Douglas-fir)	Sierra mixed conifer (white fir)
Live trees	Two or more species with wide range of ages and tree sizes	Two or more species with wide age range and full range of tree sizes	Douglas-fir and evergreen hardwood (tanoak, Pacific madrone, and canyon live oak) associates (40 to 60% of canopy)	Two or more species with wide age range and full range of tree sizes
	Douglas-fir ≥8 per acre of trees >32 inches in diameter or >200 years old	Douglas-fir, ponderosa pine, or sugar pine 30 inches in diameter or >200 years old	Douglas-fir and pine ≥6 per acre of trees >32 inches in diameter or >200 years old	Douglas-fir, sugar pine, or ponderosa pine ≥8 per acre of trees >32 inches in diameter or >200 years old
	Tolerant associates (western hemlock, western redcedar, Pacific silver fir, grand fir, or big-leaf maple) ≥12 per acre of trees >16 inches in diameter	Intermediate and small size classes are typically white fir, Douglas-fir, and incense cedar, singly or in mixture	Intermediate and small size classes may be evergreen hard-woods or include a component of conifers (e.g., Douglas-fir or white fir)	Intermediate and small classes are typically white fir with Douglas-fir, or incense cedar, or both in some stands
Canopy	Deep, multilayered canopy	Multilayered canopy	Douglas-fir emergent above evergreen hard-wood canopy	Multilayered canopy
Snags	Conifer snags ≥4 per acre that are >20 inches in diameter and >15 ft. tall	Conifer snags ≥1-1/2 per acre that are >20 inches in diameter and >15 ft. tall	Conifer snags ≥1-1 1/2 per acre that are >20 inches in diameter and >15 ft. tall	Conifer snags ≥3 per acre that are 20 inches in diameter and >15 ft. tall
Logs	Logs ≥15 tons per acre including 4 pieces per acre ≥24 inches in diameter and >50 ft. long	Logs ≥10 tons per acre including 2 pieces per acre ≥24 inches in diameter and >50 ft. long	Logs ≥10 tons per acre including 2 pieces per acre ≥24 inches in diameter and >50 ft. long	Logs ≥10 tons per acre including 2 pieces per acre ≥24 inches in diameter and >50 ft. long

* Major series are shown in parentheses

Adapted From: Spies and Franklin 1988

Interior Definitions

The definitions for interior old-growth are more applicable to the interior forests of British Columbia than those of coastal Douglas-fir although the principles remain the same. Forest habitat types which present a succession classification system based on floristic community types and structural and developmental changes have been defined for Montana (Pfister et al. 1977). However clear distinctions and definitions for old-growth stands were not described. Steele et al. (1981) did similar classification work in central Idaho. These studies describe late seral and climax communities characteristic of each type. Similar classifications of habitat types have been conducted in Oregon, Washington and Idaho (Daubenmire and Daubenmire 1968; Franklin and Dyrness 1973). These classifications provide a basis for old-growth assessment using a clear definitional framework to be arrived at by researchers familiar with these regions.

Research on non-Douglas-fir old-growth by researchers in the Pacific Northwest revealed the same general ecological features in coastal Sitka spruce /Western hemlock ecosystems. Mixed conifer systems in the Rockies and Sierras were highly variable in terms of composition but contained the definitive structural components of old-growth forests. Pine forests showed the greatest variability. Old-growth Ponderosa pine forests exhibited far fewer downed logs due to the recurring cycle of natural fire. Old-growth lodgepole pine stands were found to lack small trees in relation to other forest types and have abundant but smaller snags and downed logs as well as earlier senescence and deterioration (Franklin and Spies 1981).

Thomas (1979), working in the Blue Mountains of Oregon and Washington, used the United States Department of Agriculture Forest Service working definition for old-growth stands as being past full maturity and showing decline; the last stage in forest succession. The minimal criteria listed in Table 1 were applied to a number of forest ecosystem, termed mixed coniferous forests, which included Douglas-fir and white fir (Thomas 1979). These definitional criteria are correlated with wildlife requirements in the publication.

