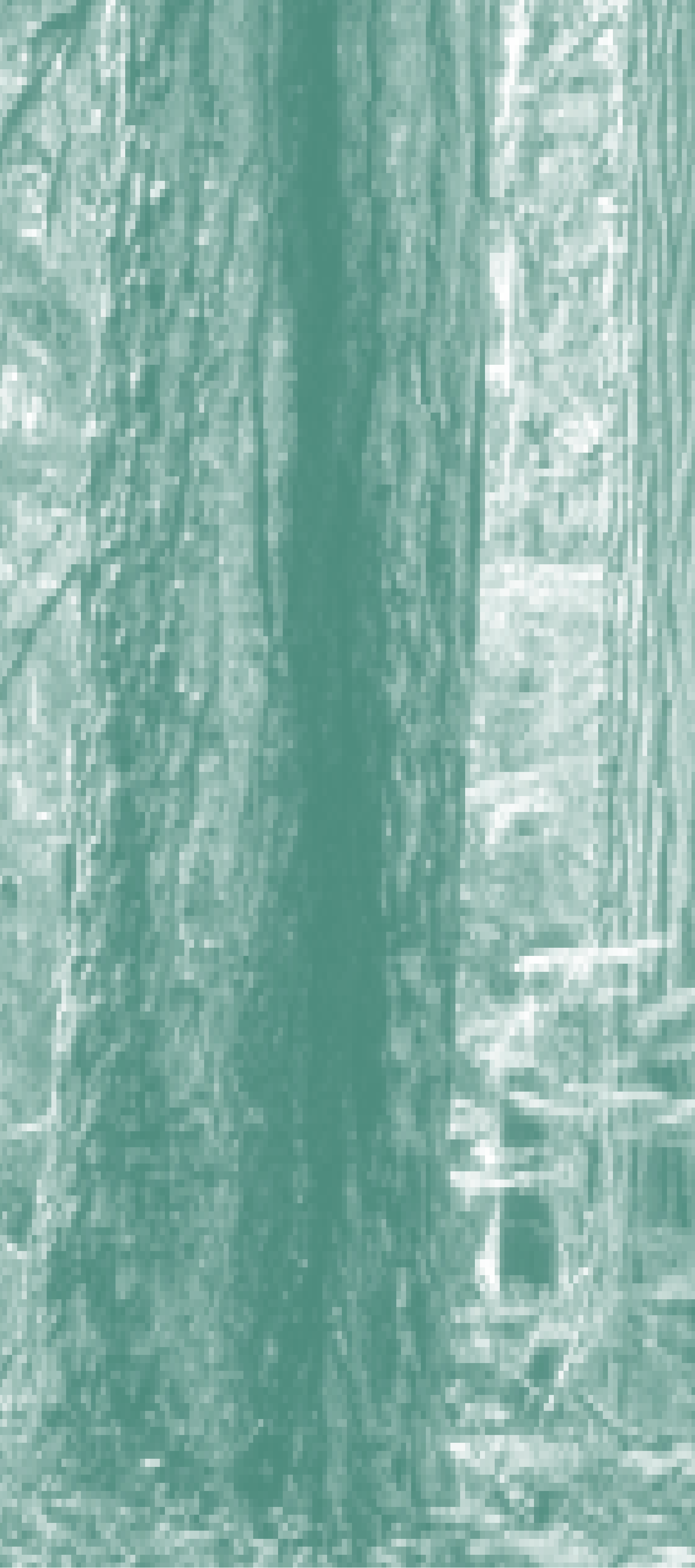

# SIMPLIFIED FOREST MANAGEMENT TO ACHIEVE WATERSHED AND FOREST HEALTH: A CRITIQUE


The Scientific Panel on Ecosystem Based Forest Management:

Jerry Franklin

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**Simplified Forest Management to Achieve Watershed and Forest Health: A Critique**

The National Wildlife Federation has worked for decades to protect habitats that wildlife and people depend upon. As our understanding of habitat function evolves, so too must our prescriptions for maintaining their health. This report is a step in that evolution.

Today, the decline of salmon and other natural systems, combined with the growing human population along the west coast, is forcing us to explore new ways of managing our watersheds and forests. But while the concepts of *watershed* or *ecosystem management* are broadly appealing, it is often unclear what they really mean. Thus, NWF asked a multi-disciplinary group of scientists to explore what kind of management will keep our watersheds and forests functioning properly. Through their findings, reported here, we seek to prompt an overdue conversation that can culminate in a stronger scientific footing on which to base management decisions.

A prescription for better management is just one part of a bigger picture. Through this report and its other ongoing efforts, NWF seeks to build public awareness of the problems facing our forested watersheds and the strategies for solving them. This will entail working for better laws, helping states and localities to safeguard their own watersheds, promoting efficient use of natural resources, and, most importantly, getting individuals involved. Only in these ways can we progress in making all our waters fishable, swimmable and drinkable.

The National Wildlife Federation rejects the outdated myth that people must choose between economic prosperity and healthy natural resources; our communities can only thrive when we have both. We value the lives and livelihoods of those who work in our forests, we want to bring stability to rural communities, and we want to conserve our renewable resources too. I urge you to join us in working toward these goals using the common sense conservation approaches exemplified by the contents of this report.

Thank you to all of those who have helped to make the report possible. And thank you to those who will use its findings to help us shape a better future for people and wildlife alike. Together, we can and will make a difference.

Mark Van Putten
President and CEO

# Contents

# I. Introduction – "Maintaining the Integrity of Forest Ecosystems"

Much has been written over the last decade about strategies to restore and maintain what is most succinctly called the integrity of forest ecosystems. In this context, ecological integrity has been described best as "a system's wholeness, including presence of all appropriate elements and occurrence of all processes at appropriate rates" (Angermeier and Karr 1994). A primary challenge to managing forests for ecological integrity—particularly on public lands—has been to find levels of timber and other resource extraction consistent with a broad set of social goals. These goals include maintaining environmental services (e.g., watershed protection and carbon sequestration), protecting biological diversity, providing goods (e.g., wood and forage), nurturing aesthetic and spiritual values, and assuring the sustained long-term health of entire forest ecosystems and landscapes. Suggested approaches for achieving a balance between extractive and non-extractive management of forests cover a spectrum ranging from total preservation with no logging at one extreme, to active logging of entire landscapes at the opposite extreme. This critique focuses on a set of widely accepted management approaches that lie at the extractive end of that spectrum.

The concept that all forests must be silviculturally manipulated (logged) and eventually replaced in order to provide desired goods and services, including the continued health of forest landscapes, is an old and honored tradition among many forestry professionals. The "fully regulated" forest landscape with its "balanced" distribution of forest age classes, or developmental states, has been a goal and icon of forest management for over a century. Another traditional view is that forests must be actively replaced, because without human intervention their ability to provide goods and services will decline and fire, storm, insects or disease will eventually destroy them.

**"Intensively managed forests cannot fully duplicate the role of natural forests."**

Proposals for widespread logging as the mechanism to create and provide for all forest values are therefore not surprising. These approaches continue to be advanced by advocates of timber harvesting under such rubrics as "Structure-Based Management" and "High Quality Forestry." Indeed, such approaches have been proposed as optimal to achieve forestry goals in the United States (Oliver et al. 1997). These proposals assert that managed forests, including plantations, are not highly susceptible to destruction by natural disturbances whereas unmanaged forests are. Therefore, proponents argue that forest reserves are a poor conservation strategy since they will inevitably be destroyed, and that active logging is thus necessary to maintain desired forest values. A parallel — although often unstated — premise is that foresters know how to grow new forests that will provide desired goods and services.

## I. Introduction – "Maintaining the Integrity of Forest Ecosystems"

The proposition that forest values are protected with more, rather than less logging, and that forest reserves are not only unnecessary, but undesirable, has great appeal to many with a vested interest in maximizing timber harvest. These ideas are particularly attractive to institutions and individuals whose incomes depend upon a forest land base. On the other hand, approaches that involve reserving of a portion of the land base, or harvest practices that leave commercially valuable trees uncut to achieve ecological goals, are often considered much less desirable as they reduce traditional sources of timber income.

**"In this report, we review scientific findings associated with the development of natural forests, landscape ecology and conservation biology with particular attention to the over-simplified structural models associated with SSBM and the importance of forest reserves to achieve various ecological goals.**

Our interpretation of the scientific literature, combined with our professional experience, leads us to some very different conclusions about appropriate approaches. Scientifically based strategies for the conservation of forest ecosystems, with a sound theoretical basis in conservation biology — including biodiversity and critical ecological services — have inevitably incorporated reserves along with ecologically sensitive management of unreserved areas (e.g., FEMAT 1993). At a regional or large landscape level, this may be partially accomplished by balancing different priorities among multiple landowners. For example, in the Pacific Northwest the responsibility for maintaining terrestrial biological diversity has been placed largely on federal lands (Tuchmann et al. 1996).

Our objective in this critique is to address the validity of the concepts and assumptions supporting forest policies and plans that call for active management of essentially the entire forest estate, and which specifically reject the consideration of biological reserves and non-traditional harvest techniques, such as structural retention. Its advocates have labeled this approach "structure-based management" or "landscape management" (e.g., Oliver 1981, Oliver and Lippke 1994). (Much of forestry practice and forest management is determined and informed by the structural characteristics of forest stands; we do not wish to see this term appropriated for limited and specific management proposals). Consequently, we specifically criticize the "simplified structure-based management" approaches derived from simple structural models and traditional silvicultural systems such as clearcutting.

