OLD GROWTH

LITERATURE REVIEW

by

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OLD GROWTH LITERATURE REVIEW

1. INTRODUCTION: WHAT ARE OLD GROWTH FORESTS AND WHY ARE THEY IMPORTANT?

What are old growth forests? The term "old growth" refers to two separate but related concepts:

1. a phase in the life cycle of all forests, and
2. a critical part of the functioning forest landscape.

Ecologists often describe old growth forests based on their distinctive composition and structure. Composition refers to the plant and animal species contained in the forest ecosystem, from the massive to the microscopic. Structure refers to the characteristics and arrangement of the species and non-living elements in the ecosystem.

While the species composition of old growth forests may be duplicated in other forest phases, certain structural features are found only in old growth. These special structural attributes include large trees, snags, large fallen trees, and large accumulations of forest biomass. We will see later why these structures are essential to fully functioning forest landscapes.

Working together, compositional and structural attributes support the unique ecological functions of old growth forests. Storage of carbon, filtration of water, and capture of nitrogen are three functions carried out better in old growth than in other types of forests.

Old growth forests maintain large, uniform, high quality timber volumes over time, and support stable or slowly evolving communities of plants and animals (Haynes 1986, Franklin and DeBell 1988). Thus, old growth forests are steady state ecosystems. Although individual organisms die and are replaced, the dynamics and biomass of the ecosystem remain constant over time, until some external disturbance damages or destroys the forest cover. The natural forest then begins advancing through successional stages until it once again reaches the old growth phase (Bormann and Likens 1979).

Why are old growth forests important? Old growth forests are a significant and unique part of the diverse ecological web formed by natural forest landscapes. Human activities or natural disturbances in one part of the forest landscape can affect many other parts of the landscape. As an important part of the landscape ecology of natural forests, old growth provides unique resources for plants and animals(including people) within the landscape (Harris 1984, Franklin et al 1986).

The timber industry generally encourages logging of "decadent" old growth forests so that they can be replaced by "vigorous" young tree farms. However, the unique structure and composition of old growth forests facilitate several critical ecological functions which cannot be duplicated in short rotation commercial tree farms. For example, according to Franklin et al (1981):

1. Old growth forests generally contain an accumulation of biomass on the forest site, which enriches the forest soil over time.
2. Old growth forests provide high quality, naturally filtered water from stable creeks.
3. Old growth forests provide a continuous supply of diverse, durable structures (large trees, snags, and fallen trees) which provide habitat for diverse plant and animal communities. These structures remain after natural events destroy an old growth forest and provide diversity in younger forests.

Old growth forests are also important because we do not fully understand their functions, the life forms they support, or their importance to the ecology of commercial forests. The genetic information which ancient forests contain has never been assessed. Both common sense and present knowledge indicate the danger of eradicating old growth from the forest landscape, or even reducing the proportion of old growth forests beyond a certain, unknown point. We do know that forests are a major global ecosystem and that the natural forest landscape was largely old growth. From this, we can safely conclude that global, landscape, and stand level needs exist which require a landscape dominated by old growth. Our failure to understand these needs is no justification for greatly altering the proportion of old growth forests in a region or on the planet (Thomas et al 1987, Franklin and Spies, 1989). Even with improved forest management techniques, it is unlikely that humans will ever be able to create old growth forests. Ethically, the human species does not have the right to cause the extinction of the old growth ecotype and the many species which it contains (Juday 1988).

These two questions--what is old growth and why is it important?--are discussed in more detail in the following pages. We will first discuss the composition and structure of old growth forests, including a brief description of the primary old growth forest types of B.C., a list of the types of plants and animals associated with old growth forests in B.C., and a discussion of the ecological functions of old growth forests at all levels, from the microscopic through the macroscopic. This information is very preliminary in nature and needs to be researched further, both in the field and in existing data bases. Finally, we will provide a basic outline regarding old growth forest protection.

This discussion takes place on two levels simultaneously: the stand ecology level and the broader landscape ecology level. Although we will avoid repetition as much as possible, the topics of structure, composition, function, and protection of old growth forests are interrelated, and some repetition is unavoidable.

The majority of the information presented in this review is from U.S. sources. Equivalent information for British Columbia forests simply does not exist at this time (Lertzman 1989, Dunster 1989). According to Lertzman (1989):

> *Most of the research on old growth has been conducted in Washington and Oregon and we know much less about the dynamics of old growth forest types of the interior and northern BC. This lack of data is in itself a key issue: the old growth of the interior and northern forests is not as massive, or as old as on the coast, but it is just as validly considered "old growth." Problems of loss of diversity and fragmentation are just as important in those [northern and interior] forest types.*

The extrapolation of information from the northern U.S. over much a geographical distance, and often over such climatic variation, is not completely desirable, but no alternatives exist. In our opinion, while absolute measurements (such as tree size or volume) cannot be projected over such a distance, general information from the U.S. about old growth composition, structure, and ecological function is applicable to Canadian forests. Various individuals and organizations such as the Association of B.C. Registered Professional Foresters, the Canadian Parks Service, and the Forest and Land Use Liaison Committee apparently concur with this approach, as they also use U.S. sources for much of their information on old growth forests. There is also general agreement that more research into British Columbia old growth forests is needed.

2. WHAT IS OLD GROWTH? - COMPOSITION

Composition refers to the plant and animal species which make up the forest ecosystem. According to Franklin et al (1981), "Old growth forests obviously differ in composition from young stands. Ecological succession produces changes in the array of plant and animal species as well as in their relative abundance."

Despite the common perception that old growth means spectacular giant trees, tree size is not the critical factor which determines old growth, nor is forest age. In some old growth forest types, such as lodgepole pine, the trees are small relative to other old growth forests (Franklin and Spies 1983). However, much of the scientific and public attention on old growth has focused on the ecotypes which produce giant trees, which may have led to distorted management decisions (Juday 1988). Particular old growth forest compositions are unique and important because of their structural attributes and the related functions which their structure and composition facilitate.

A preliminary listing of the old growth forest types of British Columbia is presented in section D below. However, little is known about the composition of the communities of plants, animals, and microorganisms in B.C. old growth forest ecosystems. Some information is available regarding which of the larger, more visible species <u>occur</u> in old growth forests, but little information is available as to what species <u>depend</u> on old growth or about the nature of that dependence. Information is particularly limited with regard to the small or microscopic organisms of the soil community, which make up only 20% of the forest biomass but which may consume over 50% of the forest energy production (Franklin 1990).

The following discussion will focus primarily on old growth composition as represented by tree species. This is not meant to imply, however, that trees are the only significant species in old growth. The information given below must be understood in light of the fact that a forest is an interconnected web of organisms which focuses on sustaining the whole, and not on producing any one part or commodity.

2.1 FOREST SUCCESSION AND OLD GROWTH COMPOSITION

Old growth forests are <u>dynamic</u> steady state ecosystems. Although the total timber volume and the general forest structure of an old growth forest do not change substantially over time, individual organisms within the ecosystem die and are replaced (Haynes 1986, Franklin and DeBell 1988, Bormann and Likens 1981). This phenomenon can cause a slow shift in species composition as the forest ages. With trees this process of gradual change is largely controlled by the relative tolerance to shade of the various tree species in the forest, and by the principles of forest succession.

Most plant communities are shaped by competition for resources among individual plants and among plant species. In many forest communities, more plants are trying to grow in any given area than the light, water, and nutrient resources of the forest site can support. Plants which are best adapted to the site and existing conditions will use the available resources most efficiently and will prosper and grow. Species which are marginally adapted to site conditions will remain alive, waiting for a change in conditions, but they will not thrive. Plants which are poorly adapted to the ecological conditions will fail and die.

Some tree species need full or almost full sunlight to grow. These shade intolerant species have evolved to exploit the ecological niche which occurs after a fire or windstorm has created an opening, large or small, in the forest. Called <u>seral</u> species, these trees grow more swiftly than shade tolerant species which may also be trying to colonize the same site. In this way, seral species out compete other species and gain dominance on the site (Bormann and Likens 1981). However, these species frequently cannot replace themselves when they age and die, because they cannot regenerate in the shade beneath the forest canopy. Thus, seral tree species usually only dominate the site for the life span of the original colonizing trees. For long-lived seral species such as Douglas-fir, this life span can be from 800 to 1200 years (Fowells 1965). Seral tree species are often found mixed with shade tolerant trees in old growth forests. Small forest openings, created as trees die for various reasons, furnish locations for successful reproduction and growth of seral trees on an ongoing basis.

Shade tolerant species adopt a slow but steady approach to growth and stand dominance. Although shade tolerant tree species generally cannot grow as fast as seral tree species, they can regenerate and grow in the partial light beneath a seral forest canopy and eventually grow up through the canopy to attain dominance over the site (Bormann and Likens 1981). After attaining dominance, these shade tolerant species can continue to regenerate on the shaded forest floor, and will occupy the site until a catastrophic disturbance starts the process over again. Shade tolerant species are termed <u>climax</u> species, and the forests which they form are called climax forests. The entire process--disturbance through seral forest through climax forest--is termed <u>forest succession</u>.

Old growth forest types can contain seral species, climax species, or a mixture. One of the best known old growth forest types--coastal Douglas-fir and western hemlock--is a mixture of a long-lived seral species (Douglas-fir) and a climax species (western hemlock). The species composition of such forests changes naturally as the seral species slowly dies and is replaced by the climax species. If the forest is not disturbed by wind, fire, landslides, volcanoes, or other natural or people induced processes, the climax species will virtually replace the seral species. One study estimated that this process would take 1205 years in a coastal Douglas-fir and western hemlock forest (Franklin and DeBell 1988). Thus, old growth forest composition can change slowly through forest succession as the forest ages.

The 22 coniferous tree species found in British Columbia are listed in Table 1, in order of approximate shade tolerance, with the most shade tolerant species listed first.

Table 1: Coniferous tree species found in B.C.

	Common Name	Scientific Name
Most	Western yew	Taxus brevifolia
Shade	Amabalis fir	Abies amabalis
Tolerant	Sub-alpine fir	Abies lasiocarpa
	Grand fir	Abies grandis
	Mountain hemlock	Tsuga mertensiana
	Western hemlock	Tsuga heterophylla
	Black spruce	Picea mariana
	Western red cedar	Thuja plicata
	Yellow cedar	Chamaecyparis nootkatensis
	Engelmann spruce	Picea engelmannii
	Sitka spruce	Picea sitchensis
	White spruce	Picea glauca
	Douglas-fir	Pseudotsuga menziesii
	Western white pine	Pinus monticola
	Limber pine	Pinus flexilis
	White bark pine	Pinus albicaulis
	Yellow pine	Pinus ponderosa
	Lodgepole pine	Pinus contortus
	Jack pine	Pinus banksiana
Least	Alpine larch	Larix lyallii
Shade	Tamarack	Larix lariciana
Tolerant	Western larch	Larix occidentalis
		(from Watts 1983, Fowells 1965)

In old growth forest phases, some of these species occur more commonly than others, and some are not major components of the old growth forests of B.C.

2.2 FIRE HISTORY AND OLD GROWTH COMPOSITION

The pattern of forest fires over time has had a profound effect on the composition of old growth forests. Before the advent of modern logging, fire was the most significant factor in the establishment, evolution, destruction, and reestablishment of coastal forests (Spies and Cline 1979), interior forests (Habeck 1988), and boreal forests (Pojar 1984). Natural fires which killed most of the forest trees usually occurred on cycles varying from 50 years to about 1000 years, depending on the forest ecosystem type (Kimmins 1990, Agee 1990).

Timber managers who defend clearcut logging and slash burning allege there is a similarity between a forest fire and a clearcut/slash burn, and maintain that such conventional timber management practices "mimic nature." However, the disturbances caused by logging and by natural fire are vastly different in three important aspects (Hansen 1990, Grant 1990):

1. <u>Repeat time</u>--Logging is planned to occur on 60-120 year intervals, a much shorter period than the natural repeat time of major "stand replacement" fires in many forest ecosystems.
2. <u>Biomass removal</u>--Logging removes the vast majority of the trees in the form of logs. In a natural fire, all the "bodies" (dead trees) remain to play important ecological roles in forest change.
3. <u>Maintenance of tree cover</u>--Approximately 90% of timber extraction in British Columbia is carried out by clearcutting (Ministry of Forests 1990), which leaves no "merchantable" trees on an area. Wildfires commonly leave a significant portion (as much as 30%-70%) of the trees alive.

Hence, natural fire has few similarities compared to logging and timber management. Natural fire is a process of forest change. Logging is forest removal.

Most current forests in B.C. evolved after a catastrophic fire, and/or under the influence of repeated forest fires. British Columbia old growth forest types can be divided into three general groups, based on differing climatic areas and differing fire histories due to climate:

- coastal old growth forests,
- interior old growth forests, and
- boreal old growth forests.

"Coastal" refers to areas within a moist maritime climate zone or a zone of topo graphical induced rainfall, while “interior" refers to areas within a dry continental climate zone or a leeward rain shadow. In simple terms, coastal is wet and interior is dry. This terminology does not reflect fine gradations between the two, or the fact that some interior areas have moist climates due to high levels of precipitation. However, these descriptions are suitable for this general discussion. Boreal forests are northern forests, adapted to short growing seasons, harsh winters, and limited soil fertility.

The moist, coastal forests are less susceptible to fire than dry interior forests. Before the advent of extensive fire suppression activity, fires in coastal forests were less frequent than in interior forests. Estimates of the average time span between major fires in coastal forests range from 230 to 450 years (Franklin 1988, Agee 1990)--a time span sufficient for shade tolerant climax tree species to become well established at all levels of the forest canopy, and for the deep, multi-layered canopy common to coastal old growth forests to develop.

This deep, full canopy contains large quantities of available fuel for a forest fire. The fuel stretches uniformly throughout the forest and extends well off the ground. However, the naturally moist conditions common in coastal forests may result in this fuel being relatively non-combustible much of the time (Perry 1988). Although fire is infrequent in such stands, it is in the long run inevitable (Pojar and Hamilton 1989). Due to the fuel conditions, fire in coastal forests can quickly become a major, stand replacing conflagration which kills most (but almost never all) of trees. Following such a fire, succession begins again with a new forest of seral tree species(Habeck 1988, Hemstrom 1990).

Some of the wetter coastal old growth forests may never have experienced "stand replacement" fires. Possibly some west coast western hemlock forests may have only experienced small spot fires which had little impact on the composition of the forest landscape.

Before modern fire suppression, the average fire interval in the drier southern interior varied from 5 to 40 years (Habeck 1988, Achuff 1989). Stand replacement fires were no more common than on the coast, but forest succession and composition were altered by a pattern of frequent light fires (Habeck 1988), which prevented the buildup of high levels of fuel. Most of the tree species native to the interior have thick, corky bark which is reasonably fireproof and can survive repeated light fires. Any thin barked climax tree species which naturally regenerated beneath such an interior old growth forest were incinerated. As a result, many interior forests were maintained in an open, parkland condition for centuries, composed almost solely of seral tree species. These forests may include trees of many different ages due to gradual processes of mortality and recruitment, but they lack the deep multi-layered canopy associated with coastal old growth forests (Habeck 1990).