Habeck (1988) assessed the Lolo National Forest management plan as an example of the old-growth planning process in the northern Rockies of Montana. The old-growth management units represent a wide range of elevations, aspects, habitats and vegetation types which are distributed throughout the Lolo forest. Old-growth indicator species of pileated woodpecker, pine marten, hermit thrush and goshawk are provided for under the plan (Habeck 1988). The definition listed in table 1 indicates the criteria used for assessment of the old-growth management units.

An additional qualification is the minimum size requirement of 12 ha. No stand age criteria were established in defining old-growth although the 50 cm live tree diameter suggests an age of 200 or more years (Habeck 1988).

In western Montana old-growth frequently refers to late seral, mature subclimax forests 200 to 500 years old which were originally maintained in an open-canopied savanna state by frequent (five to twenty year intervals) low-intensity ground fires (Habeck 1988). This created parklike ponderosa pine and western larch stands which exhibited few of the dead snag and decadence elements required for current old-growth definitions. In montane zones of northwestern Montana the climax old-growth forest were dominated by western redcedar and weatern hemlock. Although fire occurred less frequently (100-200 year intervals) it was often of great intensity and destroyed much or all of the stand (Habeck 1978). This patttern created a mosaic of successional stages with the major seral species being western white pine and western larch which also may form old-growth stands (Habeck 1988). Within the subalpine zone, beyond most fires, centuries-old forests also occurred. Forests of 500- to 700-year-old alpine larch were reported at timberline in the northern Rockies (Arno and Habeck 1972 in Habeck 1988). Any old-growth definition must in some way accomodate forest types occupying severe habitats at upper timberline as well as ponderosa pine stands in warm dry grasslands (Habeck 1988).

Achuff (1989) assessed the old-growth forests of the Canadian Rocky Mountain national parks using as a definition an age criteria exceeding 275 to 300 years for the largely climax or self-perpetuating ecosystems examined. Much of the park's vegetation, especially at lower and middle elevations, is seral due to the natural occurrance of fire within the last 150 years. The author describes the environmental, vegetation community associations and geographical characteristics of the major old-growth forest ecosystems encountered. This qualitative description provides an important reference point for comparison to British Columbia interior forests.

British Columbia Definitions

The British Columbia Ministry of Forests Inventory branch use a number of criteria in describing the forest landbase of British Columbia: forest land, unproductive forest land and non-forest land; tree species composition; age; height; productivity (site class); crown closure; stand structure; density; stocking class; environmentally sensitive areas (ESA); operability; history. Tree species are listed by declining percentage of stand composition; a minimum greater than six percent cover and a maximum of 5 species being used in the listing. Stand age is determined on the basis of the average of the dominant and codominant trees for the leading species. This figure is approximated to the nearest 10 years unless the exact age can be determined. A twenty year difference is used to identify homogenous strata. Stands are considered even-aged if the difference in age of the main canopy is less than 20 years. Uneven-aged stands may contain a highly variable or complex age pattern with no well defined age and a very uneven crown canopy. Uneven-aged stands are common in the interior dry-belt and all aged Douglas-fir stands. The stand age is determined from representative dominant and codominant trees using an age range for all stems in the main crown canopy above 7.5 cm d.b.h. An age range is not required for undisturbed old-growth climax stands as wide variations are considered normal and predictable (McLellan and Britnoff 1982).

Biogeoclimatic ecosystem classification (BEC), the system of ecological classification currently in use in British Columbia, is based on climate, vegetation and soil data (Pojar et al. 1987). The BEC is similar to the habitat type system of the western United States (Daubenmire and Daubenmire 1968). In the BEC system an ecosystem is defined as the vegetation, animal population, microorganisms and physical environment of a site (Pojar ei al. 1987).

Regional climate is the most fundamental determinant of terrestrial ecosystems and plays an important role in describing zonal ecosystems. However due to sparse or non-existant data for many areas the BEC system uses the concept of the zonal ecosystem in conjunction with vegetation criteria. Ecosystems are organized according to similarities in vegetation and site to produce vegetation and site units. Geographically related ecosystems are then arranged at a regional level using vegetation-inferred climatic similarities to produce biogeoclimatic units (Pojar et al. 1987). The biogeoclimatic zones will be used in this text as the basis for arranging ecosystem specific old-growth definitions.