In our view, the assumptions underpinning simplified structure-based management (SSBM) are not supported by the published scientific literature on structural development of natural forests, disturbance ecology, landscape ecology and conservation biology, or by the relationships between ecosystem structures and processes. In this report, we review scientific findings associated with each of these areas with particular attention to the over-simplified structural models associated with SSBM and the importance and viability of forest reserves to achieve various ecological goals.

## I. Introduction – "Maintaining the Integrity of Forest Ecosystems"

We agree that many issues raised by the proponents of SSBM about ecosystem management are valid and require attention. For example:

- Reserve strategies must account for habitat loss through natural disturbances. In recognizing this point, we also note that management implications will be different for areas with different disturbance regimes.

- Fire exclusion, high-grade logging and active management to create fully-stocked have increased the susceptibility of many dry forest types in the West to catastrophic disturbance, a situation that puts important habitat at risk. Well-planned, carefully executed thinning of smaller trees may help reduce the risk of stand-replacement fire.

Thinning densely stocked, young to mid-aged stands can increase tree vigor, encourage understory growth, and enhance structural complexity. Management regimes such as those involving variable density thinning and the creation of coarse woody debris and decadence in living trees (e.g., cavities), may be very effective in creating structural complexity in managed stands (see, e.g., Carey et al. 1996).

Hence, we support the notion that silvicultural activities — structure-based management in the broadest sense — can assist in the maintenance of biological diversity and other ecological services in managed stands. We do not believe, however, that scientific literature or forestry experience supports the notions that intensively managed forests can duplicate the role of natural forests, or that sufficient knowledge and ability exist to create even an approximation of a natural old-growth forest stand.

> **"We do not believe that the scientific literature or forestry experience support the notions that intensively managed forests can fully duplicate the role of natural forests, or that sufficient knowledge and ability exist to create even an approximation of a natural old-growth forest stand."**

### What is Old-Growth?

Much of this report, and indeed many of the issues facing ecosystem-based management in general, have to do with the functional aspects of old-growth forests and the degree to which old-growth functions can be duplicated in forests managed for commodities. In discussions of these issues, it is imperative to define clearly what is meant by "old growth." This is especially important because two quite different definitions appear in the literature.

Because ecological characteristics of old growth vary from one forest type to another, no single specific definition is appropriate. However, US Forest Service definitions for all major types in the Pacific Northwest adopt five criteria: number of large, old trees; variation in tree diameter; degree of tree decadence; amount of large, dead wood; and the degree of vertical heterogeneity and/or horizontal patchiness in the canopy. (See NRC 2000 for a more thorough review). These are the characteristics used in this report.

*continued*

## I. Introduction – "Maintaining the Integrity of Forest Ecosystems"

Oliver and Larson (1996) adopt a different, much more restrictive definition. According to them, forests don't enter a "true old growth stage" until the trees that became established immediately after the last stand-initiating disturbance have died and been replaced by trees (virtually always shade tolerant species) that established under the canopy of the original invaders.

The difference in these definitions cannot be overstated, especially in forests dominated by long-lived, fire resistant conifers such as Douglas-fir, ponderosa pine, longleaf pine, and redwood. In these forest types, trees established after a given disturbance characteristically live many hundreds of years, and the stands typically exhibit the set of characteristics most commonly associated with old growth by their 200th year (NRC 2000), remaining in an old-growth phase for centuries thereafter and, in some cases (e.g. ponderosa pine), in perpetuity barring a change in climate or disturbance regime. Using Oliver and Larson's definition, however, the old forests of Douglas-fir and ponderosa pine that dominated much of the west when EuroAmericans arrived would not have been "old growth," and in fact very little old growth would have existed.

Names such as "old growth" are a convenient and necessary shorthand for discussing what often are complex and variable sets of conditions. Whatever we choose to call a particular stage of forest development, the basic question remains the same: what are the relationships among its structure, its functions, and the objectives we are trying to achieve.

In setting forth the following critique and management considerations, we have, by necessity, summarized a great deal of information. Whole texts have been written on subjects restricted to short summary analyses in this report. We urge readers to consult the extensive bibliography when preparing or critiquing forest management plans or prescriptions. In addition, our examples draw largely from the forest ecosystems of the Pacific Northwest with which we are most familiar. Our generalized conclusions and considerations, however, will apply to many additional forest types throughout the U.S.

# II. "The Importance of Considering the complexity of Natural Forests"

The following critique is organized around six key considerations that we believe are essential to ecologically based forest management, but which the simplified structure-based approaches address either inadequately or not at all. These are:

(1) The complexity of natural forests;
(2) The resistance of older forests to catastrophic disturbance;
(3) Habitat requirements of species of concern;
(4) The importance of understanding the impacts of roads;
(5) The importance of regional context; and
(6) The role of reserves in ecological management.

The literature describing and promoting SSBM is somewhat inconsistent, but reviewing it we found some common themes that represent what we consider serious errors of commission or omission. Perhaps more importantly, these six considerations respond to the themes land managers and policy makers have most often taken from the literature of SSBM and applied in management plans or silvicultural practice. We offer examples from several regions but our discussion is most pertinent to the forests of the Pacific Northwest, both "westside" and "eastside" (i.e., both west and east of the Cascade-Sierra cordillera).

### Simplified Structure-Based Management

Simplified Structure-Based Management (SSBM) is not a single theory or practice. It is a set of loosely associated forestry concepts drawn principally from traditional silvicultural science, and applied to landscape-level forest management. SSBM relies on traditional silvicultural techniques—harvest, thinning, chemical application (herbicide and pesticide), and pruning—to create salable timber and other forest "products," including wildlife habitat. SSBM is, in fact, simply an updated version of the traditional foresters' "regulated forest" with a few stand structural types substituted for age classes.

Management plans relying on SSBM generally share the following characteristics:

- Recognition of only four or five forest stand structures: Savanna, Stand Initiation, Stem Exclusion, Understory Re-initiation, and Old Growth.
- Use of intensive silvicultural management techniques in lieu of natural forest management approaches.
- Reliance on intensive management to move the forest through each of the stand structures.
- Intensive management of stands across the forested landscape to provide a constant flow of wood products and wildlife habitat diversity.

II. "The Importance of Considering the complexity of Natural Forests"

## 1. The complexity of natural forests.

**"Simplified stand structural models present an extremely limited view of forest structural development with respect to time and ecological process."**

Simplified structural models (e.g., Oliver 1981) gloss over many complexities and paint a dangerously abstracted picture of forests, potentially leading to poor forest management decisions. One of the greatest revelations in forest ecosystem science over the past several decades has been the recognition of structural complexity and its importance in providing habitat and regulating natural processes at a variety of scales. With rare exceptions, natural forests are diverse in terms of individual structures and are highly heterogeneous in their spatial arrangement. Indeed, more than three decades of ecological research has shown that natural forests are far more than a collection of living trees distributed uniformly over a landscape. Managing for ecological functions requires recognizing the complex and varied structures found in a variety of spatial patterns and scales in natural forests, and understanding the implications of different structural patterns for habitat and ecological processes. Those numerous processes include gene flow, migration, hydrology, nutrient cycling, the spread of disturbances, herbivory, predation, and system recovery from disturbance.

The following outline of four key components of structural complexity, should be addressed in the development of ecosystem-based management plans — and are notably absent in simplified structure-based approaches.

### Multiple Structures in Addition to Live Trees

Traditional forestry models of stand development recognize living trees as the only structure in a forest landscape. Yet, managing for ecological functions requires a recognition and understanding of the complex and varied structures found at a range of scales in natural forests. Natural forests, or forests managed for all their ecological functions, can provide environmental services ranging from habitat for conservation of biological diversity and consistent yield of high-quality water, to non-traditional forest commodities (e.g., mushrooms and pharmaceuticals), recreation, and high-quality timber.

Even live trees can and should be differentiated by such variables as size, canopy position, vigor, species, and levels of decadence. Other structural elements important to ecosystem management include standing dead trees (snags), boles on the forest floor, and other large pieces of wood (coarse woody debris) (Franklin, Shugart and Harmon 1987, Harmon et al. 1986, Maser et al. 1988). Such structures have great importance as habitat for forest-dwelling species, including rare species, and for other ecological processes. Both standing riparian forests and dead and downed boles and branches are critical to shaping the habitat structure and dynamics of forest streams and rivers (Harmon et al. 1986, Abbe and

Montgomery 1996, Bilby and Bisson 1997). Recruitment of coarse wood plays a crucial role in the recovery of streams and rivers from natural disturbances such as wildfire (Minshall 1997, Gresswell 1999) and volcanism (Sedell et al. and Dahm 1984).

The fact that dead trees and logs are as important to ecosystem function as living trees challenges traditional forestry models that treat such materials as waste, fire hazards, and mechanical impediments. To move away from ecologically simplistic models, new forest management regimes must address questions such as: How much coarse woody debris is needed? and: How many snags in various stages of decay are required? to fulfill important ecological functions (see e.g., Maser et al. 1988, Franklin 1992).

