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Old Growth Forests and Biological Diversity in British Columbia

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ABSTRACT

Much of the forest cover of British Columbia is still in an old-growth condition, although old-growth forests are considerably reduced from their original extent. Old growth is fundamentally an ecological concept, and B.C. old-growth forests generally conform to existing conceptual/ecological definitions, but do not necessarily fit mensurational and structural definitions – especially in interior zones and at higher elevations. Characterization of old growth should be done within the context of an ecological classification, and by using multiple criteria including age, size, disturbance, stand composition, structure and function, and minimum area.

Old-growth forests are most widespread in the coastal, higher elevation, and wetter interior regions of the province, and contribute correspondingly more to the biological diversity of these regions. But it appears that interior old growth has greater vascular plant diversity than coastal, and also that overall biodiversity (at least at selected species and ecosystem levels) is greater in interior zones. This is probably because interior zones have greater habitat diversity, as a result of more active disturbance regimes, more diverse land use, and more intricate successional mosaics.

INTRODUCTION

Most of British Columbia is forested and much of the province's forest cover is still in an old-growth or mature condition, although old-growth forests are considerably reduced from their original extent. Old-growth forests contribute much to the province's ecosystem and landscape diversity, which in turn are major components of overall biological diversity (Norse *et al.* 1986). Therefore, conservation of biological diversity in British Columbia must deal with old-growth forests – but not to the exclusion of everything else. Recently in British Columbia, the spotlight of public and management concern has been mostly on old growth (Fraser 1990), with biodiversity usually being considered in surrogate form, if at all. The discussion and debate have been rather narrow, usually derivative (largely of facts and opinions from the western United States), and focussed on southwestern British Columbia. In this paper, we discuss some of the biological and social aspects of old growth in British Columbia, but also move on to examine the role of old-growth forests in the broader concept and issue of biological diversity.

DEFINITIONS OF OLD-GROWTH FOREST

Why is Old Growth Difficult to Define?

There is much confusion over what constitutes old-growth forest because it has no single definition that is all inclusive, universally applicable, and generally accepted (Thomas *et al.* 1988; Hunter 1989). The

most suitable definitions are largely qualitative and conceptual, and therefore somewhat fuzzy. Contributing to the confusion is the evolving concept of old-growth forest. Among early white settlers, old growth was just mature forest that had not yet been cut or cleared (old growth as Nemesis). Distinctions among climax forest, silviculturally mature forest, and other types of older forests were made in this century as the science of ecology and the profession of forestry developed and matured (Juday 1988). The concept of old growth has continued to evolve in recent decades. Already in the eastern United States old growth does not necessarily mean a forest that originated in the presettlement era, and in England a forest established before 1700 is called "ancient". Some segments of our modern society perceive old growth as an aesthetic, experiential phenomenon that evokes awe and psychological and spiritual well-being (old growth as Sanctuary).

A simple definition of old growth could be "climax forest that has never been disturbed by humans" (Hunter 1989). But climax forests are notoriously difficult to characterize, and the concept of climax is itself elusive and often dubious. Furthermore, human disturbance in the broad sense is manifest everywhere in the biosphere these days.

Definitions and Attributes of Old Growth

Before examining the application of existing definitions to British Columbia forests, it would be helpful to review some of the definitions and attributes of old-growth forests. Much of this information comes from recent work on the ecological characteristics of old-growth forests in the U.S. Pacific Northwest (Sollins *et al.* 1980; Franklin *et al.* 1981; Meslow *et al.* 1981; Alaback 1984; Franklin and Spies 1984; Maser and Trappe 1984; Sedell and Swanson 1984; Juday 1988; Maser *et al.* 1988; Spies and Franklin 1988; Thomas *et al.* 1988; Carey 1989).

Definitions

The definitions can be classed as economic, mensurational, conceptual/ecological, and spiritual/aesthetic.

a. Economic

1. Any stand beyond financial maturity (does not gain its owner wealth by remaining unlogged).

b. Mensurational

1. A stand 150-200 years or older (Alaback 1984).

2. Any stand beyond culmination of mean annual increment (average volume growth beyond its peak).

3. Stands age class 8 and 9 (141+ years old) and height class 3 to *4.* (at least 30 m tall) (B. C. Forest Service inventory classes; (Roemer *et al.* 1988).

c. Conceptual/ecological

1. A stage of forest development characterized by greater diversity of structure and function than in younger successional stages (Thomas *et al.* 1988).