Northern interior boreal forest have a distinct fire history. The spruce and pine trees in these forests do not attain the dimensions of the larch and Douglas-fir trees in the southern interior, and lack the fire proof bark of the southern species. Limited tree height, and the high shade tolerance of spruce, result in uniform fuel loads which extend into the forest canopy. These forests are susceptible to catastrophic fires, and have a mean fire return time of 140 years (Pojar 1984). As a result, boreal old growth forests are often younger than coastal old growth forests. Boreal old growth may have abundant dead and down woody material, but usually lacks the large widely spaced trees and deep multi-layered canopy common to coastal old growth (Pojar and Hamilton 1989).

Due to these differing fire histories, coastal and moist interior old growth forests tend to be composed of shade tolerant, climax tree species, often with an overstory or scattering of long lived shade intolerant seral species. There is sufficient time between fire disturbances under coats conditions to develop this type of forest composition. Dry interior old growth forests tend to have compositions weighted to shade intolerant seral tree species with open under studies. Notable exceptions exist in interior wet belt forests where fire history is similar to coastal situations. Here old growth forests composed of climax species such as western red cedar and western hemlock are common. The ecology of interior forests is now changing due to modern fire suppression, but the old growth forests of today reflect a pre-fire suppression ecology (Habeck 1988). Boreal old growth forests are composed of typical boreal tree species (lodgepole pine, white and black spruce, deciduous trees), which generally do not attain the size or age of southern old growth forests.

2.3 WINDSTORMS AND FOREST SUCCESSION

Coastal forests are also periodically disturbed by hurricane force winds. Windstorms can blow down large tracts of standing forest, initiating a successional process. However, wind-caused forest mortality creates a different successional pathway than does fire mortality. Wind increases the proportion of shade tolerant species, such as western hemlock and the true firs. These species already exist in various sizes in the understory of all coastal old growth and many mature forests. Some proportion of this shade tolerant understory will survive the wind disturbance, and be released to grow to maturity. Thus, the replacement forest will contain significantly more shade tolerant species from the start of succession. Such a forest may never develop the overstory of massive, shade intolerant tree species and the heavy loadings of coarse woody debris associated with fire successional forests (Spies and Cline 1979).

2.4 OLD GROWTH FOREST TYPES IN BRITISH COLUMBIA

The following pages present capsule descriptions of the main old growth forest types, or tree species groups, which are found in British Columbia. This list is not definitive, but will indicate the extent and variety of old growth forests in the province. We have used broad, inclusive species groupings instead of precise groupings. Ecologically, this choice reflects the fact that forests are a variable continuum and that forest tree species have overlapping and variable natural ranges. Administratively, this choice represents the fact that the available data on the species composition of B.C. old growth forests is often based on estimates from aerial photographs. Sound management of remaining old growth forests required more detailed and accurate information from an improved forest inventory.

Each of the old growth forest types discussed below is a separate biological community, with specialized, perhaps unique, associations of trees, shrubs, herbs, mosses, lichens, fungi, invertebrates, amphibians, birds, mammals, and microorganisms. It is beyond the scope of this report and also beyond the scope of existing knowledge to describe all life forms in any particular forest type.

Frequent reference is made in the following discussion to biogeoclimatic zones. The forest ecosystems of B.C. can be classified into 14 biogeoclimatic zones, each of which defines a unique ecosystem type. Different ecosystem types contain different mixtures of native tree species, and each type has a distinctive climax old growth forest type. Some trees which are considered seral species, such as lodgepole pine and Engelmann spruce, can also form old growth forests, and occur in more than one biogeoclimatic zone. Other tree species, such as Sitka spruce, occur in only one biogeoclimatic zone. We will use the biogeoclimatic zones to define the approximate range of the various old growth forest types under discussion.

2.4.1 Coastal Douglas-Fir

Coastal Douglas-fir old growth forests are the most well known and the most studied form of old growth. This is the forest type which most people picture when they hear the words "old growth forest." Douglas-fir occurs in pure stands and in association with western red cedar on southeastern Vancouver Island and the Gulf Islands--the area known as the Coastal Douglas-fir biogeoclimatic zone. Mixed forests of the Douglas-fir and western hemlock type are found over most of eastern and central Vancouver island, and on the mainland coast opposite Vancouver Island. These forests occur at elevations below 500 m in the Coastal Western Hemlock biogeoclimatic zone (Roemer et al 1988). Examples of these forest types are also found in the United States Pacific Northwest, which is the source of much of our current knowledge regarding old growth forests.

Douglas-fir usually prefers moderate to full sunlight for regeneration and early growth. Douglas-fir forests often begin after a catastrophic disturbance which destroys most or all of the existing forest cover and permits full light to reach the forest floor. However, spot fires or small openings created by other disturbances also provide locations for Douglas-fir regeneration.

Douglas-fir is an extremely long-lived species. Ages in excess of 500 years are reasonably common, and individual tree may reach 1200 years (Fowells 1965, Spies and Cline 1988). The longevity and immense size of the trees and fallen trees provide a forest structure which supports the unique ecological functions of this old growth forest type.

Due to the desirability of Douglas-fir wood and the accessibility of these forests, most old growth coastal Douglas-fir has been logged and/or lost to urban and agricultural uses. Remaining coastal old growth Douglas-fir is badly fragmented and exists only at an individual stand level. Perhaps the best known example of this old growth forest type is the forest fragment called Cathedral Grove, located 20 km east of Port Alberni on Vancouver Island.

2.4.2 Coastal Red cedar

Western red cedar is a another long-lived forest tree species, which can attain sizes and fulfill ecological roles similar to Douglas-fir (Franklin et al 1981). Red cedar is a shade tolerant species, which may exist in self-perpetuating climax forests. Red cedar is also commonly associated with Douglas-fir, western hemlock, Sitka spruce, and yellow cedar.

2.4.3 Coastal Western Hemlock

Western hemlock is an extremely shade tolerant species, retaining green, healthy limbs in areas which receive very little light. As a result, old growth hemlock forests tend to have dense, irregular canopies which cast heavy shade at ground level and produce large amounts of acidic litter, resulting in patchy undergrowth, often dominated by young hemlock trees (Roemer et al 1988). Hemlock is commonly associated with amabalis fir. Old growth hemlock-fir forests are the typical climax forest type in the wetter portions of the Coastal Western Hemlock biogeoclimatic zone.

Old growth forests formed of western hemlock and associated species (red cedar, amabalis fir, Sitka spruce, and subalpine fir) are the most widespread form of remaining coastal old growth forest. Except in the driest parts of the Straits of Georgia, variants of this old growth type occur virtually everywhere on the coast, from sea level to the lower boundary of the subalpine forest (Roemer et al 1988).

2.4.4 Coastal Mountain Hemlock

Mountain hemlock is a subalpine tree species of the coastal mountains. Like western hemlock, mountain hemlock is a shade tolerant species which can regenerate in full shade beneath a closed forest canopy. Old growth climax stands of mountain hemlock, often associated with amabalis fir, subalpine fir, and/or yellow cedar are found throughout the Mountain Hemlock biogeoclimatic zone. The climate of these areas is typically subalpine--cool or cold and wet, with heavy snow cover for at least six months of the year (Roemer et al 1988).

Mountain hemlock old growth forests are similar in appearance to coastal hemlock. The chief difference is a general reduction in tree size due to harsh growing conditions, which exert increasing influence as elevation increases.

2.4.5 Coastal Yellow Cedar

Yellow cedar is another shade tolerant tree species, although less so than either red cedar or hemlock. It is one of the slowest growing and longest lived of the western conifers. Yellow cedar in excess of 1200 years in age are not uncommon (Fowells 1965, Roemer et al 1988).

Yellow cedar and its associates (primarily western hemlock and amabilis fir) form old growth forests at mid to upper elevations, and form subalpine forests with mountain hemlock in some locations. Although the stature of the trees in these forests varies with the severity of the site and climate, yellow cedar can attain sizes and fulfill ecological roles similar to Douglas-fir in old growth forest types(Franklin et al 1981).

The wood from this species is extremely beautiful and durable, and is in great demand by artisans and crafts people, as well as in Japan where it has spiritual significance.

2.4.6 Coastal Sitka Spruce

The Sitka spruce old growth forest type has become famous in recent years, due to the interest generated by South Moresby Island and the Carmanah Valley. According to Roemer et al(1988):

> *This forest type occurs along the length of the B.C. coast but in its typical form is restricted to a narrow shoreline fringe characterized by a hyper maratime climate accentuated by sea spray and frequent fogs. The belt widens from south to north so that on the Queen Charlotte archipelago and on the northern mainland coast Sitka spruce extends further inland and further up the mountain slopes.*

Common associates of Sitka spruce are western hemlock, western red cedar, yellow cedar, black cottonwood and red alder(Roemer et al 1988).

2.4.7 Interior Douglas-Fir

As a fully functioning forest in the landscape, this old growth forest type may be virtually extinct. According to Pojar (1980), "Some forest habitats, such as mature, lowland, productive Douglas-fir forests older than 150 year shave nearly vanished from the B.C. scene."

Interior Douglas-fir old growth would once have occurred over a variety of habitats in several biogeoclimatic zones. Habeck (1988) notes the existence of riparian zone Douglas-fir old growth forests, and Achuff (1989) identifies dry site montane Douglas-fir old growth in the Rocky mountains. We would speculatively add to this list a moist southern interior (Columbia-Kootenay) Douglas-fir old growth type, which would likely be markedly similar to coastal Douglas-fir old growth.

Many younger forest areas throughout the Interior region contain scattered old growth Douglas-fir "veterans"--trees which survived the fire which created the younger stand. In locations where these veteran stands are sufficiently dense, the forest may approach old growth status. Such stands should receive high priority for protection from human disturbance.

2.4.8 Interior Western Larch Forests

Western larch is found only in the southeastern portion of British Columbia, primarily confined to the lower, more accessible areas throughout the Interior Cedar Hemlock biogeoclimatic zone. Larch is a fire dependent, long lived seral species which can grow to the immense sizes needed to provide the structural attributes of a classic old growth forest. Pure larch old growth stands likely once existed in southeastern British Columbia in gentle valley bottoms. However, these forests were entirely liquidated (other than remnant trees) by logging, railway construction, and settlers. The remaining B.C. larch forests are largely mixed species forests of larch, Douglas-fir, and pines.

2.4.9 Interior Cedar Hemlock

This old growth forest type is composed of the same primary tree species found in the coastal old growth cedar hemlock forests discussed above. Interior cedar hemlock forests are found throughout the Interior Cedar Hemlock biogeoclimatic zone, which is the second most productive forest area after the Coastal Western Hemlock zone. The interior cedar hemlock forests receive significantly less rainfall than the coastal forests, but a great proportion of the available precipitation falls during the growing season, thereby minimizing summer dry spells. As a result, the two areas share many ecological features (Ketcheson et al 1983).

As a predominantly valley bottom forest type, the original old growth forests of this type have been subject to extensive logging or to flooding by reservoirs. Most, if not all, of the high quality old growth cedar hemlock forests are gone or currently threatened.

The areas of low timber quality old growth Interior Cedar Hemlock forests which were by-passed in earlier days by the timber industry are now threatened by an expanding pulp industry and also by conventional timber managers who see these isolated old growth forests as "problem forest types “which are not contributing satisfactorily to timber yield. Foresters classify these forests as decadent, and often assert that these forests are rotting faster than they are accumulating wood fibre, and are thus losing timber volume. Although available knowledge indicates that this supposition is not true (Haynes 1986, Debell and Franklin 1987), timber managers wish to clearcut these last remnants as soon as possible in order to establish short rotation plantations (Holm and Lawrie 1989).

2.4.10 Interior Ponderosa Pine

Ponderosa pine (also called yellow pine) is a long lived, seral species well adapted to hot, dry sites. Ponderosa pine is well adapted to a fire dominated ecology, with thick bark which can withstand moderate intensity fires. This species is found in mixed stands or small pure pockets on dry sites throughout the Interior Cedar Hemlock zone, and becomes a dominant species in the hotter and drier Interior Douglas-fir and Ponderosa Pine-Bunchgrass zones. Fires are common in the dry climatic areas favored by ponderosa pine, and open canopied, savannah forests frequently develop under natural conditions. Such stands frequently contain limited numbers of snags and very little coarse woody debris because of the repeated fires which determine the composition of the ecosystem (Weaver 1943, Habeck 1988, Franklin 1983).

Ponderosa pine forests tend to occur in a narrow strip along the lower slopes of interior valleys, frequently between rock outcrops. Forests in such locations are extremely exposed to human use and logging. Pure ponderosa pine old growth, or mixed stands with Douglas-fir, may still exist, but are certainly not common.

2.4.11 Interior Lodgepole Pine

Interior lodgepole pine is a small, relatively short-lived seral species, intolerant of shade, very fast growing, and completely adapted to a fire dominated ecology. Lodgepole pine lacks the thick, fireproof bark of ponderosa pine, Douglas-fir, and western larch, relying on rapid growth and prodigious regeneration capabilities to thrive in a fire dominated ecosystem.

Lodgepole pine is maintained in extensive pure or mixed stands throughout the interior of B.C. The species is extremely hardy, and occupies sites after fires in all forested interior biogeoclimatic zones. Where fires are infrequent, pine is successionally replaced by longer lived tree species. However, in areas of frequent fire, such as the West Chilcotin region, pine tends to becomes the effective climax species. Lodgepole pine climax forests can also occur on sites which are too dry and cool to support other tree species (Pojar 1984).

Old growth lodgepole pine forests occur when a pure or near pure pine forest escapes fire for a sufficient period of time. We have measured lodgepole pine forests that are greater than 220 years in age, with individual trees greater than 300 years old. These old growth forests feature large trees for the species, with sweeping, smooth boles. Old growth lodgepole pine forests are unusual, and their relative rarity may indicate that these old growth areas are very ecologically significant within the forest landscape.

2.4.12 Interior Spruce And True Fir Forests

Interior spruce (white and Engelmann spruces) and true fir "balsam" (subalpine fir) forests occur throughout the interior of the province in two subalpine biogeoclimatic zones: the

Engelmann Spruce-Subalpine Fir zone (southern interior)and the Spruce-Willow-Birch zone (northern interior). These forests are comprised of subalpine fir mixed with Engelmann spruce in the south and white spruce in the north. Engelmann spruce and subalpine fir forests are also found in the much smaller Montane Spruce zone, a scattered mid-elevation zone in the southern half of the province.

Engelmann spruce and white spruce function as either long lived seral species or co-climax species with subalpine fir throughout these forests. Spruce tends to be the dominant species at lower elevations while subalpine fir, with its narrow, snow shedding crown, becomes dominant in upper elevation, snow dominated ecosystems.