Other important individual structural elements include understory plant communities (layers of shrubs, herbs, and mosses), and surface organic matter or litter layers. The extent of such structural elements may also be critical to decomposer organisms, wildlife species, and processes that support them. For example, the development of thick litter layers in old-growth forest stands has been identified as a key factor in production of truffle-like fungi which are, in turn, critical food sources for small mammals such as flying squirrels (North et al. 1999).

## Spatial Pattern as an Important Element of Stand Structure

Traditional models of forest structural development, including the simplified structure-based approaches, portray forest stands as

*Dead and downed trees and logs are an important component of forest ecosystems that goes unacknowledged under most renderings of SSBM.*

simple, homogenous structural units (e.g., Oliver and Larson 1996). They do not address spatial patterning in structure as an important element of forest development. Yet this spatial patterning should be fundamental to any strategy that purports to address a broad range of ecological objectives.

**"Ecological research has shown that clearcuts are quite unlike any natural disturbance."**

Natural forests are inherently spatially heterogeneous. For example, trees of particular sizes or species often are aggregated, rather than distributed either randomly or uniformly throughout forest stands. Two important and widely known spatial patterns are heterogeneity in the horizontal and vertical dimensions. Canopy gaps are an important form of horizontal diversity typically present in mature and old forests (although they also may occur in earlier stages of stand development). Such gaps typically develop as individual and small groups of trees die and function as an important habitat element. For instance, richness and density of bird species are often higher in gaps than in undisturbed forest; some species are gap specialists (Blake and Hoppes 1986, Martin and Karr 1986, Noss 1991, Noss and Cooperrider 1994). An important counterpoint to gaps — sometimes called "anti-gaps"— may occur if a dense cohort of tree saplings develops in response to a gap or other disturbed portions of a stand. The low light levels in these anti-gaps typically results in loss of most, or all, of the vascular plant understory within that portion of the stand.

In many older forests, foliage is distributed essentially from ground level to the top of the crown. This is consistently the case in old-growth forests of the Pacific Northwest. However, depending on forest type and disturbance history, trees of different sizes and ages may be relatively evenly distributed throughout the forest, occur in discrete patches, or exhibit some combination of these two patterns (e.g., Parker 1997). Old-growth trees are usually relatively widely spaced, and therefore maintain crowns extending downward for one-half to three-quarters of their total height. Consequently, especially when old-growth forests are viewed as spatial mosaics, the distribution of foliage is heavily weighted toward the lower part of the canopy. Therefore, most of the upper crown in these stands is well lighted. In contrast, dense young stands typically have all of their foliage in a single, high, layer — resulting in dense shade throughout the interior of the stand. Such differences in canopy structure have profound ecological implications. For example, multiple canopy layers can increase biological diversity by dramatically expanding the number of available habitats. Vertical heterogeneity also results in diverse thermal environments, producing a multitude of microclimates. Furthermore, older forests contain a more diverse and abundant understory of plants which support more diverse invertebrate, vertebrate, and fungal communities, including epiphytic communities.

Ultimately, most older forest stands develop very complex spatial patterns of small, contrasting structural patches. This is true of almost all old forests in temperate regions, including the Pacific Northwest coastal forests of Douglas-fir, western hemlock, and western red cedar, although the dense vegetation in these forests can obscure the pattern. Horizontal diversity is much more evident in forests subjected to frequent disturbances of low-to-moderate intensity, such as the pine and mixed-conifer forests of the Sierra Nevada and Columbia Basin, which are disturbed by wildfire (Franklin and Fites-Kaufmann 1996).

Natural forest development ultimately produces an old-growth state in which stands are composed of many small but distinctive structural units. Traditionally, foresters have recognized these structural units as "stands" but functionally, the old-growth stand is the entire forest patchwork. In effect, to understand the habitat functions, reproductive potential, and ecological services characteristic of older natural forests, one must look at the entire mosaic of structural units or patches — from the functional viewpoint, the mosaic is the stand. Foresters have traditionally recognized and proposed managing each structural unit as a stand or, alternatively, to homogenize them through even-aged management. This difference in perspective between traditional silviculture and more ecologically based approaches to forest management, is one of reasons for the intense arguments over the nature of old forests in places such as the

*Biological legacies—such as this down and decaying Jeffrey pine—provide continuity from one forest stand to the next.*

interior Columbia Basin and Sierra Nevada Range (Sierra Nevada Ecosystem Project 1996-1997).

*Unlike clearcuts, wildfire disturbances often leave dead trees standing and unconsumed wood debris on the forest floor.*

### Biological Legacies

Many of the structures and organisms found in natural forest systems originate in preceding stands. Such "biological legacies" include snags, living trees, soil fungi, and a host of other organisms that survive stand-regenerating disturbances. Biological legacies provide continuity from one forest stand to another and across disturbance episodes, greatly enriching the structural complexity of young regenerating stands. Simplified stand-structure models (e.g., Oliver 1981) generally omit the concept of legacies.

One of the myths of traditional timber-focused forest management is that clearcutting mimics fire. Ecological research, however, has shown that clearcuts are quite unlike any natural disturbance. In contrast to traditional clearcuts that retain essentially none of the harvested stand, natural disturbances rarely clear away or even kill all elements of the preceding stand. Wildfire converts many trees from living to standing-dead and downed woody debris with varying — but usually small — amounts of organic material consumed by fire. Conditions following fires often favor the establishment of shade-intolerant species, such as Douglas-fir. However, many, if not most, natural Douglas-fir stands established following wildfire incorporate surviving large old trees — legacies from the previous stands.

Catastrophic windthrow typically converts overstory trees to logs and woody debris on the forest floor. Quite unlike a clearcut, none of the organic matter in windthrow events is consumed or removed by the disturbance. If the stand has an understory of trees that have advanced far enough in their regeneration, then this cohort of trees will respond to altered light conditions provided by the disturbance (these are likely to be at least moderately shade-tolerant species). There are many examples of such stands in the Pacific Northwest, including the dense western hemlock-dominated stands that developed following the 1921 windstorm on the Olympic Peninsula (Henderson et al. 1989).

## Richness and Duration of Development Processes

Finally, and perhaps most importantly, simplified stand structural models (e.g., Oliver

*Windthrow disturbances leave all organic matter in the forest system.*

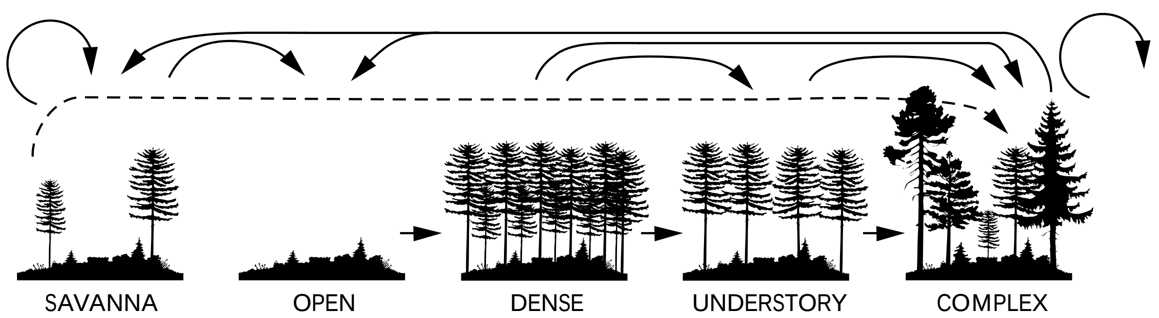
## II. "The Importance of Considering the complexity of Natural Forests"

1981) present an extremely limited view of forest structural development with respect to time and ecological process. Only half of the processes and developmental stages we consider important are represented in the widely cited model (Oliver 1981, Oliver et al. 1997). This model describes all of the post-maturation processes of vertical and horizontal diversification — critical in creating the diverse habitats and processes of the late-successional forest — simply as an "Old-Growth" or "Structurally Complex" stage. This provides no insight into the important developmental and structural attributes of late-successional forests or how their functions might be conserved in managed forests.

In places like the Pacific Northwest, many processes are associated with the structural development of natural stands (Spies and Franklin 1991). Each of these processes takes place over an extended time, rather than in distinct and mutually exclusive stages as simplified structural models suggest (e.g., Oliver and Larson 1996). As discussed in the previous section, natural disturbances vary in type, intensity, size, frequency, and homogeneity. Such variation in disturbances results in widely contrasting starting points for stand development (in terms of structural legacies), and has profound implications for the speed, composition, and density of tree regeneration. The consequence of varied time-frames for these processes and successional stages means that forest management aimed at reproducing (as much as possible) the structural complexity of natural forests, cannot be designed and scheduled based on simple time-staged actions. Instead of the generically programmed management steps that the simplified structure-based models call for, forest management should aim toward the development of stand structure and successional processes actually observed. The following six critical points outline the complex structural stages. For further detailed discussions see Franklin et al. and Carey (1999).