The classification system of Walmsley et al. (1980) has been used by the British Columbia Ministry of Environment to classify seral ecosystems and by the Ministry of Forests (MOF) to differentiate seral stage classes in the ecosystem classification system.This classification system deals exclusively with identification of structural and developmental stages in forest succession and not with the classification of seral plant associations or seral plant ecosystems.

Walmsley's classification system has been replaced by that of Hamilton (1988) which differentiates seral ecosystems by both floristic and structural/developmental attributes. Identification and prediction of the sequence of plant associations and structural/developmental stages occurring over time may be integrated into the BEC system at the site classification level.

Seral plant associations are differentiated using a diagnostic combination of species (DCS) which may include one character, differential, or companion species but must include one differential or dominant differential species. Thus a change over time in main canopy composition or key species provides the foundation for the differentiation of seral plant associations. Stand structure and other attributes, based largely on the USDA Forest Service model, are used to identify seral stages (Hamilton 1988)

Extensive ecological assessment of forests has been conducted throughout British Columbia using the following criteria: age and height of one or two tree species per stand; stems/ha; gross volume; basal area; plant associations; soils; percent ground cover of wood. The BEC system uses near-climax, climax or potential vegetation to differentiate ecosystems (Pojar et al. 1987) Thus extensive information is available from the BEC system to predict expected vegetation and other environmental conditions if a site is considered old-growth.

In Hamilton's seral classification system old-growth stands are defined as having an all age class distribution. Structural heterogeneity, caused by the fall of dead trees followed by the development of canopy gaps and increased understory biomass from light penetration to the forest floor, is expected. Snags and rotting logs are present. This stage is estimated to begin about 250 years after a succession initiating disturbance (Hamilton 1988).

Klinka et al. (1985) presented a seral classification system defined on the basis of structural and developmental features. The seral ecosystem associations are also recognized on the basis of floristically differentiated phases. The classification of even-aged stands defines old-growth as: 70% coverage of the tree stratum with frequent canopy openings; shade-intolerant species may still predominate in the tree stratum; natural regeneration of shade-tolerant tree species is present in the understory and lower tree layers.

The work of Roemer et al. (1988) reviewed the amounts and types of coastal old-growth forests in British Columbia which are protected in their original state. Their analysis was confined to coastal British Columbia in part due to the lack of a consistent old-growth definition across the province, especially for interior forests.The Interim Forest Cover Series was used for its mapped information as an overview of the areas assessed, but is considered outdated (Roemer et al. 1988). This forest cover map is divided into mature timber, immature timber, noncommercial lands, nonproductive forests and nonforested lands. The mature forest designation was used to approximate old-growth forests and was felt to include forests at least 30 m tall and at least 150 years old when compared with present provincial forest inventory maps (i.e., age classes 8 and 9, height class 3 to 4). It was noted that the mature designation of the interim forest cover maps was considered equivalent to old-growth rather than the mature class of Franklin et al. (1981) which are those in the period between culmination of maximum growth and the development of old-growth characteristics. The tree size requirement implied in the source maps excluded most old forests on poor sites and at high elevations. Forest type distributions were estimated from detailed forest cover maps using the biogeoclimatic zone system or from vegetation type maps with personal familiarity acting as a control (Roemer et al. 1988).

The Forest Land Use Liason Committee (FLULC) has defined old-growth forests as natural, mature stands of trees which have not been significantly changed by man (FLULC 1989). They are dynamic ecosystems containing trees of various sizes, species and ages. Coastal stands may range from 200-1000 years of age while interior stands may be as young as 100 years. The committee recommended the retention of old-growth stands in each biogeoclimatic area in British Columbia (FLULC 1989).

Biogeoclimatic Zone Definitions

A review of the current scientific literature for old-growth definitions applicable to ecosystems of the British Columbia interior yielded few concrete examples. The variable geographic landforms and climatic diversity of the province creates a plethora of biogeoclimatic zones, subzones and variants. The research presented will be categorized using the broad zonal classification but an effort will be made to assign the definitional information to specific site associations or habitat types comparable to those currently in use by provincial ecologists. Given sufficient information about an ecosystem, it may be possible to draw inferences about similar ecosystems which have not been extensively studied (Klinka et al. 1979).