Both spruce species are long lived, and ages of 500 to 600 years are not uncommon. Subalpine fir is generally a smaller tree than spruce on any given site, and frequently occupies the lower to mid canopy level in old growth spruce-true fir forests (Alexander 1987, Fowells 1965). Because of these factors, spruce is more likely to provide the large trees, spreading crowns, and multi-layered canopy which characterize an old growth ecology.

Spruce and true fir old growth forests grow on upper mountain slopes and in cirque basins throughout the southern and central interior. These forests were protected from human encroachment by their relative inaccessibility for many years. Although logging has fully invaded most subalpine areas in the last 20 to 30 years, substantial areas of old growth spruce-subalpine fir forest remain. However, we suspect that many of the best quality, most productive stands have been logged, and that many of the remaining forests are severely fragmented.

2.4.13 The Boreal Forest

The boreal forest is composed of a mixture of white and black spruce, lodgepole pine, trembling aspen, subalpine fir, birch, and tamarack (Annas 1983). The boreal forest in B.C. occurs on an extension of the Great Plains in the northeastern part of the province and in lower elevations of the main valleys west of the northern Rocky Mountains. This area is classified as the Boreal White and Black Spruce biogeoclimatic zone. The climate features long, very cold winters and short growing seasons. Discontinuous permafrost is found in the northeastern parts of the zone.

Old growth forests, as we commonly think of them, may not exist in much of the boreal landscape. Certainly, forests of massive old trees are not common outside of riparian zones. As explained by Pojar (1984):

> *The boreal forest of northern B.C. is essentially a lightning-fire climax system with a fire cycle or fire rotation of about 140 years. It appears that unidirectional development of vegetation and steady state ecosystems do not occur. In as much as wildfire is so frequent and such an integral part of boreal ecosystems, it may be more valid to think of the whole mosaic of "seral" ecosystems as a stable but dynamic climax.*

Although the existence of forests with "classic" old growth features is doubtful over much of this zone, the old forests which are present represent an important ecological niche which should be preserved as part of the forest landscape.

2.5 OLD GROWTH COMPOSITION - OTHER SPECIES

A variety of life forms other than trees comprise the old growth community, or make use of old growth forests. These forest organisms go through successional patterns similar to those already discussed for forest trees. The common pattern of ecological succession for mammals, birds, and invertebrates begins when a large number of generalist species occupies the early forest, before the young forest achieves crown closure. As the crown closes, the number of species present in a forest normally dwindles. The fewest number of species inhabit the forest during the period when the canopy is closed (approximately from age 25 to 150-200 years). Species diversity then rebounds to near pre-closure levels as the old growth phase begins and the forest canopy begins to open up. However, the kinds of species which comprise an old growth forest community are significantly different from those which inhabit a seral community, a young or mature forest, or a tree plantation.

The species which inhabit old growth forests tend to be specialists, adapted to old growth conditions and requiring specific types of habitat, which are often found only in old growth forests (Franklin 1990). In contrast, the species which inhabit seral forests (early forest stages) tend to be aggressive generalists--hardy species which can adapt to many different conditions and ecosystems.

The high degree of specialization common to old growth organisms is a logical survival strategy for species which share a stable biological community. However, these animals are not equipped to compete with the aggressive, adaptable, transitory species which exploit the brief period between the destruction of a forest and the closure of the forest canopy in the replacement stand (Wilcove 1988). If ecologically viable habitat is not protected for their use, old growth dependent animal and plant species are in danger of extinction (Ruggiero et al 1989, Thomas et al 1987, Connor 1989).

Table 1 presents a list of some mammals and birds which are found in old growth forests on the Pacific Northwest. The table includes species which are old growth obligates (live exclusively in old growth forests), as well as some which require old growth for a phase in their lives. Although this list is incomplete, it does indicate the diversity of species which require and/or utilize old growth forests and the diverse ways in which the forest is used.

Table 2: Utilization of old-growth habitats by vertebrates in the Pacific Northwest (Habeck 1988)

Vertebrate Species	**Utilization**	**Old-Growth Elements Used**
Bald Eagle (Haliaeetus leucocephalus)	Nesting, roosting	Riparian forest, snags, old growth beach fringe
Barred Owl (Strix varia)	Nesting, reproduction, forage	Large cavities, broken tops, coarse woody debris
B. Red-Backed Vole (Clethrionomys gapperi)	Forage, shelter	Coarse woody debris
Caribou (Rangifer caribou)	Forage, reproduction, climatic shelter	Subalpine old growth
Cascades Frog (Rana cascadae)	Feeding	Mature and old growth forest associated with water with water
Chestnut-backed Chickadee (Parus rufescens)	Winter forage and shelter	Mature and old growth
Clark's Nutcracker (Nucifraga columbiana)	Forage, reproduction	Mature and old growth
Clouded Salamander (Aneides ferreus)	Forage, reproduction	Moist dead and down material under mature canopy
Cutthroat Trout (Salmo clarkii lewisii)	Shelter	Large organic debris
Fisher (Martes pennanti)	Forage, reproduction	Large snags, large living trees, coarse woody debris
Goshawk (Accipiter gentilis)	Forage, nesting	Large living trees
Hammond's Flycatcher (Empidonax hammondii)	Forage, nesting	Large living trees
Little Brown Myotis (Myotis lucifugus)	Roosting	Cavities, snags, or large with loose bark
Lynx (Lynx canadensis)	Denning	Coarse woody debris
Marten (Martes americana)	Forage, denning	Understory diversity of dead down material
Merlin (Falco columbarius)	Nesting, roosting, reproduction	Large snags and mature growth
Moose (Alces alces)	Winter forage and shelter	Mature canopy
Flying Squirrel (Glaucomys sabr.)	Forage, reproduction	Large living trees, snags

Vertebrate Species	**Utilization**	**Old-Growth Elements Used**
Northwestern Salamander (Ambystoma gracile)	Feeding	Mature forests near still water
Pacific Giant Salamander (Dicamptodon ensatus)	Feeding	Riparian forest
Pileated Woodpecker (Dryocopus pileatus)	Forage, nesting	Large standing snags and coarse woody debris
Red Crossbill (Loxia curvirostra)	Winter forage and nesting	Large living trees
Red-Breasted Nuthatch (Sitta canadensis)	Winter forage and shelter	Mature and old growth
Rough-skinned Newt (Taricha granulosa)	Feeding	Fallen dead and down material
Ruby-Crowned Kinglet (Regulus satrapa)	Nesting	Large living trees
Saw-Whet Owl (Aegolius acadicus)	Forage, nesting	Large standing snags and coarse woody debris
Sharp-tailed Snake (Contia tenuis)	Feeding	Closed mature or old growth
Tailed Frog (Ascaphus truei)	Feeding	Moist mature forests near cold streams or lakes
Townsend's Warbler (Dendroica townsendi)	Forage, reproduction	Mature and old growth
Western Jumping Mouse (Zapus princeps)	Shelter	Coarse woody debris
W. Red-backed Salamander (Plethodon vehiculum)	Forage, reproduction	Moist dead and down material under mature canopy
White-Breasted Nuthatch (Sitta carolinensis)	Forage, nesting, reproduction	Mature, old growth, large standing snags
White-Headed Woodpecker (Dendrocopos albolarvatus)	Forage, reproduction	Mature and old growth ponderosa pine
Whitetail Deer (Odocoileus virginianus)	Winter shelter	Large living trees
Wolverine (Gulo gulo)	Forage, reproduction, denning	Large windfalls for denning, down material for prey habitat

2.5.1 Large Mammals

Old growth forests provide specific habitat features which meet the needs of large mammals such as deer, caribou, and grizzly bear. Deer, caribou and other ungulates use old growth forests as winter range. Grizzly bears, which need old growth forest for cover and foraging, favor coastal estuaries where old growth forests protect and nourish productive salmon streams.

2.5.1.1 Deer

White-tailed deer (Odocoileus virginianus) and mule, or black-tailed deer (Odocoileus hemionus) are commercially important game species and also an important part of the food web. Until the early 1980's, wildlife managers assumed that deer did not need old growth forests, and prospered in landscapes of clearcuts and short rotation, managed forests. This idea has since been set aside for all areas which receive substantial winter snowfalls. Both mule deer and white-tail deer in climates with heavy winter snow depend upon old growth forests for winter range (Schoen et al 1981, Hanley et al 1989, Mundinger 1982). Although openings such as clearcuts contain deer forage, the deer cannot access then forage efficiently under the deeper winter Snow packs. The energy spent in travel and digging exceeds the energy gained from foraging (Hanley et al 1989).

Food quality, as well as food accessibility, is also superior in old growth forests. For example, arboreal lichens are an important part of the diet of black-tailed deer in areas of high snow fall, and are available when other foods are buried by snow. Arboreal lichens are abundant in certain kinds of old growth forests, but are sparse in younger stands (Stevenson and Rochelle, 1982). Hanley et al (1989) also found that summer food supplies (deciduous leaves) within old growth forests contained levels of digestible protein which were more than two times greater than leaves from clearcuts.

2.5.1.2 Mountain Caribou

Mountain caribou (Rangifer tarandus caribou) are an increasingly rare, and often threatened, species. The mountain caribou occupy an area of heavy snowfall in the Columbia Mountains and the Central Rocky Mountains. Caribou are migratory animals, and often move considerable distances between seasonal ranges in a single season. Caribou generally range through remote wilderness areas, and often suffer increased mortality from poaching, harassment, and vehicle/train kills when humans encroach upon their territory (Stevenson and Hatler 1985).

Mountain caribou are known to use a variety of summer ranges, but their winter habitat is concentrated in forest types which contain moderate to high quantities of arboreal(forest canopy) lichens, a significant part of their winter diet. In soft snow conditions where digging is relatively easy, the caribou feed on terrestrial lichens. However, when the snow is deep and/or crusted and digging becomes difficult, the animals depend on arboreal lichens. The greatest quantities of arboreal lichen are found in older forest types, and the largest crops of arboreal lichens occur primarily in old growth forests. Mountain caribou often winter in high elevation, old growth forests, which provide thermal cover, abundant arboreal lichens, and isolation from predator species (Bjorge 1982, Stevenson and Hatler 1985, Marshall 1985).

2.5.1.3 Grizzly Bears

The grizzly bear (Ursus arctos) is widely distributed throughout British Columbia. Grizzly bears once found suitable habitat over most of western North America, but their current range has been greatly reduced by human settlement and activity.

Grizzly bears require extensive ranges which provide a variety of food and shelter resources during various seasons. Bears feed largely on vegetation, berries, and fish, complemented by other protein sources (insects, small mammals, carrion). Grizzlies prefer areas with readily available hiding cover and bedding cover. They also require movement corridors which they can use to "commute" between their seasonal ranges.

Grizzly bears make extensive use of old growth forests. Schoen and Beier (1987) and Archibald et al (1985) both found that the highest proportion of bear habitat use occurred in floodplain or side hill old growth forests. Grizzly bears may be able to survive as small remnant populations without old growth forests. However, these animals are unlikely to prosper, and any further stress, such as climate change or human encroachment, may result in local extinctions.

2.5.2 Small Herbivorous Mammals

Small, herbivorous mammals cannot move great distances to find the resources which they require to survive. Thus, small mammal species prosper in diverse habitats, such as the many small niches contained within old growth forests. The combination of varied ground cover (trees, shrubs, herbs, mosses, lichens, and liverworts) and coarse woody debris for cover and runways found in old growth provides optimal small mammal habitat (Maser et al 1979).

Carey (1989) found that while many small mammals use old growth, no forest-floor-dwelling small mammals were heavily dependent on old growth. He warns, however, that this may reflect the fact that old growth structural components (particularly large fallen trees) are still present to some degree in current young, managed forests. Franklin et al(1986) have explained that modern, intensive forestry will result in simplification of the forest. Natural forest cycles which required 350 years or more will be condensed into 60 or 80 years. Little or no coarse woody debris(snags and large fallen trees) will be present, because insufficient time will be allotted in future short rotation forests to develop these old growth structures.

Carey (1989) found two species of arboreal rodents--the northern flying squirrel (Glaucomys sabrinus) and the red tree vole (Arbirimus longicaudus)--to be abundant in old growth forests and low in abundance in younger forests.

2.5.2.1 Northern Flying Squirrel

The northern flying squirrel is a tree cavity nesting arboreal rodent. In Oregon, northern flying squirrels were found to live solely on a diet of fungi. Because of their diverse plant species and large volumes of decaying and dead biomass, old growth forests may provide a greater abundance of food (fungi) and shelter (cavities) than younger stands (Carey 1989).

2.5.2.2 Red Tree Vole

Carey (1989) found that red tree voles were three times more abundant in old growth than in young and immature stands. This vole seems to spend most of its life in the canopy, using Douglas-fir for both food and nesting material. According to Carey, "The vole is probably a weak disperser incapable of passing through clearcuts or other clearings (or blow downs). If a stand is destroyed, the voles may perish; recolonization of new stands may have to come from adjacent old stands, after the new stand has developed a closed canopy."

2.5.3 Small Carnivorous Mammals

Three members of the mustelids family of mammals--fisher (Martes pennanti), marten (Martes americana), and wolverine (Gulo gulo)--are all known to make use of old growth forests for foraging and denning. Since these animals are roughly similar in their life histories, we will discuss the habitat requirements and forest usage of the marten.

2.5.3.1 Marten

Old growth is vital to marten. To ensure successful reproduction, at least a portion of the 100-600 hectare home range of a marten must be old growth timber. Females use large cavities in standing dead trees for denning sites. The kits move to hollow portions of large fallen trees or lower snag cavities when they are mobile. Only old growth provides the stable habitat needed by this slow to reproduce species (Novak et al 1987, Mahlein 1988).

Old growth forests provide excellent sources of food for marten, especially in winter. Marten require access to the subnivean (beneath the snow) runways of many of their prey species. Subnivean access routes are provided by stumps, snags, large fallen trees, and snow craters beneath large old trees. Limitations on the number of subnivean access routes may be more restrictive on marten winter densities than the actual density of available prey (Novak et al 1987).

2.5.3.2 Bats

Several researchers have shown that bat species are more common in old growth forests than in younger stands. Researchers have found that feeding rates for bats within forests are short. Most feeding within the forest occurs in the first 15 minutes of the evening. The principle value of old growth to bats seems to be the availability of roost sites--hollow trees and shelves created by sloughing bark on snags (Carey 1989, Thomas and West 1989).

2.5.4 Birds

The interrelationship of birds and forests is complex. Birds have evolved over the millennia to take advantage of the various habitats, foraging opportunities, and nesting sites offered by various forest types and age classes. Some bird species are adapted to open spaces and young forests, thriving in the clearcuts of conventionally managed timber. However, other species are dependent on the structures or attributes found in old growth forests for their survival.