2. The third of three basic successional stages in forest development: (a) young (immature), (b) mature, (c) old (overmature, climax). Foresters generally understand mature as that stage at which the stand achieves culmination of mean annual increment.

3. A natural, mature stand of trees, not significantly altered by man; may contain trees of various sizes, species, and ages that are part of a dynamic ecosystem (Forest Land Use Liaison Committee 1989).

4. Forests that are relatively old and relatively undisturbed by humans (Hunter 1989).

5. "Old-growth forests are ecosystems distinguished by old trees and related structural attributes. Old growth encompasses the later stages of stand development that typically differ from earlier stages in a variety of characteristics that may include tree size, accumulations of large dead woody material, number of canopy layers, species composition, and ecosystem function" (Old-Growth Definitions Task Group 1989).

d. Spiritual/aesthetic

1. Forests that people identify as old growth, or that give them the old-growth experience or "cathedral effect".

2. Forests that are impressive to most people because

of the size of the trees, the quiet within the stands, the subdued and broken lighting, and the humbling scale.

3. "Ancient" forests that are revered for their heritage value and scarcity.

Attributes

Old growth is fundamentally an ecological concept, and British Columbia old-growth forests generally conform to conceptual/ecological definitions as above, but do not necessarily satisfy all mensurational and structural criteria. The age at which old growth develops and the specific structural attributes that characterize old growth vary widely according to forest type, climate, site conditions, and disturbance regime. Typically, old growth is distinguished from younger growth by several of the attributes listed in Table 1. These attributes include structural, compositional, functional, and aesthetic features.

All old-growth forests do not possess all these attributes. Old growth can include both older forests dominated by early seral species (such as fire-dependent lodgepole pine), and forests in later successional stages dominated by shade-tolerant species. Stands do not have to be climax to be old growth, nor is old growth necessarily "virgin" or "primeval". Old growth can develop following human disturbances. Disturbance is an integral part of the internal dynamics of many old-growth forests (Lertzman and Pe 1990). Canopy openings resulting from death of overstory trees often give rise to patches of small trees, shrubs, and herbs in the understory (gap dynamics). But rates of compositional and structural change are slow relative to younger forests. Different ages or classes of old growth are recognizable in many forest types.

APPLICABILITY OF EXISTING DEFINITIONS AND ATTRIBUTES TO BRITISH COLUMBIA OLD GROWTH FORESTS

I think that old growth is fundamentally an ecological concept, therefore it would be wise to deal with the old-growth issue in an ecological context – at least initially. Economic, social, aesthetic, and political considerations can be applied later to either cloud or clarify the ecological vision.

We reviewed available information on British Columbia old-growth forests to determine the extent to which existing definitions and previously described attributes of old growth were applicable to our forests (Table 2).

Conceptual/Ecological Definitions

Old-growth forests in British Columbia generally fit the conceptual definition, in that they are relatively old (i.e., older than the average catastrophic disturbance interval; Hunter 1989), composed of trees that have exceeded the average life span for the species, more diverse than younger stands, and relatively undisturbed by humans. In some parts of the province, forests that are relatively undisturbed by humans are rare because logging, underburning, and/or cattle grazing has been extensive.

Some old-growth forests in the wetter ecological zones of British Columbia can be termed climax. However, most interior forests have regenerated after catastrophic events such as fires or insect outbreaks and therefore individual stands have not often reached a self-perpetuating climax state.

Mensurational Definitions

Old growth is generally defined as being more than 150 years old, and this seems to be an appropriate age criterion for coastal old growth in British Columbia. In the Ponderosa Pine and Interior Douglas-fir zones, old-growth forests are likely over 200 years old. In the Interior Cedar - Hemlock zone, where forests survive longer, 300 years could be a more appropriate age criterion. In parts of the interior (e.g., Boreal White and Black Spruce zone) where fires have been frequent in the past, forests seldom survive for as long as 150 years.

Old-growth forests of the Coastal Western Hemlock zone are often more than 30 m in height, but this height criterion can not be applied to most forests in British Columbia.