A complicating factor in much of the interior of British Columbia is the disturbance effect of natural fires. Many of the tree species have evolved under the pressure of these frequently catastrophic disturbances (Habeck 1968). Prior to settlement, fire was a common and widespread phenomenon which created seral communities with old-growth characteristics of woody debris and snags. Although these stands did not exhibit climax tree species as the dominant canopy component, the seral tree species often attained large stature and the stand displayed structural components characteristic of old-growth. Forest protection over the last 50 years has reduced the role of fire such that changes in species composition and structure of these protected ecosystems have been observed (Tesch 1980). Although many fire-dependant communities have advanced successionally their has been an increased impact from diseases and insects (Tesch 1980).

ESSF

The Engelmann Spruce -Subalpine Fir Zone (ESSF) is situated between alpine tundra and lower elevation forests over the southern two thirds of the province of British Columbia. The climate of the ESSF is a relatively moist, snowy, interior subalpine type with short, cool growing seasons and long, cold winters (Coupe 1983 in Watts). Engelmann spruce and subalpine fir are major tree species and dominant climax trees in the ESSF. Lodgepole pine is also a major tree species and is a widespread seral species after fire, especially in drier zones (Coupe 1983 in Watts).

The work of Arno and Simmerman (1982) categorized the old-growth ecosystems observed in this zone in Montana (Table 4) as well as the successional patterns leading to the old-growth state. The habitat types used were based on the work of Pfister et al. (1977) in Montana with some modifications. The parameters used to define the structural stages were: total percentage of canopy coverage by trees; d.b.h. of dominant trees; basal area per hectare of tree stems; and years since treatment (disturbance). The old-growth stage included both "near-climax" and "climax" forest conditions although the latter was rarely found in any of the habitat types examined. This type of qualitative work on existing ecosystems provides valuable information on structure applicable to British Columbia forests.

Achuff (1989) described a number of old-growth forest types found in upper subalpine forests using dominant tree species, vegetation type, soil, aspect and other features but no other specific ages or structural components were included. Romme (1982) examined the subalpine forests of Yellowstone National Park and found that a mature pine forest stage occurred from the ages of 150-200 years but that a climax forest did not occur until after more than 300 years (Table 5). Arno and Simmerman (1982) had also found a mature seral stage dominated by pines from ages 130-250, in some of the habitat types, which died out and were replaced by the climax species. Day's work (1972) in the Alberta Rocky Mountains also identified the 150 to 200 year span after a disturbance event being dominated by even-aged pines with the development of an irregular-aged spruce-fir following as succession advances. It was felt that fire initiation was required followed by lodgepole pine dominance such that the ecosystem was fire-dependent (Day 1972).

Interior Douglas-Fir

The Interior Douglas-fir Zone (IDF) is located in the south-central third of British Columbia, centred on the interior plateau.The IDF has a continental climate of warm summers and cool winters, with frequent moisture deficits during the growing season (Mitchell and Erickson 1983 in Watts). The interior variety of Douglas-fir is the most frequent tree species as well

Table 4

Characteristics of Old-Growth ESSF Ecosystems

Habitat Type	ABLA-PSME VAGL-XETE	ABLA MEFE-VAGL	ABLA-PIEN MEFE-Vacc
Canopy Coverage Percent	(40) 55-90	40-75	40-60
Average Dominant Tree d.b.h. (cm)	30.5-56.0	35.6-50.8	38.1-45.7
Basal Area m^2/ha	(16) 28-75	30-65	50-69
Stand Age (years)	(150) 220-300+	200-300+	220-300
Number of Sample Stands	9	6	7

Data presented as a range of values.

TREES:
ABLA= Abies lasiocarpa
PIEN= Picea engelmannii
PSME= Pseudotsuga menziesii

UNDERGROWTH:
MEFE= Menziesia ferruginea
Vacc=VAGL(Vaccinium globulare)
VASC(Vaccinium scoparium)
VAMY(Vaccinium myrtillus)

VAGL= Vaccinium globulare
XETE= Xerophyllum tenax

Adapted from: Arno and Simmerman 1982

as the shade-tolerant dominant of the zone. It often dominates stands on all aspects of mid elevations (Pfister et al. 1977).