Some bird species are highly mobile, utilizing old growth forests for one aspect of their life history, while ignoring it for others. However, other species are sedentary, and stay within their home range most of their lives. These varied approaches to habitat use within the bird world make it difficult to offer a general discussion about birds and old growth forests. Instead of examining specific bird species, we will examine the uses which birds make of old growth forests for nesting sites, for special habitat, and for foraging by a variety of birds.

2.5.4.1 Nesting Sites

Old growth forests provide two structures which are extremely important for nesting sites for a variety of birds: large trees and large snags.

Many raptors, such as bald eagles (Haliateetus eucocephalus), customarily build large, bulky nests and may reuse the same nest annually, adding another layer of material every year. While these birds may not need old growth forests for foraging, they likely require large “flat-topped" old growth trees as nest sites. Conventionally managed short rotation forests will not develop the large, open crowned trees with sturdy upper limbs required to support their nests. Mannan and Meslow (1984) reported that goshawks (Accipter gentilis) also appear to require groves of large trees as nest sites.

An unusual bird species which is believed to utilize old growth forests for nesting is the marbled murrelet (Brachyramphus marmoratus). The murrelet is a small seabird which spends most of its adult life on the open ocean. However, it nests in old growth forests up to 45 km from the coast (Ralph 1989). Very little is known about the breeding biology of these birds. Recent reports have documented that this species nests in old growth Sitka spruce in the Carmanah Valley on the B.C. coast.

Large snags in old growth forests serve as nesting sites for many forest birds. Cavity nesting species such as the pileated woodpecker (Dryocopus pileatus), the red-breasted nuthatch (Sitta carolinensis), chickadees (Parus spp.), and the Vaux's swift (Chaetura vauxi) require various types of snags and/or forest conditions around snags for nesting and foraging. The requirements of cavity nesters can be highly specific. Woodpeckers prefer the upper third of broken topped snags greater than 60 cm in diameter and over 15 m tall. Mannan et al (1980) found that all of the nests of woodpeckers in their study were located in forests over 110 years old, and 70% of the nests were located in forests over 200 years old. Chickadees and nuthatches require softer snags in more advanced states of decay. Other species, such as the brown creeper (Certhia americana), nest beneath plates of loose bark on decaying snags (Mannan and Meslow 1984).

Secondary cavity users utilize nest holes after the original builders have moved to a new tree or perished. While secondary cavity users can be maintained in second growth forests through the use of nest boxes, the primary cavity excavating species (especially woodpeckers) require large snags which are not a part of younger forests (Mannan et al 1980).

Although large trees, and thereby large snags, could be included in managed forests by leaving some large trees during logging, many authors expressed reservations regarding this approach. Mannan et al (1980), Raphael et al (in press), Carey (1989), and Cline et al (1980) all caution that isolated snags in managed stands may not provide the required combination of nesting site, foraging areas, and habitat needs for these bird species. Pileated woodpeckers, for example, construct a new nesting cavity every year, and generally change nest trees after two seasons. Such a habitat use pattern requires a lot of large snags. The U.S. Forest Service bluntly states: "Optimum habitat for pileated woodpeckers is roughly synonymous with old growth forest" (Mahlien 1989).

2.5.4.2 Foraging

Unlike young forests of any kind (particularly unlike young timber plantations), the open, multi-layered canopy and the varied sizes, spacings, and species of trees found in old growth forests provide diverse niche habitats scattered throughout the forest (Franklin et al 1986). Old growth forests provide three important foraging opportunities for various types of birds:

1. <u>Bark foragers</u>--Old growth forests contain tree species of all ages, with both smooth and deeply furrowed or flaked bark, and a variety of snags and fallen trees in all states of decay. These varied substrates provided varied feeding opportunities throughout the year for bark foragers (Mannan and Meslow 1984, Mannan et al 1980).
2. <u>Seed eaters</u>--The mixture of conifer tree species found in many old growth forests provides a diverse source of seeds for non-migratory seed eaters such as the red crossbill (Loxia curvitosa) and the pine siskin (Carduelis pinus). This diverse species mix provides food for these seed eaters in years when Douglas-fir, which dominates younger forests in many regions, does not produce a good seed crop. Liquidating old growth forests is expected to cause greater population fluctuations in these species and more local extinctions (Carey 1989).
3. <u>Foliage foragers</u>--Old growth provides a rich resource for foliage foraging, insect eating birds. Because of the depth of the canopy and the high levels of vegetative transpiration carried out in that canopy, old growth forests tend to maintain a cool, moist, stable interior environment. This is more favorable to many forms of insect life than younger forests, which tend to be hotter and drier than many insect species can tolerate. In one study, 66 species of arthropods (insect and related genera) were found in the foliage of an old growth forest while only 15 species were found in a nearby young forest (Schowalter 1989).

As old growth forests are converted to short rotation tree plantations, loss of food supplies and habitat modification is expected to reduce bird populations (Perry 1988). If pesticides are used to control insects and plants, further harm will result for bird populations.

In conclusion, old growth forests, because of their variety, provide high quality habitat and foraging opportunities for a diverse array of bird species. For many species of birds the habitat provided by old growth is the best available.

2.5.4.3 Overall Habitat

The previous two subsections have examined nesting sites and foraging provided by old growth forests. We now will briefly examine the characteristics of overall habitat provided by the "interior" of continuous old growth forests, and the importance of this habitat to several bird species. One well known interior forest dweller is the northern spotted owl (Strix occidentalis). Although not common in British Columbia, this species has been extensively studied in its range in the U.S. Pacific Northwest. The scientific knowledge of the spotted owl indicates the sort of problems which old growth dependent bird and animal species may face when their habitat is impacted by logging and managed forests.

There are numerous theories as to why spotted owls are dependent on old growth forests. All center around the fact that spotted owls are adapted to interior old growth habitat--that is, the area within a continuous old growth forest, as opposed to the area near the edge or boundary with a younger forest or opening. Their prey species--flying squirrels, tree voles and wood rats--may be more abundant or more easily caught in these old growth conditions. Logging activity which fragments forests, reducing the size of interior old growth forest areas, may also lead to colonization of current spotted owl habitat by other owls such as the barred owl, which can out compete the spotted owl, or by great horned owls which eat spotted owls (Wilcove 1988). Spotted owls are not expected to survive continued unmanaged loss of their interior forest habitat (Marcot & Holthausen 1987).

Conventional clearcut logging activity reduces the amount of interior old growth forest habitat and increases the amount of forest edge habitat. Displacement or predation of forest interior birds by aggressive bird and animal species from open early successional forests is a common problem. For example, the nests of interior forest dwelling songbirds maybe subjected to predation from a variety of small mammals which live along the forest edge, and to parasitism from brown headed cowbirds. These stresses on bird populations are believed to result in a net breeding failures, as well as population losses (Wilcove 1988).

Finally, old growth forests provide special plant communities which are absent in conventionally managed forests. For example, Mannan and Meslow (1984) found that the Townsend's warbler (Dendroica townsendi) and the golden crowned kinglet (Regulus satrapa) were more abundant in old growth forests than younger forests. Both of these birds favor foraging in the understory of grand fir within the old growth forest. This habitat combination of a large stemmed overstory and a small stemmed, shade tolerant understory is unique to old growth or older mature forests. Although their study did not indicate that these bird species were dependent on old growth, it did indicate that their preferred habitat was a forest condition found only in older stands.

<u>2.5.5 Fish</u>

Old growth forests produce pure, cold water in stable creek beds, regulate stream flow levels (Borman and Likens 1979), and release important nutrients for aquatic plants into water courses. These factors contribute to high quality fish habitat. Probably the most important contribution of old growth forests to fish is large organic debris in stream channels. Fallen trees and large branches form eddies in larger watercourses and break smaller streams into a series of stable pools, falls, and riffles (Franklin et al 1981). In all streams, large organic debris provides accumulation areas for organic material and invertebrate life, slack water for fish breeding and rearing, and hiding cover for fish. Old growth forests, the only source of these large fallen trees in the water, are vital in maintaining the integrity and fish habitat value of water courses of all sizes.

2.5.6 Amphibians

The only research regarding the types and numbers of amphibians found in old growth forests comes from the U.S. Pacific Northwest. Amphibians are divided into two classes: aquatic amphibians and terrestrial amphibians. Salamanders are the main type of amphibian found in the Pacific Northwest forests.

Aquatic amphibians found in small streams and headwaters of the Pacific Northwest include, in order of abundance, giant salamanders (Dicamptodon ensatus), tailed frogs (Ascaphus truei), Olympic salamanders (Rhyacotriton olympicus), and Dunn's salamanders (Plethodon dunni). Although these animals are not dependent per se on old growth forests, they are dependent on sediment free, stable watercourses and cold water for survival (Carey 1989). Old growth forests are the most effective source of this habitat.

Terrestrial amphibians found in the forests of the Pacific Northwest include northwestern salamanders (Ambystoma gracile), rough skin newts (Taricha granulosa), clouded salamanders (Aneides ferreus), ensatina (Ensatina eschscholtzi), and the Oregon slender salamanders (Batrachoseps wrighti) (Carey 1989).

Although salamanders are seldom thought of as important life forms, the ecological significance of salamanders increases with forest age. There can be several thousand salamanders per acre in old forests, where salamanders may represent the greatest biomass of vertebrate predators (Corns and Bury 1989). Carey (1989) found that northwestern salamanders and rough skin newts were most common in old growth forests, and Corns and Bury (1989) found that Olympic salamanders were more common in old growth forests. However, both authors warn that the other species of salamanders which were found throughout younger forests live in partially decayed coarse woody debris. Coarse woody debris is a product of old growth forests. The large fallen trees, snags, and large living trees which persist after natural disturbances will be absent from conventionally managed forests after the second or third rotation. Without these habitat types, terrestrial salamanders will be unable to survive in a managed forest landscape.

2.5.7 Invertebrates

Old growth forests have extremely rich and varied invertebrate populations, including many species of foliage feeding insects and boring beetles as well as generalist predators such as spiders. The foliage eating insects in old growth forests are generally held in check by the predator insects and birds, and by the difficulty foliage eaters have finding adequate food supplies in a diverse forest.

In their travels about the forest, insects perform important ecological functions, including movement of fungi and bacteria from site to site and contributing to litter fall while feeding and excreting frass (Schowalter 1988, 1990).

Arthropods and other small invertebrates play a critical role in the soil community. Snails, mites, millipedes, spring tails, and beetles attack fallen debris, ingesting and digesting large quantities. This process continually increases the surface area of the soil litter, spreads microbes and yeasts throughout the litter, diverts energy back into the animal food chain, and incorporates organic matter into the soil. This thriving soil community is the key to the essential recycling of nutrients within the old growth forest (Bormann and Likens 1979, Amaranthus et al 1989).

The timber industry considers many species of insects to be “forest pests" because their feeding habits are perceived to be detrimental to short term timber supplies. Wilcove (1988) provided an interesting alternative view of the insect "pest" problem:

> *With very few exceptions, the organisms generally considered pests in the national forests are native species. They have played a role in the dynamics of these forest ecosystems since long before the arrival of European settlers. They are considered pests partly because the vegetation dynamics of forest ecosystems occur on a time scale far greater than the human life span. Therefore, insect and disease infestations which seem catastrophic to a land manager may, in fact, be normal events in the lifetime of a forest.*

Most insects "pests" exist at endemic levels in all forest areas. Endemic populations are held at low levels by biological controls. When ecological factors change significantly, epidemic populations of insects can quickly form and kill large numbers of economically valuable trees. According to Schowalter (1990):

> *Whereas there have been many statements made that old-growth forests or wilderness areas are going to be sources of insect pests, in fact most of the data indicate that young managed stands are going to be more vulnerable to and support insect outbreaks. In fact, the very high insect densities achieved in these young stands may actually become a threat to other types of stands (such as old growth) which would otherwise not be exposed to those very high levels of insect pests.*

2.5.8 Soil Organisms - The Rhizosphere

The forest soil community is powered by photosynthesis in green vegetation. This energy is transferred to the soil community directly from tree roots and indirectly through litter fall. Healthy forest soil, such as that found beneath an old growth forest, is a biological wonder. According to Amaranthus et al (1989):

> *Estimates of the types and numbers of these (soil) organisms, which vary in function and are strongly interdependent, are staggering. For example, 10 to 100 million bacteria and actinomycetes (mould-like organisms), 1,000 to 100,000 fungal propagules,, and several kilometers of fungal hyphae can be present in a single gram of forest soil. Mites and nematodes can number from thousands to hundreds of thousands per square meter of surface soil, and larger soil organisms such as worms, insects and animals from 10 to well over 100. The resulting biomass of these numbers is immense. For example, in the Pacific Northwest, the soil of an old growth Douglas-fir stand can contain some 4,200 kg/ha dry weight of fungal mycelium and 5,400 kg/ha of mycorrhizal tips alone.*

Many forest trees and other green plants have a symbiotic, or mutually dependent, relationship with a type of fungi called mycorrhizae which live beneath the surface of the soil. Forest soils harbor a diverse mix of mycorrhizal species, which are adapted to varying climatic and soil conditions. Mycorrhizae are associated with pines, hemlocks, spruces, true firs, Douglas-firs, larches and alders--all of the forest tree genera of B.C. (Amaranthus et al 1989, Perry et al 1989, Conner 1989).

Forest trees pass up to 40% of the net energy they produce to the mycorrhizae which surround their roots. In turn, the organisms of the rhizosphere increase the amount of water, phosphorous, iron, and other minerals the plant can take up. Mycorrhizae greatly increase the surface area of roots they colonize, and thereby increase the volume of soil that roots can access for water and nutrients. Mycorrhizal hyphae (fungal "roots") fill small gaps between plant roots and the soil, maintaining "liquid continuity" in dry periods (Amaranthus et al 1989). Mycorrhizae also colonize decaying logs, which contain water during the driest parts of the year, and transport water back to their associated trees (Maser and Trappe 1984). Mycorrhizae are not confined to old growth forests. However, when the trees which provide their energy are removed, mycorrhizae themselves are at risk (Perry et al 1989).

Mycorrhizae aid in the production of hormones, vitamins, and other substances which affect plant growth and actively protect their tree associates from soil dwelling pathogens, such as root rots. Mycorrhizae can provide physical barriers against root penetration by pathogens, and can also manufacture antibiotics or stimulate other rhizosphere organisms to attack the pathogens (Amaranthus et al 1989).

Mycorrhizae and tree roots are part of a larger network of bacteria, fungi, protozoa, and soil invertebrates in the soil community. The entire range of organisms which makes up this community is termed the "rhizosphere" (Perry et al 1989, Amaranthus 1990). The rhizosphere obtains energy through the decomposition of organic matter which falls in the forest. All sizes and forms of litter, from needles and flecks of bark to the huge boles of fallen old growth trees are converted by the animals, invertebrates, fungi, and bacteria of the forest floor into humus and basic organic building blocks. These organic compounds or nutrients are in turn absorbed by the rhizosphere and returned to the forest ecosystem.