*An example of the "stages" of forest development derived from a simplified structure-based model (Oliver et al. 1997)*

**Changes in stand structures following growths (dashed arrows) and disturbances (solid arrows).**



## II. "The Importance of Considering the complexity of Natural Forests"

**Cohort Establishment.** The time required for this developmental stage – which produces a group of individual trees of the same age, established concurrently – varies greatly, depending upon seed source, environmental conditions, and competing vegetation. Regeneration may be almost immediate and dense (as in the case following many windthrow events), or may take decades. In some stands regeneration may be insufficient to produce a "fully stocked" forest, and the "self-thinning stage" may never occur.

**Canopy Closure.** Canopy closure is probably the most dramatic process in stand development in terms of the degree and rate of change that occurs in the ecosystem. Assuming regeneration of a fully stocked stand, as the overstory tree canopy closes, environmental conditions at the forest floor undergo major changes in light, temperature, humidity, and wind speed. Canopy closure mediates important microclimatic and hydrologic changes that influence the rate of runoff, and subsequent nutrient loss, soil and channel erosion (see e.g., Berris and Harr 1987).

**Competitive Exclusion or Self-Thinning.** This can be an extended period of dominance by the new tree cohort if the new growth is dense. Intra- or inter-specific competition among the trees — which results in density-dependent tree mortality — is a major process during this phase. Overstory dominance and competition is most intense early in the self-thinning stage, but eases gradually as the stand matures. Forest ecosystem structure and composition is usually simple early in the self-thinning stage. At this stage, species diversity typically is low, due to limited availability of resources in the understory, and limited spatial variety in the overstory (Harris 1984). Re-establishment of understory plants and tree regeneration comes late in the self-thinning stage, as mortality and growth of dominant trees creates increased light levels in the understory. Many natural stands actually bypass this stage of development due to low initial stocking levels.

**Maturation.** The maturation stage of stand development has many distinctive structural features and processes: maturation of the pioneer species cohort, development of shade-tolerant trees in the understory, development of minimal masses of coarse woody debris, and a shift from density-dependent to density-independent tree mortality processes. The dominant tree cohort reaches maturity at this stage, attaining maximum height and crown spread. It is important to note that this development requires about 200 to 250 years for Douglas-fir on productive sites in the Pacific Northwest. Douglas-fir typically only have 60-65% of their eventual height at 100 years. The mass of coarse woody debris is typically at its lowest level at this stage in development (Maser et al. 1988) because the inherited legacy of large snags and boles has undergone substantial decay, and significant inputs from the current stand are just beginning. Development of height and mass can be very important in creating the potential for other processes, such as massive uproots.

**Vertical Diversification.** The major process during this stage is the growth of shade-tolerant associates into intermediate and co-dominant positions in the canopy and development of decadence in the overstory in Douglas-fir forests. The growth of the shade-tolerant associates gradually results in the development of a continuous canopy from the ground level to the top of the crown. Douglas-fir trees redevelop branch systems on the middle and lower bole from epicormic (define) branches, a process initiated during the maturation stage. The vertical diversification stage may develop very slowly. Observations in natural, mature stands of Douglas-fir indicate that re-establishment of shade-tolerant tree associates and their movement into mid- and upper canopy levels may take several centuries (W. Keeton, personal communication, T. Spies, personal communication). Decadence develops in earnest through death and breakage in the tops of the dominant Douglas-fir, development of decay via a variety of entry points, and damage to residual trees from bole and butt rots.

**Horizontal Diversification.** This stage is characterized by increased horizontal diversification in environmental and structural conditions within a stand. Such diversification results from many processes including creation of canopy gaps by wind, insects, and disease, as well as establishment of dense patches of shade-tolerant associates. Clearly, gaps are not simply areas of greater light, but also places where coarse woody debris and other resources may be located. Indeed, the spatial complexity introduced by gaps is far greater than would appear at first glance. Some resources — such as increased moisture, nutrients and woody debris — largely coincide with the gaps, while other resources — such as increased light and heat — are displaced to the north of the gap (Van Pelt and Franklin 1999).

The horizontal diversification stage shifts a stand from homogeneity, and a relatively uniform distribution of structural features and environmental conditions, to a highly heterogeneous condition, with high levels of niche diversity and therefore, biological diversity. The complexity resulting from both vertical and horizontal diversification clearly is one of the major factors producing the combinations of habitat conditions needed by species which favor, or require, late-successional forest conditions (Ruggiero et al. 1991, Noss and Cooperrider 1994).

Most of the six processes described take place throughout stand development. In some cases, stages are skipped and multiple pathways of forest development are possible. For example, the development of distinct structural units within a stand (horizontal diversification) may begin with a stand-regenerating disturbance and the establishment of the new tree cohort, although it is often identified with the development of gaps during advanced stages of stand development. Nevertheless, specific processes typically dominate at particular points and can, therefore, be used to recognize process-based stages in stand development.

## 2. The resistance of older forests to catastrophic disturbance.

Two implicit assumptions run through simplified structure-based management approaches (e.g., Oliver 1981) and are made explicit in the 1997 Report on Forest Health of the United States (Oliver et al. 1997): (1) older forests are highly vulnerable to natural cataclysms, particularly stand-replacement wildfires and pest epidemics and (2) forest health can be restored and maintained through active management. In fact, quite the opposite is often the case. While there are some instances in which these assumptions hold, in general they are supported neither by data or experience. Older forests are more resistant to catastrophic disturbance than younger stands, and management often has increased, rather than decreased, the severity of fire and pests (Perry 1988a, 1998, Franklin et al. 1989).

The questions surrounding vulnerability and appropriate management practices, however, are not a simple either-or situation. Management — done with the aim of protecting all values — can, in some cases, reduce fire hazard and susceptibility to some pests (although that remains largely a hypothesis to be tested). Instances in which careful management may confer health benefits are most common in the dry forest types of the interior West. But the current vulnerability of those forests to disturbance is the result of many factors including fire exclusion, high-grade logging, livestock grazing and active conversion of stands from low to high levels of tree stocking rather than natural conditions (Agee 1993, Belsky and Blumenthal 1997).

To analyze the relationship between age and vulnerability, and provide managers with an appropriate framework to evaluate susceptibility to disturbance, we focus on several common natural disturbances in North American forests: fire, insects and pathogens, and landslides. Under each category, we briefly evaluate the

effectiveness of management in mitigating or exacerbating the effects of disturbance.

### Fire Susceptibility

With the exception of lodgepole pine, and some other high-elevation species in fire-prone environments, old-growth conifer forests in the West (and old-growth longleaf pine in the South) are relatively resistant to stand-destroying wildfires. Depending on the forest type, their resistance can be explained by three primary factors: (1) the ability of older trees to survive ground fires, (2) the fact that frequent ground fires kept fuels from building to levels that would carry fire into crowns (in areas of frequent fire) and (3) the extraordinarily cool, moist microclimates of the westside forests (i.e., west of the Cascade-Sierra Nevada cordillera).

Old-growth forests of ponderosa pine, sugar pine, Jeffrey pine, longleaf pine, and dry-site Douglas-fir, have a history of frequent ground fires that kept fuels (dead biomass and flammable understory trees) from building to levels that would support large, stand-destroying fires (Agee 1993, Hermann 1993). Because older trees of most of these species have thick bark, they are more likely to survive ground fires than young trees. And because fuels rarely accumulated to levels that would carry fire into the tall crowns of the older trees, these old-growth forests were quite resistant to stand-destroying wildfire (Agee 1993, Perry 1994).

Drawing upon historical surveys, (e.g., Cowlin et al. 1942), Henjum et al. (1994) calculated that nearly 90% of low and mid-elevation ponderosa pine forests in eastern Oregon and Washington had been old growth prior to the commencement of logging. This is similar to conclusions reached about the pre-settlement extent of Sierran mixed-conifer forest (Franklin and Fites-Kaufmann 1996). The only way such a proportion could be maintained within a regime of frequent fire is if older forests were fire resistant. Given the measured age-class distributions, it can be roughly calculated that, on average, stand-replacement disturbance events (fire or insects) during the 600-800 years prior to 1936, occurred on less than one-tenth of one percent of the landscape per year. (That does not include small-scale patch regeneration, the norm in those forest types.) Evidence of frequent ground fires in dry forest types is confirmed by studies that have dated the scars left on living trees by fire (e.g., Bork 1985). In contrast to eastern Oregon and Washington, two general types of fire regime have been documented for the ponderosa pine forests in the Black Hills of South Dakota — frequent, low-intensity and infrequent, catastrophic — depending on location and topography. Black Hills ponderosa pine forests apparently experienced a greater proportion of stand-destroying wildfire than in Oregon and Washington (Shinneman and Baker 1997).

Historically, fires in the west side moist, temperate conifer forests—the giant Douglas-fir and redwood forests of the Pacific Northwest—were less frequent but on average, more severe than those in dry forest types. There were also similarities, most notably the relative fire resistance of old-growth trees.

Furthermore, the cool, moist microclimatic conditions found within old-growth stands are not favorable to the ignition and spread of fire. Extreme conditions were necessary for them to burn and, in fact, major fires that affected westside old-growth forests (e.g., the Tillamook and, Yacholt Burns and their multiple reburns) were initiated by human activities outside of the old-growth forest and driven into them by strong winds under severe burning conditions. Old-growth westside forests are very resistant to fire ignition and spread. As we discuss in more detail later, experience in various Pacific Northwest forest types shows young plantations to be more susceptible to intense crown fires than old growth (Andrews and Cowlin 1940, Cowlin et al. 1942, U.S. Forest Service 1988).