Achuff(1989) found in his observations in the Rocky Mountain parks that Douglas-fir stands occured generally on subxeric to mesic sites of moderate south and west facing slopes of morainal and colluvial landforms withh rapidly to well drained Brunisolic and Regosolic soila. He found 5 vegetation types in forests ranging from closed to open canopy conditions, with the open stands occurring on drier, more exposed sites. Old-growth forest stands were of 150-300+ years of age (Table 5). He noted a mean fire return of 20-40 years of light to medium surface fires in Banff and Jasper National Parks (Achuff 1984).

Arno and Simmerman (1982) conducted studies on stand structure in old-growth Douglas-fir stands in their successional analyses (Table 6). The Douglas-fir/ ponderosa pine (PSME-PIPO) stands were not the theoretical climax forest expected under those site conditions of only Douglas-fir. The pre-1900 forest communities developed under the influence of recurrent surface fires at 5-50 year intervals which favoured the retention of the ponderosa pine element in the community. The successional stage described is therefore not defined as old-growth by the authors but as a mature seral stage (Arno and Simmerman 1982). This accounts for the young age (100 years) at which this type of stand was observed to have developed. No climax or old-growth stands were observed for this vegetation type probably due to the fire component in this ecosystem. The Douglas-fir habitat type which did contain old-growth stands required at least 190 years (Table 6) to develop. Tree size, canopy coverage and basal area were similar between the two which may indicate that the mature seral stage in fire-prone areas should be considered for inclusion under the old-growth definition with the effect of recurrent fire as a definitional modifier.

Kessell and Fischer (1981) describe the role of fire affecting successional models in coniferous forests. This community modeling is based on knowledge of the adaptive traits and the life history of each tree species involved. The old-growth state arrived at after 220 years (Table 5) would preclude the occurrence of fire during that period on that site. Low intensity ground fires may be tolerated by species such as Douglas-fir but a severe fire would return the successional model to an earlier stage requiring another 220 years to attain old-growth status. Tesch (1980) found in studying uneven aged stands with advance regeneration dominated by Douglas-fir that the effects of aspect were important in differences in stand development. Thus he observed varying regeneration times and establishment patterns following disturbance on north and south aspects of similar areas.

Table 5

Age Criteria for Old-Growth Interior Zones

ESSF

Author	Arno & Simmerman	Romme	Day	Davis et al.
Location	Montana	Yellowstone	Alberta	Montana
Date	1982	1982	1972	1980
Age-Years	>200	>300	>150-200	>100-200

Interior Douglas-Fir

Author	Arno & Simmerman	Kessell & Fischer	Achuff
Location	Montana	Montana	Alberta
Date	1982	1981	1989
Age-Years	190-300+	>220	150-300+

Ponderosa Pine

Author	Thomas
Location	Or.& Wa.
Date	1979
Age-Years	>150

Sub-Boreal Spruce

Author	Pojar et al.
Location	B.C.
Date	1984
Age-Years	>120-135

Boreal White and Black Spruce

Author	Foote	Viereck	Juday & Zasada	Hawkes
Location	Alaska	Alaska	Alaska	Alaska
Date	1983	1970	1982	1982
Age-Years	>100	>220	>150	>150

Table 6

IDF Old-growth Structural Characteristics

	PSME-PIPO PHMA±AMAL	PSME VAGL-CARU
Canopy Coverage Percent	(30) 40-75	45-70
Average Dominant Tree d.b.h. (cm)	30.5-61.0	35.6-61.0
Basal Area m^2/ha	23-60	32-76
Stand Age (years)	100-300+	190-300+
Number of Sample Stands	33	15

Range of values represents about 90% Of the data; extreme values are shown in parentheses.

TREES:
PIPO= Pinus ponderosa
PSME= Pseudotsuga menziesii

UNDERGROWTH:
AMAL= Amelanchier alnifolia
CARU= Calamagrostis rubescens
PHMA= Physocarpus malvaceus
VAGL= Vacinium globulare

Adapted from: Arno and Simmerman 1982.