Rhizosphere organisms also create and maintain soil structure by secreting organic glues which bind soil particles together in small groups. Soil aeration and water permeability is improved by the spaces maintained between the rough irregular edges of these soil particles.

2.5.9 Nitrogen Fixing Bacteria

Nitrogen fixing bacteria obtain nitrogen from the atmosphere and convert it to a stable, accessible form which can be stored and utilized within the forest ecosystem. Plants depend on nitrogen to synthesize amino acids and proteins for growth, but cannot obtain nitrogen from the atmosphere. Thus, nitrogen fixing bacteria are critical components of the forest ecosystem.

Nitrogen fixing bacteria are an important component of the rhizosphere (discussed above), but are also found insubstantial numbers in rotting wood. The total amount of nitrogen fixed in dead wood is determined by the amount and the size of the dead wood in the forest. Franklin et al(1981) report that larger organic debris (large fallen trees) is more favorable to nitrogen fixing bacteria because large pieces of decomposing wood stay consistently moist, have a low oxygen environment, and disintegrate slowly. This input of nitrogen into the forest ecosystem is biologically significant, and would not be possible without an old growth phase in the life of forests to provide large pieces of coarse woody debris.

Modern logging and timber management practices deplete forest nitrogen reserves through timber removal and the use of site preparation techniques such as broadcast burning (Amaranthus et al 1989). The biological disorganization which follows intense, widespread disturbances such as clearcutting permits large amounts of stored nitrogen to escape from the forest ecosystem (Borman and Likens 1979).

2.5.10 Other Plants

We are aware of very little research into non-tree old growth plant communities. This quotation from Franklin et al (1981) still sums up the level of knowledge regarding smaller plants in old growth forests:

> *Few vascular plants appear confined to old growth ecosystems in the Douglas-fir region. Lists of species from the old growth Douglas-fir/western hemlock stands at the H.J. Andrews Experimental forest show that none are confined to old growth forests.*
>
> *Some vascular plants do find optimum habitat in old growth Douglas-fir ecosystems. These are often saprophytic plants belonging to the orchid and heather plants . . . which favor heavily shaded environments rich in organic debris. Saprophytic plants obtain all or part of their energy from decomposition of dead organic materials rather than by photosynthesis. Most vascular plants characterized as saprophytic have fungal associates essential to their survival. These species are not confined to old growth, but often find suitable habitats there.*
>
> *For lower plants--including mosses, lichens, liverworts. algae and bacteria--there currently is no way of systematically assessing the dependency of a species on old growth. Many species find optimum habitat in old growth forests, and some probably require old growth habitats for survival. For example, snags in old growth forests have a rich flora of lichens. Species that occur in old growth rarely occur on the drier snags in younger forests.*

One important plant species common in old growth forests is the nitrogen fixing lichen Lobaria oregana. This species can account for half of the epiphytic (tree living plant) biomass in the Oregon Douglas-fir region and can contribute 5 to 9 kg per hectare per year of usable nitrogen to the forest ecosystem--a significant annual input of one of the most essential nutrients into the forest. These lichen are thought to be largely confined to the moist, yet moderately well lit microclimate beneath the old growth forest canopy (Franklin et al 1981, Franklin 1990).

3. WHAT IS OLD GROWTH - STRUCTURE

Structure is the second vital component of the structure- composition-function triad which drives old growth. According to Franklin and Spies (1989/1), "Old growth forests are the later stages in forest development which are often compositionally and always structurally distinctive from earlier successional stages." Structure refers to the size, shape, and arrangement of the "parts" of a forest--the distinctive species, living and dead, which characterize a forest ecosystem. These special structures found in old growth serve as the foundation, or substrate, for many specialized plants and animals within the old growth forest community and provide the foundation required for old growth ecological functions (Franklin et al 1981).

Franklin and Spies (1989/2) provide a useful framework for discussing the structural attributes of old growth:

> *The age at which old growth develops and the specific structural attributes which characterize old growth will vary widely according to forest type, climate, site conditions and disturbance regime. . . However, old growth is typically distinguished from younger growth by several of the following attributes:*
>
> 1. *Large trees for species and site combination.*
> 2. *Wide variations in tree sizes and spacing.*
> 3. *Accumulations of large-size dead standing and fallen trees which are high relative to earlier (forest) stages.*
> 4. *Decadence in the form of broken or deformed tops or bole and root decay.*
> 5. *Multiple canopy layers.*
> 6. *Canopy gaps and understory patches.*

The presence or absence of combinations of these structures can also be used to identify old growth forests. In this section, we will examine these six attributes in more detail.

3.1 LARGE TREES

All old growth forests contain trees which are large for that particular tree species growing on that particular forest site. Not all old growth forests contain spectacularly large trees. For example, we have assessed an old growth lodgepole pine forest in the West Chilcotin region which contains trees which measure only 20.5 meters tall and 27.4 cm in diameter on average. The forest is over 250 years old. Although these trees are small, not more than saplings by coastal standards, they are nearly 40% larger than trees in younger stands on the same quality forest site (Bradley and Hammond 1989).

Most old growth, however, contains trees which are significantly larger than the pine type discussed above. In coastal old growth forests, and in some interior forests, massive old growth tree trunks and crowns form ecological niches within the forest. Franklin et al (1981) discussed the importance of large Douglas-fir trees in coastal old growth forests:

> *. . . though size varies with condition and age, diameters of 1 to 2 m and heights of 50 to 90 m are typical. They are highly individualistic, much less uniform*

> *than trees in a 50 to 150 year old stand. . . . Few old growth Douglas-firs have vertical trunks. Even a slight inclination of the trunk results in an important differentiation of habitats on its two sides. The upper side gets almost all the moisture, both from direct precipitation and from stem flow and through fall. Consequently it is colonized by epiphytic plants (plants that grow on other plants) with relatively high moisture requirements, chiefly mosses. The lower side is a "desert," colonized by scattered colonies of lichens.*
>
> *The large, deep irregular crown characteristic of many old growth Douglas-fir trees is as ecologically important as the massive trunk. . . . Many lower branches are horizontally flattened, fan shaped arrays . . . (which) can spread out to surround over three-quarters of the circumference of the trunk. Upper surfaces of large branches are covered by organic "soil" which is perched on the branches and supports entire communities of epiphytic plants and animals. Large branches are the home of myriad invertebrates, as well as birds and arboreal mammals. Branches in the upper third of the crown are more numerous and regular shape; they resemble those of younger trees.*

Sitka spruce, western red cedar, western hemlock, yellow cedar, and western white pine can attain sizes and fulfill ecological roles similar to Douglas-fir. Although limited to interior climates, Engelmann spruce, white spruce, western larch, and yellow pine may also produce the large size and branch structures noted above. One of the major climax forest tree genera, true firs (amabilis, grand, and subalpine fir), lack the wide spreading irregular crowns, but often attain sizes similar to their associates in old growth forests. The immense size, unusual branching pattern, and long life of old growth tree species contribute greatly to the special ecology of the old growth forest (Franklin et al 1981).

Large trees are an important structural and functional component of old growth forest ecosystems even after they die. Because of their size, large snags and fallen trees persist for long periods in the forest ecosystem, providing habitat and cover for large animal species, invertebrates, fungi, and microorganisms (Maser et al 1979).

3.2 VARIATION IN TREE SIZE AND SPACING

Old growth forests generally contain a diverse mix of tree sizes and spacings. This is particularly true for forests which contain a mix of long lived seral species and shade tolerant species which have regenerated beneath the forest canopy. The Douglas-fir/western hemlock old growth type is a good example. True climax forests, which lack the long-lived, extremely large seral tree species, have a lesser range of stem sizes, but still include a wide range of trees from seedlings and young saplings to mature and large old growth stems (Franklin et al 1981). Fire dominated, dry interior forests often contain only seral tree species and may not have a wide range of tree sizes. The frequent light fires prior to modern fire suppression burned the forest floor and prevented most regeneration from becoming established beneath the main canopy in these old growth forests (Hamilton 1989, Habeck 1988).

Franklin et al (1981) and Spies and Franklin (1988) showed that the distribution of tree diameters was different in old growth, mature, and immature forests. The presence of widely varied tree sizes is indicative of old growth forest conditions.

3.3 ACCUMULATION OF COARSE WOODY DEBRIS

The size, shape, and volume of the standing snags and fallen dead trees within most old growth forests endows these structures with biological functions which are very different from those of smaller, younger dead trees. The large diameter coarse woody debris found in old growth decays more slowly than small diameter material from younger forests, providing an array of animal habitats and stable micro-environments which are not available in smaller snags and logs (Maser et al 1979). Franklin et al (1989) summed up the functional importance of coarse, woody debris:

> *Ecologically, a dead tree is as important to the forest ecosystem as a live one. At the time a tree dies, it has probably fulfilled only half of its "life" in the ecosystem. The importance of dead wood, especially snags for wildlife has long been recognized. Coarse woody debris is also an important component in nutrient and energy flows, as a source of soil organic matter, as a site for asymbiotic nitrogen fixation, and in erosion control. In waterways, logjams dissipate energy to reduce channel erosion. Logs also provide major structures for retaining food and sediments in stream reaches serving as habitat for a variety of organisms, including fish.*

The large pieces of coarse woody debris produced by old growth forests are extremely persistent both prior to and following large disturbances such as fire and wind. This enduring nature of coarse woody debris provides a linkage, or biological legacy, between old growth forests and post-disturbance ecosystems. The nutrients, insects, rodents, mycorrhizae, and water contained in coarse woody debris facilitate the recovery of ecosystems after an old growth forest has been destroyed by fire or windstorm (Spies and Franklin 1988). Decaying fallen trees hold available water long after all other sources on forest sites have been exhausted by seasonal droughts. This factor can be extremely important in sustaining post-disturbance forest communities on harsh sites (Maser and Trappe 1984).

Repeated fires can greatly reduce the quantity of coarse woody debris carried forward as a biological legacy in natural forests. Young, closed canopy forests are very susceptible to forest fires because the tightly packed crowns and dry lower branches provide a continuous fuel layer (Perry 1988, Franklin and Hemstrom 1981). Some similarities exist between the natural process of repeated juvenile fires and conventional forest management using clearcutting. Clearcut logging and slash burning may partially mimic a phase in forest succession which forests are adapted to survive. However, natural forests eventually escape the repeated juvenile fire cycle and grow to a true old growth stage, thereby replenishing the coarse woody debris reserves of the ecosystem. This natural cycle will not occur in managed timber plantations. Many ecologists fear that forest productivity will decline as current supplies of coarse woody debris from past old growth forests run out (Maser et al 1988, Franklin et al 1989).

3.4 DECADENCE - BROKEN TOPS AND DECAY

"Decadence," as used by Franklin and Spies (1989/2) and other forest ecologists refers to individual trees within the forest which have broken or deformed tops from storm or other damage, and to trees which have been successfully colonized by wood decaying fungi.

These attributes are part of the natural processes which occur during or near the end of trees' long lives, and are indicators of old growth forests. Broken topped and hollow trees contribute to the ecological diversity of old growth ecosystems by providing unique nesting sites for birds, roosts for bats, habitat for specialized mammals, and a substrate for invertebrates.

Timber managers use the term "decadence" to mean that old growth is rotting away on the stump, and that insects and disease are wiping out old forests. The implication is that if these old "decadent" forests--these "cellulose cemeteries"--are not logged soon, they will rot away to dust. Research, however, indicates that while the timber volume in old growth forests may vary around an average overtime, the average net volume of standing timber does not change until a large scale disturbance (fire, wind) starts the successional process over again (Haynes 1986, Franklin and DeBell 1988, Bormann and Likens 1979).

Tree death is a normal part of the cycle of the old growth forest. Trees which fall are replaced by younger trees from the lower levels of the forest canopy. This process maintains stand diversity, contributes coarse woody debris to the forest floor, furnishes large organic debris to forest streams, and results in dynamic, yet stable, old growth forests.

3.5 MULTIPLE CANOPY LAYERS, CANOPY GAPS, AND UNDERSTORY PATCHINESS

These three factors are responsible for much of the structural diversity and the above ground ecological diversity in an old growth forest.

The vegetative canopies in the coastal and moist interior old growth forests are multi-layered. Living green plants exist at all levels, from the shaded forest floor to the sunlit upper canopy. Small plants, shrubs, understory trees, and the trees of the main canopy extend branches into every available fleck of sunlight in the forest. Multiple canopy layers, spread over the height of the forest, enable the plants in an old growth forests to maintain a foliage area which is much higher than that of a closed canopy young forest (Franklin et al 1981).

Canopy gaps are formed when individual large trees die from disease or other damage. The light which flows into the forest through canopy gaps stimulates the understory of young conifers and shrubs in some places, while the dark areas beneath the denser canopy are almost completely devoid of understory vegetation. The complex of canopy gaps and “anti-gaps" produces the patchy, diverse understory common within many old growth forests (Franklin 1990).

The diversity in function provided by the multi-layered, variable forest canopy in moist old growth forest is on a par with the ecological diversity provided by coarse woody debris. A diverse canopy provides varied micro habitats for plants and animals of all sizes.

In contrast, young forests lack diversity between the time canopy closure first occurs and the point when the canopy begins to open. Most of the resources on the site are diverted to growing trees, and the uniform closed canopy blocks almost all usable light from reaching the ground. Trees of one size and age class dominate the forest, and the understory is very limited or nonexistent. The populations and species diversity of most life forms (mammals, invertebrates, shrubs, herbs, etc.) decrease during this period of forest development. The natural diversity starts to rebound only when the forest canopy begins to open from individual tree mortality (Franklin and Maser 1988).

Dry interior and boreal old growth forests do not have the distinctive multi-layered canopies of moist coastal or interior old growth forests. Dry interior old growth forests tend to have very open canopies, although dense patches do occur. The forest are all aged and self perpetuating, but stocking in all height classes is so light that the canopy does not conform to the deep, multi layered model discussed above. Boreal old growth forests are generally too young and composed of trees which are too small to have the deep, multi-layered canopy common to coastal forests.

As the store of knowledge about forest ecology grows, we are beginning to see that the old growth stage is what makes all forests work. The ecological processes in old growth forests replenish forest soils and maintain the gene pool needed to sustain healthy forest ecosystems. Without old growth, the components necessary to sustain all forests are threatened. According to John Bedell of the USDA Forest Service, Supervisor of the Carson National Forest (1989):

> *Old growth or ancient forests are a dwindling remnant of the past, without which we cannot sustain our future. . . We must all recognize that the old growth component, and its associated processes, are critical ingredients to providing an appropriate level of sustainable woods products for now and the future.*

Including the old growth phase, forests operate on cycles of 300 to 2000 years. In contrast, few people live beyond 100 years. Thus, humans are only able to experience small "snapshots" in the life of a forest. We are largely unable to see the effects of removing these forests from the landscape and preventing their future development. The changes brought about by conventional logging of old growth forests are drastic, but these changes are spread out over such a length of time that they are invisible to most humans. We assume, when we view a landscape which is mostly green, that healthy forests abound.