**"The current vulnerability of dry forests of the interior West to disturbance is the result of many factors including fire exclusion, high-grade logging, livestock grazing and conversion of stands form low to high levels of tree stocking, rather than natural conditions."**

Mid- to high-elevation conifer forests include forest types that are among the most susceptible of North American forests to stand-destroying wildfires. Lodgepole pine, along with its close cousins jack pine and sand pine, are classic examples of forest types with a high probability of stand-replacement fires (and bark beetles) before trees reach 200 years of age. Because of its frequent serotinous cone habit, lodgepole pine in the Rocky Mountains often regenerates abundantly following fire, and that species tends to occupy areas with high lightning frequency. Such a dynamic cannot be generalized to other high-elevation conifers, however. Stand-replacement fires return, on average, every 800 years in subalpine forests in Oregon and Washington, and every 140-340 years in subalpine forests of Montana (an area with greater frequency of lightening) (Agee 1993). White fir-grand fir and mixed conifer forests experienced relatively frequent low-intensity fires that reduced fuels, while sparing many older trees, a dynamic much like the dry forests, but with a longer interval between fires (Agee 1993). Although longer fire-free intervals, and consequent greater build-up of fuels, suggest a greater probability of stand-replacement fires in true fir and mixed conifers than in ponderosa pine, age-class distributions in the former types suggest the older forests were not highly susceptible to crown fires. The 1936 forest survey of eastern Oregon and Washington classified 96% of white fir stands as "large," with most volume in trees greater than 12 inches diameter-at-breast-height (DBH) (Cowlin et al. 1942). Seventy-one percent of upper slope mixed conifers was classed as "large." At mid- and high-elevations in the Interior West it may take from 50 to over 200 years for a tree to reach 12 inches in diameter (Perry and Huang 1998). Large blocks of old-growth forests – rather than large contiguous blocks of young growth or highly simplified forests – are the best scenario for reducing catastrophic wildfire. Once west-side forests reach 350-400 years of age, they tend to be resistant to both fire ignition and initial spread, with forests of 1,000 years or older even more resistant than younger forests (J.F. Franklin, personal observation).

## II. "The Importance of Considering the complexity of Natural Forests"

There is considerable evidence that, in contrast to old growth, young stands are highly susceptible to crown fires. Early foresters often commented on the flammability of young stands. For example, Andrews and Cowlin (1940) documented and commented on fire in young second-growth stands in the Douglas-fir region. Early foresters in the ponderosa pine region (eastern Oregon and Washington) documented a similar pattern. Between 1924 and 1932, 32% of the total area of saw-log stands that experienced fire burned at stand-replacement intensity, whereas 73% of the area of second-growth stands (less than saw-log size) that experienced fire burned at stand-replacement intensity (Cowlin et al. 1942). In other words, once a fire was in a stand, the probability the stand would be destroyed was 2.3 times greater in small second growth (less than saw-log size) than in large second growth or old growth. That statistic applied to all commercial forest types, not just ponderosa pine.

More recent fires tell the same story. For example, in the 1987 Silver fire in southwestern Oregon, 45% of old-growth and mature stands (average DBH > 21 inches) and only 20% of small saw-timber stands (average DBH 12-21 inches) escaped with less than 10% mortality. Stands with average DBH less than 12 inches were most heavily affected, 65% having "less than adequate stocking" after the fires (U.S. Forest Service 1988, Perry 1994). In these and other examples, burned plantations often were destroyed.

Various factors may explain the susceptibility of young stands. Typically, a high level of continuity or contact exists between adjacent tree crowns. Combined with a high volume of crowns close to the ground, this makes young stands highly flammable (Andrews and Cowlin

1940). Large amounts of debris, either large or small in size, left as logging slash, or as legacies from earlier fires, can greatly increase fire hazards (see, e.g., Huff et al. 1995).

### Does Logging in Older Forest Stands Reduce Fire Hazard?

The variety of forest types, environmental conditions and approaches to logging precludes a simple yes-or-no answer to the question of whether or not logging older stands reduces fire hazard. In the Douglas-fir region, and upper-slope true fir stands of the Interior West, logging is much more likely to increase rather than decrease fire hazard for two reasons. First, old-growth stages are generally the most fire-resistant structural stages a forest can attain. Any activity that replaces fire-resistant old trees with fire-susceptible young trees, or that fragments the old-growth forest, increases hazard to the entire stand and surrounding landscape. Second, logging generates slash that increases fire hazard, and methods to reduce slash carry risk in themselves. The same arguments hold for the dry forest types of the West, but the incursion of young trees following fire exclusion and livestock grazing introduce a complication not found in more mesic old-growth forests (or at least not to the same degree). In forests with a dense growth of understory trees, the probability of crown fires has almost certainly increased over what it was under natural conditions. Using logging to reduce this hazard must be carefully assessed, because logging may exacerbate other environmental problems or create new ones.

Any logging that reduces average tree size, at either the stand or landscape scale — including clearcutting, shelterwoods, seed tree cuts, selective cutting of larger trees, or thinning that lowers average stand diameter — will increase the risk of stand-replacement fires rather than decrease it. Thinning only small and intermediate trees less than 100 years old could decrease fire risk, depending on how much new risk is introduced by logging slash (or its disposal). Under-thinning done carefully can be a useful tool to reduce fire risk in dry forest types. Logging that compacts soils, creates roads, or depletes nutrient stocks simply trades one kind of problem for others. *The challenge is to alleviate one problem without exacerbating others or creating new ones* (Perry 1995). Therefore, each project requires careful thought and analysis.

### Insects and Pathogens

Proposals for active management to maintain forest health (e.g., Oliver et al. 1997) are often predicated on the flawed assumption (similar to that of fire), that older forests are more susceptible to insects and pathogens than young forests. Susceptibility, however, depends on the particular insect or pathogen, the tree species, and the environmental context. In some cases, older trees are more susceptible, in other cases, younger trees are. In most cases, factors other than tree age are the primary determinants of susceptibility. The dynamics of host-pest relations emerge from complex interactions among climate, efficacy of the natural enemy complex, uniformity of host species across landscapes, and vigor of individual trees (Perry 1994). In many instances, even the assumption that healthy, vigorous trees will be the least susceptible to insects or disease proves incorrect, for example, vigorous Pacific silver fir and subalpine fir are more susceptible to balsam woolly aphid than slow growing specimens.

Among insects, defoliators often preferentially kill suppressed and intermediate trees rather than larger ones in a stand — a phenomenon more related to tree vigor than age per se (Waring and Schlesinger 1985), whereas bark beetles often kill older, senescent trees. For western pine beetle in ponderosa pine, tree-kill is more of a plucking out of scattered individuals than a widespread killing of trees. What foresters called a "severe epidemic" of bark beetles in ponderosa pine during the 1930s, resulted in loss of all trees "on areas up to 10 acres" and "losses of 15% of the stand over large areas" (Cowlin et al. 1942) — a level of tree-kill that created holes within a basically stable landscape. On the other hand, mountain pine beetles periodically erupt to kill trees over wide areas in lodgepole pine, a pattern associated with that species' tendency to grow in even-aged stands. Lodgepole is well adapted to and benefits from such episodic outbreaks.

Among fungal pathogens, obligate parasites such as rusts prefer vigorous young trees, while (facultative parasites define) such as some heart rots — which never cause epidemics — prefer weakened or slow-growing trees (which may or may not include older trees). Root rots — one of the disease complexes exacerbated by modern forestry practices — attack both young and old trees (Manion 1981). Oregon State University pathologist Greg Filip (in personal communication) attributes an ongoing epidemic of Swiss needle cast in the Oregon Coast Range to widespread conversion of old growth to Douglas-fir plantations.

Even in cases where low vigor reduces the production of chemical defenses by older trees, compensatory factors often come into play at the ecosystem level. The diversity and complex structure associated with older forests reduces the continuity of hosts, and increases diversity and abundance of the natural enemy complex, both of which act to dampen pest outbreaks (e.g., Schowalter 1989, 1995). In both the northwestern and southeastern U.S., old growth supported a more complex community of insects that prey on foliage-feeding insects than that found in younger forests. In the Pacific Northwest, old growth supported the greatest diversity, and more than three times greater biomass of predatory insects per kilogram of foliage than young stands, whereas the ratio of folivores to predators was approximately 1:1 in old growth, and 7:1 in young stands (Schowalter 1989). Another study found that genetic diversity of foliar endophytes, symbiotic fungi that help defend trees against insects and pathogens, was highest in older Douglas-fir trees, intermediate in young Douglas-fir near old trees, and lowest in young trees within a superior tree orchard (McCutcheon and Carroll 1993). One of the biological legacies that appears to be passed from old trees to nearby young ones is a diversity of foliar endophytes, which should increase the ability of young trees to resist pathogens and defoliating insects. Preserving legacies such as endophytes, which depend on the presence of old, living trees, is one of the primary objectives of green-tree retention as an alternative to clearcutting.