Interior Cedar-Hemlock

The Interior Cedar-Hemlock Zone (ICH) occurs at low to middle elevations of southeastern British Columbia. Another ICH area lies east of the Coast Mountains in the Nass Basin and adjacent portions of the Hazelton and Skeena Mountains of west central British Columbia. The ICH has a continental climate of cool, wet winters and warm, dry summers with the highest productivity in the interior of British Columbia. Western hemlock and western redcedar are the dominant climax trees with a diversity of successional tree species present (Ketcheson et al. 1983 in Watts).

Habeck (1988) noted that sites in this zone burnt less frequently (an interval of 100-200 years being common) but that fires were often of high intensity , destroying most of a stand. This pattern created a mosaic of successional stages throughout this zone. Turner and Franz (1985), in assessing old-growth stand structures in the ICH of Idaho, found relic western white pine to support the idea that the stands originated with a catastrophic disturbance such as fire as this species is shade intolerant. Downed logs of up to 1 m d.b.h. found in the stands did not create sufficient space for gap phase replacement. Sites were assessed as old-growth if tree d.b.h. exceeded 1 m and no evidence of human disturbance was found (Turner and Franz 1985).

Sub-Boreal Spruce

The Sub-Boreal Spruce Zone occurs in the central interior of British Columbia on the Nechako and Fraser plateaus and the Fraser basin. The continental climate is characterized by seasonal temperature extremes, severe, snowy winters, relatively warm, moist, and short summers and relatively low annual precipitation. Hybrid white spruce, white spruce and subalpine fir are the dominant climax trees. Lodgepole pine is a fire-climax species over much of the drier portion of the zone (Meidinger and Pojar 1983 in Watts).

Pojar and others (1984) described the sub-boreal forests as a mosaic of microsites each of which may be in a different state of successional development. This creates a dynamic balance of a more or less stable system dependant on the processes of regionl climate and the additional factor of recurrent fire. Theoretically the forest could, with time and freedom from disturbance, mature to a climax state but due to the frequency and prevalence of wildfire it may be more valid to view the whole mosaic as a stable climax. Thus the age of 120-135 years, despite the fact that some species cannot regenerate under their own canopy, was chosen for the SBS old-growth definition (Pojar et al. 1984).

Boreal White and Black Spruce Zone

The Boreal White and Black Spruce Zone (BWBS) is found on an extension of the Great Plains into northeastern British Columbia and the lower elevations of the main valleys west of the northern Rocky Mountains. The BWBS has a continental climate of long, very cold winters and short growing seasons. The ground freezes deeply and permafrost is common. Forest fires are frequent such that a variety of successional stages can be found as well as a large number of tree species including white spruce, black spruce, lodgepole pine, tamarack, trembling aspen, subalpine fir, balsam poplar, common paper birch and Alaska paper birch (Annas 1983 in Watts).

Foote (1983) defined the final successional stage as the spruce stage. It features closed to open stands of spruce with the occasional hardwood. Most stands sampled were from 100 to 200 years of age but are infrequent due to the extensive fires characteristic of this zone. The duration of this stage is unknown; the oldest stands or trees observed are just under 300 years old (Foote 1983).Reproduction within these stands is self-perpetuating until a disturbance event.

Among the white spruce community types (Table 7), three major changes were noted as stands moved into the final old-growth state:

1. an increase in tree diameter but no change in height.
2. an increase in cover and depth of the moss layer.
3. an increase in the density of American gren alder.
   (Foote 1983)

This final white spruce successional stage occurs 150-300+ years after a fire. The average stand examined was 170 years of age (Table 9). The white spruce canopy may be open to closed with a few hardwood relics potentially present in the early years of the stage. This stage may develop earlier than 150 years after fire if the hardwoods die quickly or are not present in the earlier stages (Foote 1983).

Hawkes (1982), working in Kluane National Park, found that mature white spruce stands ranged from 150 to 400 years of age and were characterized by the lack of hardwoods in the canopy. Juday and Zasada (1982) examined old-growth white spruce stands on Alaska floodplains and found dominant tree ages to be from 100 to 300 years with white spruce replacing balsam poplar and becoming an old-growth stand at 150 years (Table 5). At least one generation of white spruce is present in the understory such that a two-story canopy is produced. A stand with the last white spruce generation has a multi-layeered canopy of less than 18 m., dominant trees averaging 200 years old, and a balanced, stable diameter size-class distribution (Juday and Zasada 1982).