Thanks to the work and to the education provided by Jerry Franklin and other researchers, we are beginning to <u>see</u> the effects of conventional timber extraction on the forest. We are beginning to understand the ecological destruction our ignorance has allowed, and to realize that conventional logging methods threaten old growth forests, and thereby all forests.

As we consider the importance of old growth ecosystems, it may appear that researchers have all the answers. However, nothing could be further from the truth. Science and biology cannot weigh the value, requirements, and overall importance of old growth, and decree with authority how much should be "saved" (Franklin 1986). As Glen Juday, editor of the Natural Areas Journal and one of the original old growth researchers, points out:

> *The natural areas profession assumes that old growth is worth preserving in its own right, as a phenomenon of the planet Earth and because it is the habitat for many species that may disappear or decline unacceptably without it. We assume that the human species does not have the right to eliminate old growth or leave it in such a debilitated state that significant components of it may disappear. Old*

> *growth must play a significant role in multiple use and sustained yield forest management. Although we can justify saving old growth, that puts the argument backwards. We see unacceptable loss in causing old growth to be eliminated. After all, old growth forests are disappearing from North America because of people and their conscious decisions; old growth would be in fine shape without us. (Juday 1988)*

Jack Ward Thomas, a respected wildlife biologist, also addressed the subject of our present level of knowledge regarding old growth forests:

> *The present state of scientific knowledge in forest and wildlife ecology serves as a strong caution against further haphazard reduction in the quality, quantity and distribution of old growth forests. Knowledge, and common sense, is adequate to indicate that old growth should be retained as part of managed forests. ..Moreover, it would be, at the least, short-sighted and illogical to eliminate future management options for old growth while simultaneously acknowledging our current state of relative ignorance about potential ecological ramifications. (Thomas et al, 1987)*

In this section, we will examine the <u>function</u> of old growth forests--how their unique composition and structure interact to form the vital and irreplaceable old growth forest ecosystem, and the importance of these interactions. We will also explain the basis for our assertion that old growth is a critical phase in the life of any forest ecosystem. A complete discussion of the function of old growth forests is too large an undertaking for this project. However, the overview and examples which we will provide in the following pages will show the importance of old growth forests to the forest ecosystem, and to our species.

3.6 WATER

Water is life. Clean, potable water is becoming one of the most valuable resources on our planet. The market value of water resources will continue to rise as pollution, careless use, and ill conceived water management projects continue to degrade rivers, lakes and underground aquifers, in Canada and across the globe. In British Columbia, the entire population relies on water which comes directly or indirectly from forests. Clean, cool water is also needed for fish habitat, to support valuable sport and commercial fish species, and to maintain the aquatic ecosystems in our environments. Old growth forests, because of their unique ecological functions, provide the highest quality water in the world.

<u>3.6.1 Human Use Of Water - Water Quality, Quantity And Timing Of Flow</u>

The suitability of water for human use is determined by the quality, quantity and timing of flow of the water resource.

3.6.1.1 Quality

Some forms of water pollution and siltation can be rectified by treatment, but obtaining water that is pure in the first place is preferable to extensive treatment. Old growth forests produce extremely pure water because of the structures and biological functions which occur within the forest.

The terrestrial ecosystem of the old growth forest is an immense recycling plant. Dead plant and animal material is attacked by the small animals, insects, microorganisms, and bacteria of the forest floor community. The stable, cool, moist environment beneath the forest ensures that these organisms are always present, and that decomposition proceeds in slow, uniform fashion (Franklin et al 1981). The by-products from decomposition enter the soil, where they are absorbed by the fungi/plant root community of the rhizosphere, and transferred back to the standing vegetation (Amaranthus et al 1989). As a result of these processes, nutrients are tightly retained within old growth ecosystems, and the level of dissolved or suspended materials in water flowing out of the system is low. The development of such a closed cycle is a gradual process, which progresses from the time a forest is established until a severe disturbance starts the cycle again.

Organic debris which falls directly into streams is also largely retained within the old growth ecosystem due to the structure of streams in old growth forests. Fallen trees and large pieces of woody debris form small dams in streams which act as sieves, retaining organic matter long enough for microbes and insects to break down and use the organic inputs.

Old growth forests also effectively prevent erosion and resultant siltation. The extensive root systems of the trees, the regulation of soil water levels caused by transpiration of water through the forest canopy, the loose or friable soil structure maintained by the rhizosphere, and the permeable soil surface provided by organic layers on the soils surface work together to prevent soil saturation, overland flow, and downslope movements.

Organic debris also controls channel erosion in old growth forest streams. The dams formed by the organic debris (particularly large fallen trees or "large organic debris") break the stream into a series of short falls, riffles and ponds.

This "stepped" configuration absorbs or diverts most of the energy of the moving water, and prevents stream bank and channel erosion. Thus, the high quality of the water produced in the old growth forest is preserved as it flows through creeks stabilized by large organic debris.

3.6.1.2 Quantity

The quantity of water available at any given time is a vital consideration for humans, and indeed, for all life. Old growth forests contribute to the quantity of water available from any watershed in several ways. For example, in the fog/cloud belt of mountain ranges, old growth forests can produce very large water yields from condensation. The leaves of a single old growth coastal Douglas-fir can have a combined surface area of one acre, and an acre of old growth forest can contain over 25 such trees per acre. The open canopy permits the cloud or fog to swirl through the canopy, where it condenses on exposed leaf and branch surfaces. One study found that an old growth forest in the Bull Run watershed in Oregon's Coast Range was contributing 35 inches of precipitation annually to the forest site in the form of fog drip (Franklin 1989, 1990).

3.6.1.3 Timing Of Flow

Timing of flow is an important factor in determining the usefulness of a water source. The annual yield of water from a watershed is of greatest ecological value when it is distributed relatively evenly throughout the year. A watershed which produces destructive spring floods and then decreases to a trickle by early fall is of little use for human or animal purposes. Old growth forests are very effective in buffering or regulating the timing of annual flows from forested watersheds.

Effective regulation of timing of flow requires that a watershed incorporate most of the water input into the system without significant losses to overland flow, and then release the water gradually. Old growth forests perform these functions well. The permeable, organic soil surface layers and the soil structure maintained by the rhizosphere allow efficient infiltration and storage of water in the soil. The tremendous masses of organic material, primarily large fallen trees, in and on top of the soil act as a sponge, absorbing and slowly releasing water.

Through regulation of water flow, old growth forests help to control floods. Intense summer rainstorms can be absorbed by the forest ecosystem. Spring snow melt beneath the forest canopy is controlled and gradual. The most critical flood regulation exerted by old growth forests may be during "rain-on-snow events," which occur periodically in western mountains of Canada and the U.S. In these situations, rain (relatively warm compared to snow) falls on packed snow, greatly accelerating snow melt and runoff. According to Franklin (1990):

> *Essentially all of the flood events in northwestern North America are rain-on-snow events. What we have learned from looking at the hydrology of these events is that old growth forests have a much lower potential for contributing to rain-on-snow events because of several things. For one thing, those huge canopies intercept a lot of snow, where it evaporates and sublimates back into the atmosphere. The snow that does get into the forest . . . gets there in big blobs. It does look a bit like wet cement in the understory. And of course that makes it less vulnerable to the rain on snow event. It is protected by the forest from both the warm air and the warm rains. So it is much less likely that you will get a significant contribution from an old growth mountain forest compared to a clearcut. In a clearcut the snow has accumulated to a maximum depth because none of it was intercepted. It is all laid out there nicely so that the warm air and the warm rains can melt it and bring it off the slopes.*

3.6.2 Fish Habitat

The uniform flow of high quality, cool water produced by old growth forests is a vital part of high quality fish habitat. In addition, large fallen trees and pieces of trees form pools in the beds of smaller streams and eddies in larger watercourses. These locations provide habitat for aquatic plants and insects, slack water for resting areas, and hiding cover for fish. Old growth forests are the only source of large fallen trees in streams (large organic debris),which is vital to maintaining the integrity and fish habitat value of streams (Franklin et al 1981).

A clearcutting "experiment" in the Carnation Creek watershed on Vancouver Island illustrated the importance of old growth forests and large organic debris to fish habitats:

> *Stream banks in the middle third (of the creek), logged by "normal" clearcut procedures, were the first to go. Once the roots of the old growth trees stumps started to rot away, the creek broke apart. Where before the creek and its side channels were made up of pools and riffles with maximum diversity, now, to coin a phrase, the once meandering creek became a "bowling alley"--a straightened, high velocity ditch replacing the old stream structure.*
>
> *Several years later, even the upper third ("careful clearcut") started to go. It just took a little longer where some of the old growth root systems were spared to hold back the soil, but the end result was the same. Pools and meanders were evident before logging, but had disappeared and the steam contours became streamlined. Movement of the debris loads after clearcutting resulted in changes in the stream channel and increased stream bank erosion. (Forest Planning Canada 1989)*

Other negative effects on fish habitat from this clearcutting in an old growth forest included siltation of spawning beds, flushing of young fry out to sea up to a year early, and general habitat destruction.

Degraded creeks, like Carnation Creek, cannot be rehabilitated until large fallen trees are again available to stabilize the channel and until mature to old growth forests are present to provide high quality water and to regulate flows. We believe that in most British Columbia forests this process requires at least 200-300 years following a major disturbance.

3.6.3 Riparian Zone Functions

Riparian zones are wet forest areas adjacent to streams, rivers, lakes, marshes, and wetlands. Riparian zones are arranged in a branching network which extends throughout the landscape. These zones contain varied but repeating patterns of plant and animal habitat.

One of the most obvious functions of riparian zones is the provision of essential, high-quality habitat for many forms of wildlife. Both water and essential food resources are abundant in riparian zones, in close proximity to hiding and thermal cover provided by the old growth forest itself. Riparian corridors are important travel and migration roots for many animal species. Dispersal routes for many species of plants also tend to follow riparian corridors.

Intact riparian zones are also extremely important sources and storage sites for nutrients and energy. A significant amount of the nutrients moving down a forested hillside are below the reach of plant roots. (See Figure 1.) These nutrients are collected and stored by the luxuriant vegetation in the riparian zone. Large amounts of energy from sunlight are also stored through photosynthesis in the lush plant communities. The humid, cool climate of the riparian system regulates the dispersal of this energy to the surrounding forest and water system.

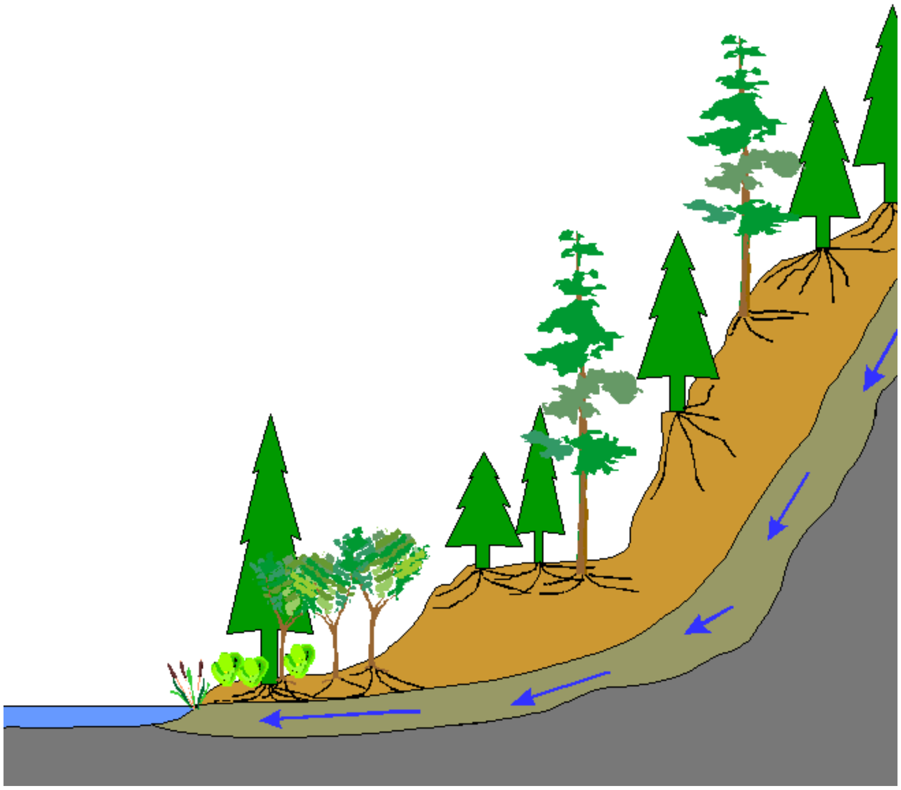

Figure 1: Water moves downslope through the sub-rooting zone.
Only after water and nutrients reach the riparian zone can additional nutrient cycling take place.

The riparian zones of old growth forests are well-designed by nature to withstand the effects of natural disturbance. Because of their wet, diverse nature, old growth riparian zones frequently survive large natural disturbances such as fire and wind. However, they can be seriously degraded by the effects of human-caused disturbances, and particularly by the effects of industrial scale clearcut logging. Removing even a small patch of riparian forest can close important connecting corridors, disrupting patterns of animal travel and migration, and plant and energy dispersal. Riparian sites are extremely sensitive to erosion, and are difficult to regenerate. Logging riparian forests is like taking links out of a chain--things tend to fall apart.

3.7 WILDLIFE

Many specialized animal species utilize the stable, dependable environment of the old growth forest. Other species have developed survival behaviors which utilize old growth forests at critical times (Ruggiero et al 1989, Franklin 1990). Various animal species depend on the coarse woody debris, the high quality browse, the large trees, the open, multi-layered canopy, or the unique plant-animal associations of the old growth forest for their survival.

Wildlife biologists are currently being challenged to identify what habitats a species needs or depends on for survival. Questions of "use vs. dependence" and "minimum habitat area required" do not have simple answers. Much remains to be learned about the relationship of old growth forests and wildlife species. Firm answers to these questions are not, and may never be, available.