Structural Attributes

Old-growth stands have been defined as having a wide range of tree sizes and ages, a deep multilayered canopy of mature and "overmature" trees, widely

TABLE 1 *Attributes of coastal old-growth forests in northwestern North America*

STRUCTURAL
wide range of tree sizes and ages
large average tree spacing and diameters
deep multilayered canopy of mature and "overmature" trees
individual large, old, live trees
large amounts of coarse woody debris in the form of snags and downed logs
horizontal patchiness (understory and overstory)
vertical diversity (different tree species and heights)
COMPOSITIONAL
usually two or more tree species
understory saprophytic plants and arboreal lichens
habitat for highly specialized and adapted species, including cavity nesting birds, canopy dwelling animals (e.g., bats, flying squirrels), other small mammals (shrews, mice), and large mammals (deer, elk, grizzly bear)
FUNCTIONAL
have existed as stable communities for the latter decades or centuries of their existence
high understory productivity (shrubs and herbs)
detritus based food webs
conservative nutrient cycles, highly nutrient-retentive with rapid internal cycling; important pathways for fixing nitrogen
produce high quality water and fish habitat
primary production high but so is respiration, so these forests tend to be stable in terms of woody biomass accumulation
produce highly valued wood
SPIRITUAL/AESTHETIC
heritage values
evoke respect for elders (veneration of old)
strong lines; humbling scale; colonnade effect
tranquillity; subdued lighting; patches of light and shade; zen views; structural complexity

spaced large trees, and significant amounts of coarse woody debris in the form of snags and downed logs. Coastal Dougals-fir old-growth forests usually possess these attributes. But in interior ponderosa pine and Douglas-fir forests, frequent ground fires have resulted in large, widely spaced trees. There is a limited amount of downed woody debris and tree canopies are generally not deep and multilayered.

In areas where catastrophic fires have been frequent, including the Montane Spruce, Sub-Boreal Pine - Spruce, Sub-Boreal Spruce, and Boreal White and Black Spruce zones, old-growth forests are often younger than on the coast and have abundant downed woody material, but usually lack the large widely spaced trees and deep multilayered canopy.

TABLE 2 *Applicability of some old-growth criteria to mature forests in different ecological zones of British Columbia*

	Forest zones[1]										
	PP	IDF	MS	SBPS	SBS	ICH	ESSF	BWBS	CDF	CWH	MH
MENSURATIONAL											
age 150-200 yrs or older[5]	y[2]	y	?	n	n	y	y	n	y	y	y
beyond culmination of MAI	y	y	y	y	y	y	y	y	y	y	y
140 yrs old and ≥30 m tall[3]	?	?	?	?	?	?	?	?	s	y	s
STRUCTURAL											
wide range tree sizes & ages[4]	y	y	y	n	y	y	y	y	y	y	y
deep multilayered canopy[4]	n	y	y	n	s	y	y	s	y	y	s
large avg. tree diameter[5]	y	y	s	s	s	y	y	s	y	y	y
indiv. large old trees (25/ha ≥ 1 m diam.)[3]	?	?	?	?	?	?	?	?	?	?	?
much var. in mean tree diam[5]	y	y	y	n	y	y	y	y	y	y	y
37 stems/ha ≥ 50 cm diam.[4]	?	?	?	?	?	?	?	?	s	s	?
large avg. tree spacing[5]	y	y	s	n	s	y	y	s	y	y	y
2 or more tree species[5]	n	n	s	n	s	s	s	y	y	s	s
abundant coarse woody debris[5]	n	s	y	y	s	y	y	y	y	y	y
exhibit decadent features[6]	y	y	y	y	y	y	y	y	y	y	y
contain snags[6]	y	y	y	y	y	y	y	y	y	y	y
snags (≥25/ha)[5]	?	?	?	?	?	?	?	?	?	?	?
down woody mat. ≥ 37 tons/ha[6]	?	?	?	?	?	?	?	?	?	?	?
FUNCTIONAL											
high understory productivity[5]	?	?	?	n	s	s	?	?	s	s	s
CONCEPTUAL/ECOLOGICAL											
relatively. old[7]	y	y	y	y	y	y	y	y	y	y	y
relatively undisturbed by human activity[7]	n	n	y	y	y	y	y	y	s	y	y
climax or shifting steady state	y	y	y	y	y	y	y	y	y	y	y
older than avg. dist. int.	y	y	y	y	y	y	y	y	y	y	y
avg. trees reached life exp. for species	y	y	y	y	y	y	y	y	y	y	y