Table 7

Old-Growth White Spruce Ecosystems

Community Type	*Populus tremuloides*/ *Viburnum edule*/ *Linnaea boreale*	*Betula papyrifera*/ *Viburnum edule*	*Picea glauca*/ *Viburnum edule*/ *Equisetum arvense*/ *Hylocomium splendens*	*Picea glauca*/ *Rosa acicularis* *Equisetum sylvaticum* *Hylocomium splendens*
Age (years)	130	-	100-200	120-200
Height (m.)	-	-	20-30	-
Canopy	open	-	open	-
Tree Density Stems/ha	700	200	500	500
Diameter (dbh-cm)				
-largest	>40	15.7-68.3	-	-
-average	32.8	-	12-35	26.1-33.5
Other Characteristics			hardwood snags decaying logs	

Adapted from: Foote 1983.

Table 8

Old-Growth Black Spruce Ecosystems

Community Type	*Picea mariana/ Vaccinium uliginosum-Ledum groenlandicum*	*Picea mariana/ Vaccinium uliginosum-Ledum groenlandicum/ Pleurozium schreberi*	*Picea mariana-Picea glauca/ Betula glandulosa*/ lichen
Age (years)	>120	>100	>110 mixed
Height (m.)	–	11	–
Canopy	–	–	open
Tree Density Stems/ha	–	2000	400
Diameter (dbh-cm) -largest	–	–	32
-average	11.4-14.8	17.0	–
Other Characteristics	Paper birch has died	Islands in younger stands, 2 age classes	Mixed ages-fire effect

Adapted from: Foote 1983.

Table 9

Average Old-Growth White and Black Spruce Ecosystems

Community Type	White Spruce	Black Spruce
Age-Average (years)	170	121
Height (m.)	30	11
Tree Density Stems/ha	566	1800
Diameter (dbh-cm) -average	19.1	15.2
Litter on floor %	26	18
Logs on floor %	-	6
Organic layer cm	12	16
Other Charactristics		Permafrost 59 cm below surface

Adapted from: Foote 1983.

The oldest black spruce stage occurs 91 to 200+ years after fire with the average stand sampled being 121 years old (Table 9). Black spruce comprises the overstory although white spruce and relic paper birch may be present. This stage is rare due to the frequency of fire. With aging the moss layer thickens, the soil temperature drops, the permafrost level moves closer to the surface and growth stagnates (Foote 1983, Viereck 1970). Characteristics of both white and black spruce community types are summarized in Tables 7, 8 and 9.

Other Problems

Definitions of old-growth are not complete without an evaluation of the size required for a stand to be ecologically viable. Many figures have been tossed around, ranging from 4 ha from the USDA Forest Service and U.S. Bureau of Land Management to at least 12 ha in Research Natural Areas to an initial 32 ha minimum set by the USDA Forest Service Old-Growth Definition Task Group (Greene 1988; Habeck 1988; Old-Growth Definition Task Group 1986). The Task Group withdrew the size criteria due to arguments that minimums were dependant on management objectives and the effects of surrounding land areas. Many studies have been undertaken to assess the effects on old-growth stands of forest fragmentation and the creation of edge by adjacent clearcuts, roads and other human intrusions.

Harris (1984) found using island biogeography techniques and theories that isolated patches can be expected over time to lose some degree of the biotic diversity originally found at that site. He found that areas of less than 10 ha may be entirely edge habitat which is an alteration of interior stand conditions and thus not conducive to the needs of old-growth dependant species (Harris 1984). Area required to retain the integrity of old-growth stands will be higher when old-growth stands are completely surrounded by clearcut than for old-growth stands which have only partially cut surrounds or mature forest perimeters (Harris 1984). The impact from clearcutting on old-growth forest requires a peripheral strip of three times the tree height to provide a buffer for the core area. Thus for a stand of 50 m trees, a 150 m buffer zone should be allowed for before calculating the amount of intact old-growth ecosystem preserved (Harris et al. undated).