3.7.1 Dependence/Persistence

The fact that an animal species occurs in old growth forests does not mean that old growth is necessary for the survival of that species. However, the fact that an animal occurs outside old growth habitats does not mean that the species can persist without old growth habitat. Franklin et al (1981) have said:

> *There currently is no way of addressing the question of dependency of a species on old growth. Many species find optimum habitats in old growth forests, and some probably require old growth habitat for survival. . . . Whether any species depends totally on old growth for survival is not clear; however, the fact that a species can survive in other age classes of a forest does not necessarily mean it can survive once the major reservoir of optimum habitat is gone.*

The concept of optimum, or preferred, habitat is crucial to this discussion. Optimal habitats can provide a refuge for species in times of extreme stress (drought, storms, winter cold). Increased breeding success of animals in optimal habitats serves as a source of populations which disperse into surrounding suboptimal habitats, which absorb more animals than they produce (Buechner 1988). Subtle ecological dynamics of this sort complicate determining ecological dependency. Ruggiero et al (1989) state:

> *It is likely . . . that habitat preferences are indicative of the long term needs of a species, since each species has become adapted to its environment over thousands of years of varying environmental conditions. Different populations and different species use specific environments in different ways. For example, a population may use an environment 1)exclusively and under all conditions, 2) exclusively but only at certain times or under certain conditions (e.g. winter conditions), 3) as one of several environments used under certain conditions, or 4) as one of several regularly used environments. . .*
>
> *When evaluating the importance of an environment to a species, it is important to recognize all ecologically meaningful time frames, and to realize that a species need for an environment cannot be evaluated solely on the basis of frequency or exclusivity of use. The persistence of a population can depend on use of different environments for different purposes, under different conditions.*

The central point here is this: If Species A prefers old growth forests, then old growth forests should be considered necessary for the persistence of Species A. Further, if it can be determined that Species B depends on old growth forests for survival during specific events, such as severe winter storms, then old growth forests should also be considered necessary for the persistence of Species B.

In the previous section on old growth composition, we listed examples of animal species which find their optimal habitat in old growth forests (e.g. spotted owl, flying squirrel, many invertebrates), species which require old growth forests for winter range (e.g. deer, mountain caribou), and species which require structures found only in old growth forests for breeding or foraging (e.g. birds, amphibians, marten). All of these animals are found outside of old growth forest habitats to varying degrees. However, we conclude that their persistence requires viable old growth forests within their local forest landscape.

Bunnell and Kremsater (1990) offer the following summary:

> *Only a few species find the resources they need in all stages of natural succession. That limitation is particularly true for breeding requirements that may be limited to specific structural features of the ecosystem, such as dead trees or snags.*
>
> *Those species adapted to the later stages of succession are of special concern for three reasons. First, these successional stages are not created easily or quickly. Second, the adaptation to old growth often results from a rather inflexible requirement, such as large diameter snags. Third, species adapted to old growth usually show slower rates of reproduction than those adapted to younger successional stages; that is, they cannot recover quickly when their numbers are reduced.*

3.7.2 Minimum Habitat Required

The subject of "minimum habitat required" is related to the question of "which species require old growth for survival." Both topics imply that society can only afford to protect the minimum amount of old growth forest required to maintain wildlife populations. Given the rudimentary level of current knowledge regarding the relationships between old growth forests and wildlife populations, such an approach is extremely hazardous. A small mistake could result in species loss. As Thomas et al (1987) explain:

> *Our knowledge and understanding of old growth communities is far too inadequate to support management of remaining old growth on the basis of criteria that provide minimum habitat areas to sustain minimum populations of one or several species. Current ecological understanding simply does not permit the fine discriminations that are implicit in such minimum standards. The potential consequences, and the distinct probability, of being wrong are too great to make such strategies defensible.*

Particularly at risk, in the face of forest fragmentation and loss of diverse old growth habitat, are species with large ranges or long migrations. According to Bunnell and Kremsater (1990):

> *Population viability of such species depends on favorable conditions in many different places and freedom for individuals to move between those places. Generally, top predators and large herbivores are the first to disappear from an area. These predators have the largest areal requirements. For example, using a minimum viable population size of 50, the areas necessary to maintain grizzly bear is about 49,000 km2; wolverines, about 42,000 km2; and wolves, about 20,250 km2.*

Protecting sufficient habitat for old growth animal species is an urgent concern. Human alteration to old growth habitat has proceeded extremely rapidly in the last 40 years. We have no way of knowing if current wildlife populations are sustainable by the current available habitat, let alone after a further reduction in available habitat. To quote the Wilderness Society report Protecting Biological Diversity:

> *The evolutionary forces that create or extinguish species typically operate over a span of thousands or sometimes millions of years. In managing for viable populations of species, it would seem logical to use a similar time scale. Yet in a world where forest plans and political careers are measured in decades, it is difficult to convince policy makers or the public of the need to adopt such a long term perspective. Unfortunately, the result may be to relegate certain species to extinction through a slow but steady erosion of their habitat.*

3.7.3 The Function Of Wildlife Species

As Juday (1989) and others have observed, old growth forests and animals do not need to justify their existence to be allowed to live in peace by human society. However, for the sake of interest, we will now examine several examples of the functions of old growth wildlife species in the forest ecosystem.

3.7.3.1 Birds

One of the most important functions of birds in the forest ecosystem is insect control. Bird communities in western coniferous forests are dominated by species which feed on insects. Approximately 80% of the food consumed by northwestern birds is animal prey, the majority being foliage eating insects. One study estimated that it would cost $1,800 per square km per year in insecticides to kill the same number of spruce bud worms that are eaten by foliage foraging birds in the forests of north-central Washington (Perry 1988).

Birds cannot control an insect epidemic once it has started, because bird populations cannot match the breeding rate of insect populations. However, birds play an important role in regulating insect populations, and thereby reducing the chance of an epidemic starting.

For example, woodpeckers eat large numbers of bark beetles, and may control small local outbreaks of bark beetles which would otherwise spread to become epidemics. Bark beetle species are present in most forests at endemic (low) population levels, surviving in weak or stressed trees. However, a local endemic beetle population may reach the level necessary to over come healthy trees through successful breeding in a group of stressed trees. If other ecological conditions are favorable, this transition can trigger an epidemic. Beetle epidemics kill large numbers of healthy trees and are extremely destructive of timber resources (Amman 1981). Woodpeckers can interact with this beetle ecology. Woodpeckers prey on bark beetles, are highly mobile, and have evolved the ability to identify bark beetle concentrations. Woodpeckers are thought to prevent beetle epidemics in some situations by congregating at the centers of rising beetle population and eating the surplus beetles (Perry 1988, Thomas et al 1979).

Many insectivorous bird species require old growth structures (large snags, hollow trees, diverse interior forest habitats) to maintain their current populations. In some cases, such as woodpeckers which nest in large old trees, old growth forests are needed or persistence of a species (Raphael et al 1989, Mannan and Meslow 1984). Reducing or eliminating the old growth forest component from the landscape will likely reduce or eliminate many bird species, resulting in increased insect populations and damage to potential timber.

3.7.3.2 Small Fungus Eating Mammals

The relationships between old growth forests, small mammals, and mycorrhizal fungi are critically important to forest health and survival. (Mycorrhizae are an important factor in plant growth and the soil community--see section 2.5.8.) Some mycorrhizal fungi produce fruiting bodies called truffles beneath the surface of the ground or in rotting logs. Small mammals such as the northern flying squirrel and the red backed vole depend on these truffles for food. These mammals eat the fruiting body, but do not digest the spores, which are deposited in the animals' feces. The vole or squirrel may thus transport the spores away from the tree, and deposit them, along with essential yeasts and nitrogen fixing bacteria, in another location in the forest (Maser 1988, Perry et al 1989). This relationship ensures that the various species of mycorrhizal fungi are transported throughout the forest (Maser and Trappe 1984).

Both red-backed voles and flying squirrels are dependent on old growth structures for their persistence. Voles (small, ground living mice) require coarse woody debris for shelter, for hiding places, and for access to truffles (Maser et al 1979). This habitat type is only produced by old growth forests. Flying squirrels are cavity nesters, and probably need woodpecker holes in large snags or hollow trees to survive (Carey 1988). Flying squirrels may also find that their mobility limited in dense second growth forests. These animals travel by gliding from tree to tree, necessitating a somewhat open situation. Thus, patchy open old growth forests or young natural forests with abundant snags and large old trees are needed.

Without old growth structures, the populations of red-backed voles and flying squirrels would decline. This would result in the loss of one major means for transporting mycorrhizal fungi throughout the forest ecosystem. The impacts of reducing this transport mechanism may not be immediately apparent, because mycorrhizal fungi already occupy most forest sites. However, this "vector" may be a fail-safe mechanism which ensures that the thousands of species mycorrhizal fungi are well distributed across the landscape, and that areas where mycorrhizae have been extirpated by disturbance can be re-colonized. Eradicating such "backup" measures is not wise forest use (Bormann 1987).

3.7.4 Conclusion

Many wildlife specialists believe that wildlife species which make use of old growth forest habitat and structures require those resources to persist. Further study may show that this is incorrect in some cases, or that old growth structures developed within managed commodity forests may provide satisfactory replacement habitats for some species. In our opinion, however, forest use plans should not assume either of these potential scenarios to be true. Rather, conservational plans which protect old growth habitat for wildlife should be instituted. Many wildlife species require an interconnected network of fully protected, ecologically viable old growth forests for survival. This network must extend through the managed forest landscape, as well as in old growth conservation areas.

3.8 BIOLOGICAL DIVERSITY AND ECOSYSTEM STABILITY

The diversity of an ecosystem governs the ability of that ecosystem to absorb stress or change without significant loss of ecological function (Franklin et al 1989, Bormann 1987). Ecological diversity also implies a system of checks and balances which allows all components of the ecosystem to function, but no one part to dominate. Biological diversity helps to control insect populations (Schowalter 1990, Perry 1988) and helps to retain microbial, fungal, plant, and animal species which are beneficial to plant life in all parts of the landscape (Perry et al 1989).

Ecological diversity can be thought of as "options" or "fallback positions." Most of us who own a car carry a spare tire. Ecological diversity provides a similar backup system in the forest landscape. If something "goes wrong," the ecosystem can respond to the new condition quickly. Ecological diversity often takes the form of redundancy--the ability to accomplish the same result through different channels, or the retention of a biological capacity in excess of that required for normal existence. Ecosystems which lack diversity have no fall back positions, no insurance policy. A homogeneous forest has a very limited range of potential responses. For example, if climatic conditions change, or if the forest is attacked by insects or disease, a forest with little diversity may perish.

3.8.1 Biological Diversity In Forests

Biological diversity within natural forest ecosystems is closely associated with old growth forests and young post disturbance ecosystems. Old growth forests provide structural diversity in the form of large old trees, varied stem sizes, open canopies, and coarse woody debris within the forest. After a natural disturbance, a substantial amount of this structural diversity is carried over into younger forests. Retained structures, such as coarse woody debris and live veteran trees, are termed a "biological legacy" from the previous forest.

The biological legacy provides a variety of structural diversity, from microscopic to macroscopic scales, within the forest. The biological legacy also furnishes specific habitats for a diverse range of organisms from animals and plants to fungi and bacteria, thus forming a healthy forest ecosystem. Young natural forests (before crown closure) have the highest species diversity of any stage of forest succession. The vibrant soil community, balanced insect population, and stabilized conditions in such a young forest provide a healthy environment for young trees (Franklin 1990, Franklin and Maser 1988, Perry et al 1989, Schowalter 1990).

In contrast, forest homogenization, or simplification, is a goal of modern conventional forest management. Forest managers plan to replace the naturally diverse forest with tree plantations, often containing only one tree species. These plantations generally come from genetically limited stock, and may soon come from genetically designed stock (Doyle 1989). Pesticides will be used to control insect “problems", and to attempt to eliminate competing vegetation. Replanted forests will be cut down at a young age, no more than 100 or 120 years, and often much younger.

Figure 2 shows the difference between a conventional forest stand managed on a short rotation and a natural forest allowed to enter the old growth phase(adapted from Franklin et al, 1986).

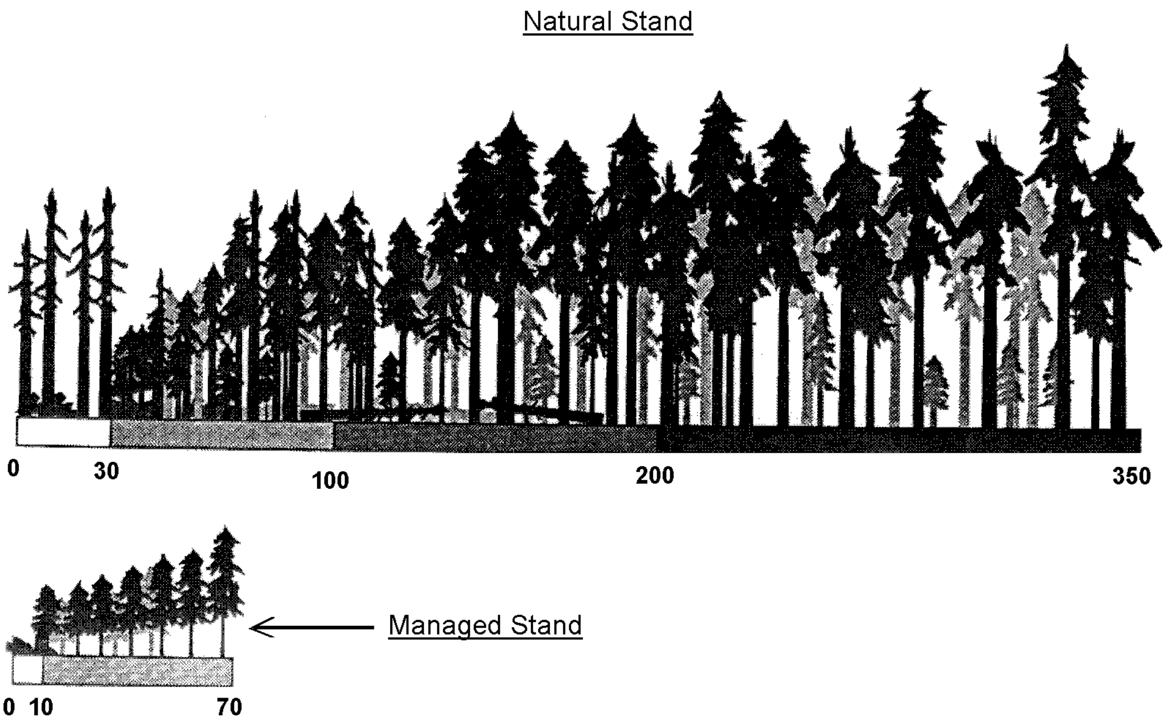

Figure 2: Contrast between natural and typical, managed forest rotation in Pacific Northwest. Mature and old growth stages are eliminated under management and the period before the canopy closes is drastically shortened.