**"The diversity and complex structure of older forests reduces the continuity of hosts and increases diversity and abundance of natural enemies, both of which act to dampen pest outbreaks"**

Ironically, factors such as heart rots in living trees and snags, large downed logs and canopy gaps resulting from tree death, diversify forests and create habitats for cavity nesting birds and ants that are important components of the natural enemy complex (Torgersen et al. 1990). In short, risk to pest and pathogen epidemics is a complex function of ecosystem complexity, landscape patterns, and individual trees. Theories of pest and pathogen management based solely on tree age are overly simplistic and, more often than not, in error.

### Can Logging in Older Forests Reduce Risk of Serious Infestations?

In limited cases — as in lodgepole pine susceptibility to mountain pine beetle — logging old-growth stands in order to reduce the risk of serious infestations may be effective. For the majority of situations, however, the experience in North America (and elsewhere) has been quite the opposite. Logging, and other activities associated with forestry, (especially road building, fire exclusion, and stand simplification) have increased the spread of a number of insects and fungal pathogens, particularly the latter (Perry 1998). According to Manion (1981), some of the more common and destructive root rots (Armillariella mellea, Fomes annosus, and Phellinus wierii) "…are important diseases only because of modern forestry practice…" Indeed, a root disease epidemic in Port-Orford-cedar, in southwest Oregon and northern California, was spread primarily through the construction and use of logging roads that serve as vectors for spore dispersal (Zobel et al. 1985).

The most striking effect of land-use on defoliating insects is associated with the eastern and western spruce budworms (Anderson et al. 1987, Wickman et al. 1993). During the 20th century, depending on location, budworm infestations have become longer, more extensive in area and have resulted in greater tree death (Perry 1988b, Wickman et al. 1993). In and the southern boreal zone of eastern Canada, fire exclusion and logging of the valuable old-growth spruce, hemlock and hardwoods, allowed the smaller and shorter-lived balsam fir to spread, effectively setting the lunch table for the eastern spruce budworm. In western North America, logging old-growth ponderosa pine, along with fire exclusion, allowed grand and white fir — prime hosts of western spruce budworm (and Armillaria root rot) — to spread, with the same results.

In instances, the right kind of logging can reduce susceptibility to pests. The best example is thinning tightly stocked stands to increase individual tree resistance to bark beetles (Waring and Pitman 1985). Such instances virtually always involve thinning young to mature, even-aged stands. Removing true firs from areas they have invaded since fire exclusion would probably help control spruce budworm outbreaks (the spruce budworm is actually performing the thinning chore itself). Neither of these prescriptions, however, involves cutting old-growth trees. What is true for the previous explanation regarding managing for fire, also applies to managing for infestations. Any proposal to improve forest health through logging must account for the fact that logging and associated activities can create problems themselves.

## Landslides and Debris Flows

Although natural and management related landslides in steep terrain are produced by a variety of factors, it is well established that older forests are relatively resistant to landsliding when compared to younger forests (Sidle et al. 1985). Moreover, the relationship between clearcutting in steep terrain and increased frequency of debris-flow has been widely documented (e.g., Anderson 1954, Bishop and Stevens 1964, Swanston 1969, Gray 1970, Fredriksen 1970, Brown and Krygier 1971, Mersereau and Dryness 1972, O'Loughlin 1974, Brown and Sheu 1975, Swanson and Dyrness 1975, O'Loughlin and Pearce 1976, Swanston and Swanson 1976, Burroughs and Thomas 1977, Gresswell et al. 1979, Wu et al. 1979, Wu and Swanston 1980, Sidle et al. 1985, Montgomery et al. 2000). The resulting increased sediment delivery to downslope channels can trigger both short and longterm channel response, and impact downstream aquatic resources.

Older forests are not only less susceptible to damage from landslides and debris flows, they also mediate or limit the frequency of such disturbances to aquatic and riparian environments. To this end, older forests provide structural soil stability via tree roots, buffer watershed hydrology, and supply large logs that anchor natural logjams and limit the propagation of debris-flow disturbances.

**"Any proposal to improve forest health through logging must account for the fact that logging and associated activities can create problems themselves."**

Tree roots reinforce the shear strength of soils. Mature trees have substantially greater root strength than young trees (Burroughs and Thomas 1977, Schmidt 1999). For example, the root strength of mature Douglas-fir provides sufficient cohesion to stabilize even cohesionless soils on steep slopes (Montgomery et al. 2000). Prior to decay, even Douglas-fir stumps provide sufficient root strength to hold thin soils on topographic noses and side slopes where soils are relatively well drained. In contrast, steep unchanneled valleys, or topographic hollows, define areas particularly susceptible to debris-flow initiation following forest cutting. Consequently, timber harvest and subsequent herbicide application that reduce the apparent cohesion of the soil would be expected to accelerate the frequency of shallow landslides in hollows and steep side slopes where landslides typically occur after timber harvest.

Another hydrologic effect of forests has to do with the forest canopy. The rainfall intercepted by the forest canopy significantly affects development of pore-water pressure in the soil. Removing the trees and canopy thereby increases the chance of a landslide on steep slopes. Older forests have far greater leaf area in their canopies than recent clearcuts and very young forests. Hence, a significant fraction of the rain falling on an older forest is intercepted and evaporated, never reaching the ground (Leonard 1961, Rothacher 1963, Rogerson and Byrnes 1968, Pearce and Rowe 1979, Rowe 1979, Teklehaimanot et al. 1991). The amount of canopy interception varies with both tree spacing (Teklehaimanot et al. 1991) and rainfall intensity (Rothacher 1963). In a Douglas-fir forest, rainfall interception varies from about 20 percent for storms with greater than 5 cm (2") total rainfall, to 100 percent for very small storms (Rothacher 1963). A 20 percent increase in rainfall intensity would result in more frequent debris-flows in cleared forest than would occur under preclearance conditions.

**"Older forests are not only less susceptible to damage from landslides and debris flows, they also mediate or limit the frequency of such disturbances to aquatic and riparian environments."**

A forest canopy also may affect the timing of moisture delivery to the ground, further reducing the intensity of the shortterm rainfall. For example, the canopy architecture of older forests can buffer the intensity of rain on snow flood events, thus affecting the amount and timing of storm runoff (Berris and Harr 1987). In addition, the erosive effects of flood events can be dampened by mature timber that provides cohesion to stream banks.

Debris-flows scour steep headwater channels and deliver both sediment and wood debris to downstream channels, often creating logjams where they deposit. The disturbance associated with scour and passage of a debris-flow is generally considered to affect aquatic ecosystems adversely. Nevertheless, in certain cases, debris-flow deposition also can create fish habitat (Reeves et al. 1995). In particular, logjams formed either by deposition of debris-flows, or by the direct recruitment of large, "keymember" logs from streamside forests, can store large amounts of sediment and thereby expand the extent of alluvial valley bottoms (Keller and Swanson 1979, Abbe and Montgomery 1996, Montgomery et al. 1996). Logjams can enhance fish habitat in mountain streams by increasing the frequency and/or depth of pools, (Montgomery et al. 1995, Abbe and Montgomery 1996) and in some locations by converting bedrock channels to alluviumfloored channels (Montgomery et al. 1996). The size and abundance of inchannel wood debris is central to both of these processes; debris derived from oldgrowth forests can trigger profound effects on channel habitat, whereas debris derived from smaller trees in plantations provides less, and probably short-lived habitat benefits (Montgomery et al. 1995, Montgomery et al. 1996).

The types of logjams that occur in stream channels reflect log size, channel size, and the nature of the processes that deliver wood to streams.

Most stable jams are founded on large, keymember logs that anchor natural logjam structures (Abbe and Montgomery 1996). Application of a simple, modified version of Wigmosta's (1983) model of the debris-flow impact force required to break a log, predicts that the reduction of log size in headwater channels will lead, on average, to longer debris runout pathways and therefore, greater disturbance to aquatic ecosystems. Unfortunately, few data are available at present to test this expectation.

In summary, old-growth forests differ from younger forests, in that old-growth forests reduce the likelihood of debris-flows, and if flows do occur, they are more likely to be beneficial because of the inclusion of large wood and limited runout lengths

## 3. Habitat requirements of species of concern.

To provide for biodiversity, among other things, simplified stand structural models seek to manage for a variety of structures across the landscape (Oliver 1992). At face value, this may seem a reasonable approach. However, it is predicated on the questionable assumption that all species and habitats are of equal management concern. They are not.

*Large woody debris from older forests plays a critical role in the creation of fish habitat in mountain streams by creating pools and storing sediment.*

II. "The Importance of Considering the complexity of Natural Forests"

## Species of Concern

Species adapted to early successional stages and edge habitat are often "weedy" (Terborgh 1976, Noss 1983). Many of these are opportunistic generalists that flourish in a variety of habitat conditions. Typically, their powers of dispersal are great, which helps them locate in recently disturbed areas. Many of these species thrive under physically harsh conditions that other, more specialized, forest species find stressful. There are many examples of disturbance-adapted plant and animal species in western Oregon and Washington including red alder, bitter cherry, Scotch broom, brush rabbits, coyotes, red fox, raccoons, black-tailed deer, garter snakes, brown-headed cowbirds – a brood parasite – and song sparrows. Importantly, disturbed habitat conditions, and the species dependent on them, usually are abundant in human-dominated landscapes, including intensively managed industrial forests, agricultural lands, and many urban areas. While some early successional species are of interest to forest managers (e.g., elk, deer and bear) disturbance-adapted species are only of concern when they create problems for sensitive species (e.g., as does the brown-headed cowbird) (Brittingham and Temple 1983). Of course, many of the weedy opportunists on harvested sites are actually exotics that compete with and displace native species.