Studies of the effects of fragmentation on vertebrate species (Rosenberg and Raphael 1986) found that although species richness of birds and amphibians increased in more fragmented stands, a number of species were negatively impacted by the decreased old-growth habitat. The authors also found that the recentness of the fragmentation precluded any solid conclusions but they did recommend the inclusion of a minimum of 20 ha for stand size in any old-growth definition (Rosenberg and Raphael 1986). The minimum old-growth requirements can be assessed on a species by species basis using old-growth indicator species such as the northern spotted owl which requires 400 ha per pair of undisturbed old-growth (Meslow et al. undated) or the flammulated owl, an interior forest old-growth dependant species. Many of the lifeforms present in the native forests have not been sufficiently studied to ascertain their old-growth area requirements (Fletcher 1989). Valuable research to apply to regional old-growth definition and size considerations include: measures of species abundance in unmanaged old-growth compared to younger, managed stands; measures of species abundance in varying sizes of old-growth stands; identification of old-growth dependant species from the species abundance studies to give priority to their requirements (Meslow et al. undated).

A number of management suggestions have been made to account for the effects of forest fragmentation and mitigate the effect on old-growth ecosystems. The use of progressive or clustered cuts originating in scattered nuclei throughout a landsape would reduce the amount of edge and road impacts (Franklin and Forman 1987). Identification and preservation of large areas of old-growth forest would maintain the needs of old-growth interior dependant species and provide valuable research opportunities into the future when gene pool access and intact natural ecosystem information may be limited (Franklin and Forman 1987).

An inventory of protected coastal British Columbia old-growth (Roemer et al. 1988) made allowances for some of these fragmentation effects by excluding high public use areas and parks of less than 50 ha. Only areas of old-growth exceeding 40 ha in size were included with fragmentation effects of traffic corridors and high-use areas taken into consideration when deriving totals.

Simulation work in Australian eucalyptus forests and southeastern U.S. National Parks and Forests have led to theories that to preserve stable habitat diversity an area of 50 to 100 times the largest disturbance area is required (Noss 1989). Thus to allow for a 20,000 ha burn a relatively compact forest of one to two million ha would be required. This would not have to be an old-growth system but should be sufficiently unfragmented to allow the migration and recolonization of species (Noss 1989).

Many of the British Columbia Interior Zones such as the IDF and SBS are subject to frequent and recurrent fires. To preserve old-growth forests in these areas requires consideration of the potential impact on preserved areas if fire occurs and allowance for adequate dispersal and size of areas so that examples of an ecological balance will be maintained. However, spatially isolated old-growth areas, especially if fragmented and lacking connective corridors, will have decreased species diversity

(Habeck 1988). Thus the preseration of old-growth areas must coincide with large scale management plans which allocate mature forest corridors in a north-south direction to allow for gene pool movement and which harvest stands so as to minimize the edge and fragmentation effects.

Selective logging may be appropriate in some areas, especially those stands with shade tolerant species composition, with consideration given to retaining the structural components discussed earlier such as snags and down woody material. Although human disturdance is present in these stands, if road construction is minimized and selection procedures are specific and accurate, these stands could possibly return to an old-growth state, if required, in a relatively short period of time.

Conclusion

The current scientific understanding of forest and wildlife ecology invokes a warning against further reduction in the quantity, quality and distribution of old-growth forests. Common sense warns us that old-growth should be retained as a viable segment of managed forests if the management intent is to maintain natural biotic diversity and ecosystem functioning. The structural and fuctional characteristics of old-growth stands discussed are integral to the requirements of some species but insufficient research demands that greater than the minimum known requirements be retained to allow for this large gap in our understanding.

For the Interior forests of British Columbia, the minimal age criteria discussed provide a starting point for assessing and defining old-growth stands. Age criteria is not, however, sufficient for a defininition so that use of the qualitative descriptions of intact old-growth stand structure as provided by the wealth of data accumulated in compiling the BEC system is imperative. The general definitions elucidated by Franklin in terms of structural components must be asessed in conjunction with:

a) qualitative studies from similar zones
b) cognizance of forest ecosystem interactions
c) tree and wildlife species requirements
d) knowledge of potential climatic and fire disturbance frequencies
e) flexibility to allow for extreme situations such as those of steep slopes or high elevation

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