Conventional forest management will eradicate some of the biological processes which have sustained forests for millennia. Coarse woody debris and large organic debris will be reduced to negligible levels in conventionally managed forests. All snags are generally removed and the deciduous (i.e. competing) vegetation, the support for nitrogen fixing bacteria and vital mycorrhizae, are killed in the commodity forest. The "working forest" encourages planting of genetically uniform monocultures or near monocultures of tree species. This approach removes the fallback positions inherent in diverse natural ecosystems, and interrupts the process of soil formation. According to Franklin et al (1989):

> *Simplification--genetic, structural, landscape and temporal--reduces ecosystem resilience, eliminating redundancies that could be important in saving the ecosystem, and us. Because the ability of an ecosystem to tolerate or absorb new kinds of stresses or changes is clearly of increasing consequence, the key to retaining resilience must be in maintaining ecological complexity or diversity.*

> *Thus we see sustainable forestry is in fact supported by three legs: ecological diversity, genetic diversity and soils.*

The truncation or elimination of forest ecosystem types and the resulting decrease in stand level diversity within the forest ecosystem has many effects. Three examples of these effects will be discussed below. We will examine the effects of loss of forest diversity on forest soil fertility, on forest insect populations, and on mycorrhizal populations. These examples have been chosen because they are vitally important factors in all forests, and are often overlooked by the general public and practicing foresters.

3.8.2 Forest Diversity And Soil Productivity

Research in the last decade has indicated that diversity, at both the small-scale stand level and the larger landscape level, is vital to maintain the productivity of forest soils:

> *The old growth and herb shrub forest stages possess the only opportunities for adding nitrogen to the soil. The intermediate conifer establishment and dominant stages are essentially a soil nitrogen mining state. In managed landscapes and managed stands, where we're trying to condense the (natural) successional sequence into a tree crop species management cycle, we essentially remove those stages that are improving soil fertility. (Schowalter 1990)*

The level of available nitrogen is the primary nutrient related growth limiting factor in most forested ecosystems. Nitrogen is the most common gas in the atmosphere, but is in a form which is unusable by plants. Atmospheric nitrogen must be "fixed" with oxygen or hydrogen in order to be accessible to plants (Spurr and Barnes 1980). This process is carried out by certain species of bacteria. Some of these bacteria live in symbiotic relationships with various species of lichens and herbaceous plants. Other "nitrogen fixing" bacteria are free living in rotting wood.

Large fallen trees are a location for nitrogen fixation in the forest. As trees decompose, nitrogen compounds are released. These compounds are conserved and concentrated by various organisms, and reenter the nutrient cycle of the forest (Maser et al 1988). Anaerobic bacteria fix atmospheric nitrogen into a form usable by plants within the moist interior of the log. While the net rate of nitrogen accumulation per volume of fallen tree is thought to be relatively low, the large volumes of biomass within which the bacteria can function and the long time spans involved result in biologically significant nitrogen accumulations (Maser et al 1979).

The types of organic matter accumulated in old growth forest soils are unique, as are their functions. While young forest litter (leaves, needles, twigs) takes only 10 to 50 years to decompose, large Douglas-fir logs can take 400 years to become incorporated in the soil. Thus, the nutrient pool of a large fallen tree cycles on a time scale which can easily include the first four centuries in the life cycle of a young, replacement forest. Large fallen trees, which provide a long lasting biological legacy, are produced only by old growth forests. Small fallen trees from younger forest are more likely to burn in a fire, decay much more rapidly than large fallen trees, and are not as biologically valuable (Maser et al 1979).

The early successional "brush" phase which naturally follows extensive forest disturbances also plays a vital role in maintaining forest soil nutrients. "Brush" species contribute large quantities of easily decomposed deciduous litter to the forest soil, and serve as plant hosts to nitrogen fixing bacteria. The largest single input of nitrogen into the ecosystem occurs during this successional phase (Franklin et al 1989). "Brush" plants may also nourish the same mycorrhizal fungi which coniferous species depend on in later forest stages. This preserves both the nutrient cycling ability and the soil structure in a disturbed area before more demanding conifers dominate later phases.

The inputs to soil productivity are all related to diverse natural forests, which pass through both a shrub/herb phase and an old growth phase. Only if natural ecosystem diversity is maintained--both through time and across the landscape--can this system of soil replenishment, with all its benefits to human use of forests, be maintained. According to Perry et al (1989):

> *Diversity--in the plant community, the microbial community, and the ecosystem as a whole--plays a seminal role in buffering against disturbance and maintaining healthy links between plants and soils. Management systems aimed at protecting diversity are an important step toward sustainable resource utilization.*

3.8.3 Forest Diversity And Insect Pests

Schowalter (1990) has observed that old growth forests have large insect populations, yet these forests are relatively free of catastrophic insect damage. Insects and forests have evolved together over millions of years. Given ideal circumstances, insects are able to reproduce rapidly, but natural forest ecosystems have evolved a wide variety of ways to prevent "ideal circumstances" from occurring. In-tree chemical defenses, chemical confusing agents, insect predators, and diversity of tree species all combine to keep insect populations at endemic levels most of the time.

Healthy trees can devote some of their net energy production to manufacturing chemical defenses such as pitch, which are properly called allochemicals. These defensive substances can drown, immobilize, or poison attacking insects. This defense mechanism is very effective as long as the tree is sufficiently vigorous to have "extra" energy (Waring and Pitman 1985). Physically damaged trees often do not have sufficient energy or vigor to manufacture defensive chemicals, are defenseless against insect attacks, and are removed from the forest canopy.

Chemical confusing agents manufactured by various plants are an interesting recent discovery by researchers. Many insects do not find host species (food) by sight, but navigate instead by means of subtle chemical smells and emissions. Some shrubs, such as Ceanothus spp., appear to exude aromatic odors which may mask the chemical emissions of young Douglas-fir trees so that Douglas-fir feeding insects are unable to find their target (Schowalter 1990). Such defense mechanisms, which are only now being investigated, depend on forest diversity.

Insect predators play a vital role in controlling insect populations. The role of woodpeckers in bark beetle control has already been discussed. Reducing the structural diversity of the forest will reduce woodpecker populations, as the birds require large snags for nest excavation and winter feeding. Forest diversity also supports other predator species. For example, certain foliage feeding birds, mice, and beetles feed on gypsy moth (Heptocampa spp.) caterpillars during moth outbreaks. When moth populations are low, these predators feed on the more constant detrivore[1] population. Thus, one forest cycle, based on detritus, supports a predator population which is instrumental in biological control in the case of an insect epidemic (Bormann and Likens 1981). Reducing forest diversity, and favoring the sterile closed canopy young forest stage, would reduce the detrivore population as well as the population of opportunistic predators which respond to increased insect “pest" populations.

The diversity of tree species in old growth forests exerts a powerful biological control on insect species. Insects tend to be very specialized feeders. When specific food types are distributed randomly throughout the immense volume of an old growth forest canopy, insects are forced to move throughout the forest, searching for their desired food type. Extended travel exposes the insect to predators. These combined factors tend to control populations of insect herbivores in old growth. In a young managed stand, however, the distance to the next food supply is usually very short, and the insect predator population is low.

A further value of forest diversity in insect control is that diverse habitat slows evolutionary development. Insects can evolve with great rapidity to new environmental conditions. The natural genetic diversity in many tree species tends to ensure that very few insects encounter identical genetic substrates (Raffa 1989). There is a very real possibility, however, that uniform managed forests will exert evolutionary pressure on herbivore insects, leading to the evolution of insect species which can easily overcome the natural defenses of genetically similar trees. This would leave pesticides as the only means of defense against insects. However, there is no physiological insecticide which cannot in turn be overcome by insect populations (Raffa 1989). In tree plantations, insects may only be faced with the simple challenge of increasing their already potent reproductive capacity to utilize fully the food supply presented by young, genetically similar, uniform trees.

3.8.4 Forest Diversity And Mycorrhizae

We have discussed mycorrhizae previously in section 2.5.8. The symbiotic relationship which trees form with mycorrhizal fungi is extremely important to tree growth. Regeneration failures have been recorded on harsh forest sites on which the mycorrhizal community has been severely damaged or eradicated by forest management practices (Perry et al 1989). Diversity within the ecosystem is important to the survival of mycorrhizae in several ways.

Researchers have found that the same mycorrhizal fungi which occur in mature forests form symbiotic relationships with the common brush species which occupy disturbed areas. The mycorrhizal fungi are then passed back to the main coniferous species when these become established on the site (Perry et al 1989). The deciduous brush species, and sometimes the fungi themselves, depend on the moisture storage capacity of well

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[1] . Detrivores are invertebrates such as mites, springtails, millipedes, and earthworms which aid in the decomposition of dead organic material

decomposed coarse woody debris and humus for survival during periods of drought. Moist, decomposing fallen trees can also protect mycorrhizal fungi during forest fires. The survival of necessary mycorrhizae depends on the diversity of the forest, both temporally and structurally. Natural successional patterns and coarse woody debris are required to maintain a vital mycorrhizal population. Conventional "brush" control or management of "competing" vegetation can interrupt this natural cycle, and greatly reduce the mycorrhizal population on a forest site (Perry et al 1989).

The mycorrhizae on any natural forest site tend to be extremely diverse. The types of mycorrhizae dominant on any given site shifts with different climatic conditions at different times of the year. Mycorrhizae which are adapted to hot, cold, wet, or dry conditions all have a particular part to play (Amaranthus 1990). Although not proven, causing the extinction of even one of these specialized species could have a significant negative effect on forest development and growth.

Mycorrhizae are critical to the successful continuance of our commercial and natural forests. Like so many other important facets of the functioning forest, they depend on forest diversity, particularly old growth forests and early successional forests for persistence. Removing these forest phases from the managed commodity forest would place the continuance of the entire rhizosphere, and our commercial forests, at risk (Amaranthus et al 1989, Perry et al 1989).

3.8.5 Conclusion

This section of the report has shown the importance of forest diversity in sustaining forests. Forests are not a group of products, they are an assemblage of processes. (Maser 1988) Process implies function. The maintenance of ecological functions in all forests is inextricably interwoven with old growth forests. Physical structures passed on from old growth forests, and the life forms within them, area vital biological legacy to younger forests. Without the diversity provided by old growth forests, and in part by early successional shrub communities, the continuance of all forests is at risk.

3.9 HUMAN USES OF OLD GROWTH FORESTS

Until the last 30 years or so, old growth forests dominated the natural forest landscape in British Columbia. People have always depended upon old growth forests for survival and well being. Human uses of old growth have included spiritual renewal, recreation, water, food, timber, fisheries, and medicinal compounds. We also require old growth forests to maintain biological diversity, to provide genetic reserves, and to protect the biosphere. Some of these uses and values may seem esoteric to people who emphasize the financial benefits of old growth timber extraction. However, biological diversity and biosphere protection are not esoteric values. People will readily recognize the value of old growth forests in protecting the earth once pure water and/or clean air are no longer sufficient. To think that we do not depend on old growth forests is arrogant and short sighted. At the most basic level, human culture has been sustained for thousands of years by old growth forests.

Old growth forests are currently widely used as sources of valuable high quality timber and pulp. Old growth forests contain large, high volume trees, which produce fine grained, high strength wood and long fibre pulp. Mitchell et al (1989) found that the strength and pulping characteristics of the mature wood found in old growth trees will not be duplicated in the immature wood found in short rotation plantation trees. The immature wood being produced by modern "fibre farms" has shorter fibres, lower density and lower strength. Economic (as well as ecological) logic indicates that we should alter our forest management practices to produce financially valuable mature wood in managed forests, and carefully consider the rate at which we log our irreplaceable old growth timber reserves. Single minded forest exploitation, coupled with climatic alterations, may have far reaching ecological effects which are not accounted for in current forest use plans.

The liquidation of old growth forests is a large scale experiment, carried out within our province---our biosphere---for which we do not know the outcome. From our limited view, we can "see" that everything is going well. Although most of the old growth forest is gone, few ill effects are noticeable. Few negative impacts can be "proven" to rigorous scientific standards.

We pride ourselves on mimicking the European approach to forest management, which after only 400 years (about one life cycle for an average forest) is collapsing (Maser 1988, Plochmann 1990). We do not consider factors such as climate change, cumulative effects, landscape ecology alterations, and loss of genetic diversity in our "long range" 5 or 20 year forest management plans.

Perhaps we ignore these factors because their meaning and importance tends to exceed our own lifespans. People are challenged to be able to relate to the time and space of forested landscape. Forests operate on cycles of 200 to 1000 years--indeed, forests are a continuum. If we are lucky our lives may last 100 years. If our governments are lucky they last four years. Our corporate institutions function on one year profit and loss statements. We are one tenth the height of a short tree. More that 40 people would have to stand on each other's shoulders to reach the top of a moderately tall Sitka spruce tree. The person at the top would only be able to see more tree tops, not the whole forest. A moderate sized watershed (e.g. 5000 hectares) would require months for two people to explore, to map, and to begin to understand the relationships within this landscape. The imbalance between human cycles and forest cycles has led us to the brink of destroying the very forests that sustain us.

Old growth forests mean different things to different people. However, our hope for survival and the survival of forests is inextricably linked with our ability to appreciate and accommodate the vast differences in scale between people and forest landscapes. We are the only organism who ever wanted to dramatically change the forest landscape, and the changes we have made now threaten the survival of the forest itself. It is now time to find our place within the forest web . . . at both the stand and landscape levels.

4. HOW DO WE PROTECT OLD GROWTH FORESTS?

We believe that old growth forests can only be protected by an approach which retains fully functioning forest ecosystems across the landscape, and which deliberately protects old growth forests within that landscape. The following four requirements must be met in order to protect old growth forests:

1. Very large (greater than 20,000 hectares), intact old growth forest ecosystems must be fully protected from consumptive human use. Such ecological reserves are needed to provide the gene pool, the species reserve, and the functioning example we need to rehabilitate damaged forests (Friedman 1988, Noss 1988). These forests should be large enough to:
    - maintain functioning communities in a diverse landscape,
    - assure the continuation of ecological processes which have co-evolved,
    - withstand the largest natural disturbance and retain viable old growth ecosystems, and
    - buffer and withstand stress from climate change, global pollution, and ozone depletion.
2. A network of protected old growth forests which extends across the managed forest landscape must be established. This web will be composed of stands up to approximately 1000 hectares in size. Although the individual forests or stands in this network will be small enough to be at risk from catastrophic disturbance, the overall network will serve to retain the old growth forest habitat type in all the forest landscapes of B.C. (Harris 1984, Mahlien and Hemstrom 1988).
3. Riparian (streamside) zones throughout the forest landscape must be fully protected. These special ecotypes provide the travel corridors for plants and animals across the forest landscape, and connect the islands of old growth in the network described in 2)above. Riparian zones connect forest stands to each other, and to other parts of the landscape. In this way riparian zones facilitate valuable habitat diversity throughout the landscape (Franklin et al 1989, Mahlien and Hemstrom 1988).
4. Ecologically responsible, wholistic timber management must be practiced on all forest lands used for timber production. The primary goal of ecologically responsible forestry is to ensure that the whole forest ecosystem remains intact and fully functioning before, during, and after timber extraction (Franklin et al 1986, Hemstrom 1990). Ecologically responsible forestry must include:
    - retaining old growth structures (large standing trees, snags, and large fallen trees) in managed forests,
    - maintaining natural movement corridors for plants and animals, and
    - maintaining biodiversity (species, genetic, and community) by matching timber extraction and timber management patterns to the habitat needs of the whole forest community.

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