**"Large woody debris from older forests plays a critical role in the creation of fish habitat in mountain streams by creating pools and storing sediment."**

As noted earlier, one of the most important ways in which simplified stand structural models and traditional silvicultural practices differ from natural forest dynamics, is by truncating forest development before mature, let alone old-growth conditions, are attained. Consequently, species sensitive to human activities, or dependent on old-growth forests, will fare poorly under simplified structure-based management approaches, regardless of what management planning documents claim. In the Douglas-fir region, such sensitive species include the northern spotted owl, marbled murrelet, Vaux's swift, Myotis bats, cavity-nesting birds, the northern flying squirrel, and several salamander species (Carey 1989). Forest carnivores such as the fisher and American marten also are at risk (Ruggiero et al. 1994). These are examples of species whose numbers and habitats have dwindled under traditional forest management regimes (Noss and Cooperrider 1994) and about which forest managers should be concerned.

Ironically, a number of the proponents of the simplified stand structural models point to the Canadian lynx, wolves, bears, bighorn sheep and several other wide-ranging species as evidence for the need for additional early-successional habitat ("stand-initiation structures") (Oliver and Lippke 1994). What these authors fail to acknowledge is that the major factor limiting most of these species across their range is the lack of large, secure, roadless areas free of human disturbance (Noss et al. 1996, Weaver et al. 1996, Mladenoff et al. 1999) The intensive management and high road density demanded by traditional silvicultural models — and recent plans based on simplified stand structural models — would pose severe threats to these species.

## Habitats of Concern

Some proponents of simplified forest stand structural models have warned that where all harvesting is curtailed, there will be a shortage of open habitat and therefore a reduction of biodiversity (e.g., Oliver 1992). Even if the argument that open habitat will be scarce is correct, the case can be made that the type of habitat that is really at risk in this region is unsalvaged, legacy-rich, early-successional habitat. For instance, Wisdom et al. (in press), summarizing findings of the Interior Columbia Basin Ecosystem Management Project, note that "current early-seral communities were found to commonly be devoid of large tree emergents and snags, to have comparatively high levels of disturbed soil, and contain exotic weeds."

Another assumption implicit in simplified stand structural approaches (e.g., Oliver 1992), is that forests managed for commercial timber production can also provide the entire suite of habitats found in a natural successional sequence. We are aware of no evidence to support this assumption. As discussed earlier, aside from the fact that living trees are killed, intensive forest management has little similarity to natural disturbances, which leave a plethora of structural legacies, usually have a frequency distribution characterized by many small and a few large events, and hence leave a relatively variable patch mosaic (Perry 1998). Moreover, where economics is the motivation, forests will be harvested long before reaching old-growth, the developmental stage with greatest biological diversity.

**"Species sensitive to human activities, or dependent on old-growth forests, will fare poorly under simplified structure-based management approaches, regardless of what management planning documents claim."**

Silviculture can, and in some cases has been adapted to more closely approximate natural disturbances, grow trees to longer rotations, and with the hope of providing habitat for at least some species requiring complexly structured forests. These silvicultural approaches hold substantial promise as techniques that provide for higher levels of native forest diversity following timber harvest, both initially and over the long term. Extensive research is currently underway and work during the preceding decade has already documented substantial differences between areas harvested using traditional clearcut prescriptions and those using structural retention prescriptions with regards to varied organismal groups such as invertebrates, lichens and birds. ( e.g., As replacement for clearcutting, the Canadian corporation MacMillan-Bloedel has adopted this approach. The Weyerhaeuser Company, who recently purchased MacMillan Bloedel, has agreed to continue this practice.) However, much remains to be learned with regard to how many old-growth species and processes can actually be sustained using such an approach.

## 4. Understanding the impacts of roads.

**"Aside from the fact that living trees are killed, intensive forest management has little similarity to natural disturbances."**

Logging roads have a profound effect on forest ecosystems — increasing erosion and stream sedimentation, serving as vectors for diseases and invasive species, and fragmenting habitat.

Silvicultural science has long suffered from a myopic focus on the dynamics of regeneration, tree and stand growth, with much less attention to the logging and transportation systems necessary to implement its prescriptions. The forest stand structural models scrutinized in this report are no exception. Several of these approaches emphasize management of the entire forested landscape through silvicultural operations. To access every stand across the landscape, extensive road systems would need to be built and maintained. These roads, in turn, would introduce a broad suite of environmental impacts to aquatic and terrestrial ecosystems.

As described in the literature, and in the 1997 Report on Forest Health in the United States

*Traditional forestry practices, including dispersed-patch clearcutting, produces highly fragmented habitat conditions and large amounts of biologically poor early-successional habitat.*

(Oliver et al. 1997), these simplified stand structural management approaches appear to assume and require a permanent, high-density road network distributed across the landscape. Yet discussion of the logging and transportation systems necessary to implement these management approaches is conspicuously absent in the literature presenting those models (e.g., Oliver and Larson 1996). As Matthews (1989) and others have pointed out, design, construction costs, maintenance, and the potential environmental impacts of the necessary transportation system are central to the evaluation of any silvicultural system.

Logging roads are now generally recognized as the most pervasive source of damage to streams from forest management activities (Furniss et al. 1991, Noss and Cooperrider 1994, Frissell and Trombulak 2000). Roads permanently alter the hydrology of slopes (e.g., Megahan 1972, Montgomery 1994, Wemple et al. 1996,), and thus contribute to many forms of hillslope erosion and sediment contribution to streams (e.g., Reid and Dunne 1984, Hagans et al. 1986, Hicks et al. 1991). Erosion from roads can chronically elevate suspended sediment, reducing the growth and survival of aquatic species (Newcombe and Jensen 1996) and otherwise impair fish (Buck 1956). Roads also threaten terrestrial species in a multitude of ways (see review in Frissell and Trombulak 2000). For example, forest roads can serve as vectors for tree diseases (Zobel et al. 1985) and non-native weeds (Tyser and Worley 1992). In addition, logging roads provide hunters and other recreationists with access to previously remote

*Some silvicultural activities including selective harvest, green tree retention, and extended rotation, have shown some promise in providing diverse forest habitats.*

areas, increasing human harassment, exploitation and inadvertent road-kill of sensitive species (see reviews in Noss and Cooperrider 1994 and Frissell and Trombulak 2000).

**"Logging roads are now generally recognized as the most pervasive source of damage to streams from forest management activities."**

Many recent studies have demonstrated that large forest land tracts that are roadless, or of low road density, support sensitive fish and wildlife species (e.g., Brody and Pelton 1989, Eaglin and Hubert 1993, Thurber et al. 1994, Rieman et al. 1997, Baxter et al. 1999). As such, preservation or restoration of roadless areas is an essential component of management strategies designed to protect biological diversity (FEMAT 1993, Noss and Cooperrider 1994, Noss et al. 1999). The success of watershed and aquatic restoration programs in forested landscapes will depend upon a series of measures related to roads, including improved maintenance and reconstruction of permanent road obliteration of unnecessary road and avoidance of road construction in watersheds that are currently road-free. (Weaver et al. 1987, Harr and Nichols 1993, Frissell and Bayles 1996). Moreover, naturally functioning watersheds with low road density can serve as regional landscape refugia for sensitive species and ecosystems (Reeves and Sedell 1992,

*Logging roads have a profound effect on forest ecosystems— increasing erosion and stream sedimentation, serving as vectors for diseases and invasive species, and fragmenting habitat.*

Noss and Cooperrider 1994, Frissell and Bayles 1996).

A silvicultural system that requires an extensive road network is inimical to regional conservation needs for many sensitive and protected species. The repeated harvest entries dispersed extensively over the landscape of intensive silvicultural systems that numerous simplified structure-based management forest plans require, appear almost certainly to preclude the persistence of any large-scale ecological refugia free from human disturbance Road systems and their impacts are an important element of any management strategy, one that SSBM fails to address.

All of the aforementioned factors — among others — must be considered when prescribing an intensive silvicultural management regime. By failing to account for such factors and some of the more severe impacts associated with intensive silviculture, the simplified stand structure model now being applied to various management regimes (e.g., Oliver and Larson 1996) fails to address road systems and their impacts.

## 5. The importance of regional context.

The simplified stand structural model is predicated on creating a "balance" of stand structures across the landscape, but does so without considering historical management practices. It also has been applied without regard for regional context (e.g., Oliver 1992, Oregon Department of Forestry 1999).

Prior to European settlement it has been estimated that before European settlement, 60-70% of the commercial timberland in the Douglas-fir region was covered by old growth. (see, e.g., Franklin and Spies 1984 and Wimberly et al. 2000). By comparison, Norse estimated that in 1990, only 13% of the region's old growth in the remained. Significantly more has been lost since 1990. Similar reductions in old-growth ponderosa pine forests have occurred in interior Oregon and Washington (Henjum et al. 1994). This loss of old growth has serious consequences for the species dependent on, or closely associated with this stage, including those of Douglas-fir forests cited earlier (Carey 1989). A recent study of disturbance history in forests of the Coast Range (Wimberly et al 2000) indicates that the present proportion of old growth in the region is far below the natural range of variability in the region over the last 3000 years.