TABLE 2 *continued*

more diverse than younger stages[8]	y	y?	y	y	y	y	y	y	y	y	y
nat. mature stand, not sign. alt. by man, may contain var. size, spp., and age trees[9]	y	y	y	y	y	y	y	y	y	y	y

[1]Forested ecological zones (Pojar 1983): PP - Ponderosa Pine, IDF - Interior Douglas-Fir, MS - Montane Spruce, SBPS - Sub-Boreal Pine - Spruce, SBS - Sub-Boreal Spruce, ICH - Interior Cedar - Hemlock, ESSF - Engelmann Spruce - Subalpine Fir, BWBS - Boreal Black and White Spruce, CDF - Coastal Douglas-Fir, CWH - Coastal Western Hemlock.
[2]y=yes, n=no, s=somewhat or sometimes, ?=unknown
[3] Roemer *et al.* (1988).
[4] Spies and Franklin (1988).
[5] Alaback (1984).
[6] Habeck (1989).
[7] Hunter (1989).
[8] Thomas *et al.* (1988).
[9] FLULC (1989).

Forests that have been disturbed less frequently by catastrophic fires, including forests of the Interior Cedar - Hemlock and Engelmann Spruce - Subalpine Fir zones, are more similar to coastal old-growth stands. These forests have large widely spaced trees, abundant downed woody material, and a deep multi-layered canopy.

Detailed definitions, specifying the sizes and number of trees and snags and amount of downed woody debris, have been developed for some U. S. old-growth coastal forests (Alaback 1984; Spies and Franklin 1988). It is unlikely that these definitions would apply to most forests in British Columbia, although they are probably appropriate for coastal Douglas-fir stands and some forests of the Coastal Western Hemlock zone.

Compositional Attributes

Coastal Douglas-fir, some Coastal Western Hemlock, and some interior old-growth forests have more than two tree species while other coastal, ponderosa pine, and interior Douglas-fir forests often consist of only one tree species. Forests in the other zones include one or more tree species.

Functional Attributes

We currently have very little information on the functioning of old-growth forests in British Columbia. We can assume that forests that are similar in structure and composition to coastal old-growth forests in the U.S. Pacific Northwest will function in a similar manner.

CRITERIA

Here are some considerations relevant to the development of criteria for defining old growth.

Conceptual

Will second-growth plantations develop into old growth? This is theoretically possible, but such long-rotation management is currently anomalous in our intensively managed landscapes. There is no guarantee that such old growth renewal would also replicate the original biological diversity, or provide suitable habitat for old growth-dependent wildlife, or that

such wildlife would still be around.

Disturbance

On the Coast, the most frequent catastrophes are windthrow, mass movements, and insect outbreaks; fire is less frequent but in the long term probable, at least in drier coastal regions. A watershed on the order of 2000 ha or more could probably buffer indefinitely just about any natural catastrophe on the coast. A much larger area would be required in the interior. Another way to deal with the inevitability of disturbance is to replicate old growth reserves.

Mensurational

Available evidence suggests that the important structural and functional attributes develop with age, and in B.C. this means in stands older than 150 to 180 years. Although age may not always be a reliable indicator of old growth status, it is one of the few criteria that could be used to identify the extent of old growth in B.C. using existing forest cover data.

Some of the stands that satisfy the age criterion are not in the climax state (e.g., western hemlock - amabilis fir stands that originated after windthrow on northern Vancouver Island) but in other respects meet the criteria for old growth.

Structural

Height and diameter criteria should be flexible, depending on what is understood by "forest" (e.g., stunted subalpine stands). Structural criteria will have to be developed later using available information from the Ministry of Forests' ecosystem program and new data as they are gathered.

Compositional

Number of tree species should remain variable; in some cases there may only be one species while in other cases four or more exist in old-growth forests.

Functional

The development of functional criteria will require considerable research into old-growth forest functioning.

Minimum Area

Minimum area and effects/implications of habitat fragmentation have yet to be determined; in some subzones and for some forest types the issue is already foreshadowed by what is left, and patterns of land tenure and use.

Even if patches of forest are left, they could be too small or too isolated from other patches to function effectively as habitat for old growth - dependent wildlife (Harris 1984; Norse *et al.* 1986).

PROPOSED APPROACH

We propose that a general conceptual or ecological definition of old-growth forests be adopted, and then working definitions for all ecological zones and major forest types (after Eyre 1980) be developed. Hunter (1989) argues that we should first consider a set of age and disturbance criteria that are likely to have ecological significance. For example, has the forest reached climax, or at least a "shifting mosaic, steady state"? Is the forest older than the average interval between severe disturbances such as wildfire and windthrow? Have the dominant trees reached the average life expectancy for that species? Is it a virgin forest?

Once appropriate age and disturbance criteria are chosen, forest ecologists could develop a unique old-growth definition for the major forest types of the province's ecological zones. These specific ecological definitions should include forest structure and associated plant and animal species.

Another issue that must be addressed is the minimum area required to maintain wildlife and fish habitat and biological diversity. Minimum size for a viable old-growth stand is difficult to specify because it depends on management objectives and on the nature of surrounding areas. However, it will still be necessary to specify for a given old-growth stand a minimum size below which "the extent of edge influence (alteration of interior stand conditions) and vulnerability to catastrophe are unacceptable based on management objectives" (Old-Growth Definitions Task Group 1986).

So we conclude that characterization of old growth

TABLE 3 *Vascular plant diversity in some coastal and interior old-growth forests of British Columbia*

Biogeoclimatic zone/subzone	Number of releves	N (richness)[1]	H (Shannon-Wiener index)[2]
Coastal Western Hemlock zone (CWH)	2889	18.8	2.7
Sub-Boreal Spruce zone (SBS)	1117	31.8	3.4
Very Wet Maritime CWH subzone (CWHvm)	114	18.4	2.1
Moist Cold SBS subzone (SBSmc)	133	27.5	3.3
CWHvm zonal sites	44	15.7	2.6
SBSmc zonal sites	59	26.6	3.6

[1]Mean number of vascular plant species per 400 m^2 releve

[2] $H = -\sum_{i=1}^{s}(p_i)\ (\log_2 p_i)$, where s is total number of species, p_i is the percentage cover value for the i^{th} species, and $(\log_2 p_i)$ is the log to the base 2 of that percentage.

should be done within the context of an ecological classification (by ecological zone, by forest type or ecosystem), and should use multiple criteria including age, structure and function, composition, disturbance regime, and minimum area requirements. We recommend that an old-growth scorecard (Raphael *et al.* 1989) or index of "old growthness" (Spies and Franklin 1988) be developed for each forested biogeoclimatic subzone (Pojar *et al.* 1987) and each major forest type in British Columbia.

OLD-GROWTH FORESTS AND BIOLOGICAL DIVERSITY

The distribution of old-growth forests in British Columbia is related primarily to disturbance history. Parts of the province where the average interval of catastrophic disturbance exceeds 150-200 yrs are more likely to have stands of old growth than are areas where disturbance is more frequent. Old-growth forests are most widespread in the coastal and wetter interior portions of the province, and at higher elevations generally. Consequently, in these regions old growth contributes correspondingly more to overall biological diversity than in more disturbance-prone regions, both in terms of habitat/landscape diversity and species diversity (because such forests harbour certain old-growth dependent and forest-interior species). Old growth dominates (or at least used to dominate) the landscape of these wetter regions, and old stands usually are more structurally complex and have greater within-habitat diversity than young stands.

Components of Diversity

Biological diversity encompasses the full range of natural variety, and includes the genetic diversity of populations, species diversity, ecosystem diversity, and the various ways in which organisms interact and function in their environment (Norse *et al.* 1986; McNeely 1988; Salwasser 1989). This paper does not deal with genetic diversity or with functional diversity. However, we can examine some aspects of both species and ecosystem diversity.

Species Diversity

There is a large literature on species diversity, both on methods of measurement (e.g., Hurlbert 1971; Whittaker 1972; Peet 1974) and on geographic patterns and ecological relationships (e.g., Woodwell and Smith 1969; MacArthur 1972; Whittaker 1975; Begon *et al.* 1986; Scott *et al.* 1987; May 1988). We chose to examine some simple indices of species diversity for vascular plants and terrestrial vertebrates, and some simple comparisons between coastal and interior old-growth forests.

a. Vascular plants

Table 3 presents figures for vascular plant diversity expressed as simple richness (N) and as the general diversity or Shannon-Wiener index (H') (Barbour *et al.* 1980). The data are from releves sampled over the past 15 years by the Ministry of Forests' ecological classification program (Pojar *et al.* 1987), and represent 400m^2 plots in mature coniferous forest. Coastal data are from the Coastal Western Hemlock zone and from stands that were at least 150 years; interior data are from the Sub-Boreal Spruce zone of central interior British Columbia and from stands usually older than 100 years.

b. Terrestrial vertebrates

Table 4 presents merely the number of different species of selected terrestrial vertebrates known to occur in maritime subzones of the Coastal Western Hemlock zone and in moist to wet subzones of the Sub-Boreal Spruce zone. These data are from distributional records maintained at the Royal British Columbia Provincial Museum, from provincial experts (R. W. Campbell, S. Orchard, I.M. Cowan, W. Munro, A. Harestad, personal communications 1990), and additionally for birds, from species lists developed by local naturalist clubs. This information applies to the geographic areas in general, it is not specific to any given parcel of old-growth forest.

Ecosystem Diversity

Ecological maps can, at appropriate scales, provide a good indication or representation of ecosystem diversity, or at least the visible aspects of such diversity. In habitat mapping, map unit or polygon size should give a crude estimate of ecosystem diversity over a forested landscape. We compared habitat maps for which we had roughly comparable information because the same personnel did the mapping, methods were similar, and the maps were at the same scale (1:20 000). The areas included two coastal watersheds where grizzly bear habitat was mapped, the Kimsquit River (Banner *et al* 1985) and the Khutzeymateen River (Clement 1990), which have forests of the Coastal Western Hemlock zone. The two interior, Sub-Boreal Spruce zone map areas were the Smithers Community Forest and Grizzly Lake, site of a study of marten biology (Lofroth and Banci 1989). Table 5 compares the results of the mapping of these largely forested, coastal and interior landscapes.

DISCUSSION

It is impossible to make unequivocal statements about the contribution of old-growth forests to biological diversity, because of the current lack of knowledge about many of the components of diversity. We have tried a partial approach, using existing information.

Vascular Plants

The data base for vascular plants in mature forests of British Columbia is reasonably good, because of extensive sampling and the fact that vascular plants are fairly "accessible" and well known. Based on the characteristics of old-growth stands, we would expect greater vascular species diversity in interior forests (of the Sub-Boreal Spruce Zone, for example) than in coastal forests because SBS stands are more open, have more light and generally better developed understories with more seral remnants, and less dominance by Ericaceae and bryophytes. According to our data (Table 3), SBS old-growth forests have

TABLE 4 *Number of species of selected terrestrial vertebrates in some coastal and interior subzones of British Columbia*

Vertebrate taxon	Maritime Coastal Western Hemlock subzones	Moist to Wet Sub-Boreal Spruce subzones
Amphibians and Reptiles	15	6
Birds[2]		
falconiformes	13	12
gallinaceous	3	6
owls	12	9
woodpeckers	7	8
passerines	80	88
Total	115	123
Mammals[3]	60	54

[1] Non-marine, non-estuarine species; no strictly urban species.
[2] Breeding, wintering, or year-round resident populations.
[3] Some small mammals restricted to the Fraser Valley Lowland not included.

more species diversity than CWH old-growth forests. But remember that this is for vascular plants only; the situation would probably be reversed if we looked only at bryophytes.

Terrestrial Vertebrates

Current information indicates there are 448 species of birds, 143 species of mammals, 19 species of reptiles, and 20 species of amphibians in the terrestrial vertebrate fauna of B.C. (Cannings and Harcombe 1990). From basic ecological principles, we might expect there to be higher vertebrate species diversity in a coastal zone than in an interior zone. Why?

Wildlife habitat use in British Columbia reflects the avoidance of harsh winters (migration, hibernation, winter range, etc.); there should be more year-round and wintering populations on the coast (CWH) than in the central interior (SBS) simply because the winter living is easier (warmer, less snow). Also, more species should occur in warmer southern or coastal zones than in north temperate and subarctic zones, and wildlife species diversity increases with increased habitat productivity (Ricklefs 1988). The CWH is warmer and more productive than the SBS.

Furthermore, coniferous forests make up a large proportion of wildlife habitat in both coastal and interior B.C. and coastal coniferous forest (especially old growth) has greater structural heterogeneity than SBS coniferous forest.

Countering these three trends would be an anticipated higher level of habitat or landscape diversity in the SBS, due to more active disturbance regimes (fire, insects, disease, erosion, logging, clearing, livestock grazing); a greater variety of successional stages and

TABLE 5 *Habitat mapping at 1:20 000 of two coastal and two interior forested landscapes in west centralBritish Columbia.*

Locality	Map area (ha)	Number of polygons	Mean polygon size (ha)
COASTAL WESTERN HEMLOCK ZONE			
Kimsquit River	5 000	419	12
-lower valley (some 70 year old logging)	29 943	1 058	28
- entire watershed			
Khutzeymatteen River	33 000	1 200	27
SUB-BOREAL SPRUCE ZONE			
Smithers Community Forest	1 840	230	8
Grizzly Lake	5 910	640	9

pathways and more coverage by successional ecosystems; and perhaps a greater variety and distribution of azonal habitats such as wetlands, shrub-steppe, cliffs, riparian habitats, lakes and ponds.

As Table 4 indicates, there were no obvious differences in simple richness of terrestrial vertebrate species between the CWH and SBS, except for herptiles. One would expect this for herptiles, because they are ill adapted to the cold continental climate of the SBS. Overall, there would of course be more birds in the CWH if the entire avifauna was considered, because of marine birds and a greater component of shorebirds than in the SBS.

Ecosystems

There appears to be greater ecosystem and landscape diversity in the SBS than in the CWH, at least for those areas where we have comparable habitat maps (Table 5). The greater habitat heterogeneity of interior forests is probably a result of more active disturbance regimes and more complex succession. Besides the underlying topographic and edaphic variation, the drivers of ecosystem diversity in both of these forested zones are largely disturbances. Fire, insect outbreaks, windthrow, logging, and agricultural clearing are the main disturbances in the SBS (Pojar *et al.* 1984), whereas fluvial processes, mass movements, windthrow, and logging prevail in the CWH - at least on the north coast (cf. Brady and Hanley 1984; Harris 1989; McLellan *et al.* 1990; Parminter 1990).

So there are indications that interior old-growth forests have higher vascular plant diversity than coastal old growth, and that interior forests in general have greater ecosystem and landscape diversity than coastal forests - even though coastal old growth is more structurally heterogeneous. But that only scratches the surface of biological diversity. There are so many different kinds and groups of organisms about which we know little, so many interactions of which we are ignorant, so many aspects to biodiversity.

Just consider the fractal geometry of forest vegetation. In fractals, lines are jagged not smooth, and exhibit a peculiar kind of nested irregularity (Sugihara and May 1990). The notion of fractal dimension could apply to the measurement of available habitat space. For example, some arthropods live on vegetation (leaves or needles) whose surface area is believed to be fractal; i.e., the surface area appears to expand greatly at finer and finer scales (Sugihara and May 1990). Fractal scaling of the vegetational substrate provides small arthropods with much more living space than is available to larger ones on the same substrate. Organisms an order of magnitude smaller in length can have 3 to 10 times more available living space, and therefore presumab-

ly there could be many more species of small, canopy arthropods (cf. Schowalter 1989).

CONCLUSION

So what we have attempted to do in this paper is present a balanced portrait of old-growth forests in British Columbia and recommendations as to how they should be characterized. Old-growth forests are more widespread on the coast than in the interior, and contribute correspondingly more to coastal biodiversity. Therefore, to conserve biodiversity, we need proportionately more coastal old growth. And we have also presented some approaches to dealing with the complex topic of biological diversity, using coastal and interior forests as the habitats to explore this marvelous and sometimes strange notion.

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