**"Preservation or restoration of roadless areas is an essential component of management strategies designed to protect biological diversity."**

This historical perspective suggests that maintaining — indeed, re-growing and restoring — old growth should be a high priority for forest management on public lands, particularly where public and private lands are intermingled, such is the case in the Oregon Coast Range, where state forest lands exist primarily as islands within a landscape of industrial forests managed intensively for wood products on short rotations. These and other places where intensive forestry has been practiced long enough to change the overall matrix of the forest will almost certainly be deficient in high quality habitats for populations of locally sensitive or rare species. For example, old-growth forests and associated species populations have become highly isolated in Oregon's northern Coast Range (Noss 1993, Oregon Department of Forestry 1999).

It is beyond the scope of this report to critique the Oregon Department of Forestry's (ODF) management plan for their lands in the northern Coast Range. (A thorough scientific review has already been done; Hayes 1998). It is instructive, however, to briefly mention some aspects of the ODF plan, as it incorporates positive examples of movement away from traditional intensive management, toward a more ecologically based silviculture. It also illustrates what many conservation scientists believe to be unwarranted optimism regarding the degree to which a completely managed, forested landscape can contribute to conservation. Dealing almost exclusively with second-growth stands originating after wildfire earlier in the century, the ODF plan for the Tillamook State Forest includes significantly longer rotations than those in surrounding industrial lands, with 20%-30% of forest lands targeted to achieve "older forest

*Understanding regional context — including past management on adjacent forested parcels — is a key to planning appropriate management activities.*

structure." The plan proposes regeneration harvest in a patchwork of different sizes and retains living trees to provide structure.

In terms of reestablishing and maintaining complex forest structure, the ODF plan definitely moves in the right direction (though questions remain about some details — such as level of retention). On the other hand, the plan leaves no lands free from eventual regeneration harvest. From the standpoint of conservation biology, this is a significant weak point, especially in a region where ownership patterns provide no other options for reserves (Noss 1993). ODF acknowledges the Department has a role in regrowing habitat for old-growth associates such as spotted owls and marbled murrelets, but assumes a priori that this goal can be accomplished without reserves, an assumption with which most conservation biologists would disagree (e.g., Hayes 1998), and that is at best an untested hypothesis.

Practices such as retention harvests and long rotations clearly produce more complexly structured forests than intensive forest management. But are they alone sufficient to produce high quality habitat for all the many old-growth associates? The majority of biologists who reviewed the Tillamook plan were doubtful (Hayes 1998). We agree that the plan inadequately considers the regional and historical context of the planning area. Species whose populations or metapopulations operate on spatial scales larger than the limited planning area, or which require large blocks of late-seral forest, are unlikely to fare well under the ODF plan. Consequently, a prudent forest manager interested in assuring maintenance of biological diversity would incorporate a system of reserved areas. Some conservation biologists have characterized the decision to fully manage the landscape as a lost opportunity for restoring refugia in the heavily degraded northern Coast Range landscape. On the other hand, if the time ever comes when reserves are shown (by rigorous and widely accepted peer-reviewed science) to be unnecessary for conservation, a fully managed landscape might become a viable option for achieving the conservation and timber harvest goals for the Tillamook, rather than wishful thinking on the part of forest planners.

## 6. The role of reserves in ecological management.

Some of the simplified stand structural models explicitly dismiss the need for ecological reserve areas as part of a healthy landscape. In place of reserves, some have called for a "landscape approach" to ecosystem management that entails active management of all forestlands. Oliver and Larson (1996) define the two approaches:

1) The 'landscape' approach is based on the 'dynamic' theory of forest development... and advises active silvicultural manipulations to imitate, avoid, and/or recover from natural disturbances to maintain the full range of stand structures, landscape patterns, processes, and species across the landscape.

2) The 'reserves' approach establishes large areas where stands are expected to develop toward the old-growth development stage over large areas by setting aside large forest areas where human activities are restricted or excluded...This approach relies on the *'steady state'* ecological theory. (italics in original)

**"If a forest is managed according to the principles of the simplified structural models, with no stands permitted to attain true old-growth conditions, then (JR) some species dependent on, or closely associated with, old growth will have a high probability of disappearing from the managed landscape."**

Such characterizations of the two approaches are highly biased and misleading. Oliver and Lippke (1994) claim that the steady-state ecological theory underlies the reserve approach and is "outdated." They advocate the dynamic theory of forest development, which they claim supports the "more accepted" landscape approach. In fact, the strategy of creating and managing protected areas is the only strategy that has been shown — at least occasionally — to work (Noss and Cooperrider 1994, Meffe and Carroll 1997). Interestingly, the landscape approach (Oliver and Lipkke 1994) is actually a steady-state or equilibrium landscape concept. The idea of a balanced or targeted distribution, or percentage, of each of 4 or 5 structural types in each 2,000 to 10,000-acre "landscape" is nothing more – or less — than an updated version of the traditional foresters' "fully-regulated" forest in which a perfect distribution of age classes provides a steady flow of timber. Furthermore, the reserve strategy does not depend at all on steady-state or equilibrium theory, nor are reserves usually envisioned as "unmanaged" areas free from human disturbances. The modern literature of conservation biology is replete with case studies of reserve management prescriptions and challenges, with few champions of a "hands-off" approach, and no hint of dependence on steady-state theory. As pointed out by Noss et al. (1997):

Maintaining ecological processes at appropriate levels usually requires active management and, in many cases, restoration. In most if not all conservation plans, we cannot count on natural processes operating effectively if we establish reserves and then leave them entirely alone. This problem arises largely because many natural processes operate on spatial scales much more vast than our reserve networks.

Perpetuation of natural disturbance regimes — not simply preservation of a particular seral stage — is often discussed as a design and management goal for protected areas (Pickett and Thompson 1978, Baker 1992, Noss and Cooperrider 1994). On the other hand, as pointed out earlier, if examination of the regional landscape context shows that old-growth is depleted — which is the case in most forest regions — then protection and restoration of old-growth forests in reserves is a legitimate management goal, and casts doubt on analyses that dismiss reserves as part of an "outdated steady-state" paradigm.

## II. "The Importance of Considering the complexity of Natural Forests"

While the emerging simplified stand structure approaches establish a false dichotomy between so-called "landscape approaches" and the establishment of reserves, reserve establishment is, in fact, a crucial component of landscape or ecosystem management (Noss 1983). Although biologists differ in the emphasis they give reserve design versus management of the landscape matrix in conservation plans, few would deny that both are necessary. Reserves make at least three important contributions to a landscape conservation and management strategy.

First, reserves serve as habitat for species that are unlikely to persist in the multiple-use landscape. If, for example, a forest is managed according to the principles of the simplified structural models (e.g., Oliver 1992), with no stands permitted to attain true old-growth conditions, then some species dependent on, or closely associated with, old growth will have a high probability of disappearing from the managed landscape. In this case, a network of old-growth reserves will provide the only refugia for such species. These reserves also will serve as sources from which disturbance-sensitive species can recolonize the broader landscape after disturbance. Many species also are sensitive to exploitation, persecution, or harassment by humans — or, in some cases, to the mere presence of humans. Large and medium-sized carnivores (e.g., grizzly bear, wolf, wolverine, and lynx) are examples of such species. Roadless reserves with restricted trail systems can provide security to these sensitive species. The larger and less accessible the reserve, the greater the security offered (Noss and Cooperrider 1994).

**"Roadless reserves with restricted trail systems can provide security to sensitive species. The larger and less accessible the reserve, the greater the security offered."**

Reserves, especially when large and roadless, serve as reference sites and control areas for management experiments. Few scientists would dispute the need for control areas in any credible approach to adaptive management, yet the simplified structural approaches (e.g., Oliver and Lippke 1994) do not acknowledge the need for such control areas. Proponents of these emerging management schemes appear to assume that foresters understand forest ecosystems well enough to manipulate them for long-term commodity production and other uses, without losing biodiversity and ecosystem function. To test the validity of this assumption by comparing treated areas to untreated or natural areas, reserves are necessary (Frissell and Bayles 1996). When (adaptive) ecosystem management experiments are carried out on a landscape scale, control areas (reserves) that span entire watersheds are required.

# III. Considerations for Ecosystem-Based Management Approaches

In this section, we provide managers with a checklist of important considerations that should be included in fashioning and/or evaluating an ecosystem-based management plan. This list is by no means exhaustive. Rather, it is a distillation of the issues raised in the preceding text. It should be treated as a starting point for thinking about ecosystem management and reviewing forest plans that purport to be ecosystem-based. [See also Noss (1999) for a listing of "green lights" and "red flags" for evaluation of ecosystem management plans.]

### Questions to consider: Natural forest stands are structurally and functionally complex

- How well does the management prescription account for multiple forest structures and spatial heterogeneity in structure, including but not limited to living trees? For example, does it provide for coarse woody debris and give a rationale for the amount and type of coarse woody debris to be maintained? Does it provide for multiple canopy layers and variable stand densities, including gaps?
- If the plan purports to mimic natural disturbances, does it recognize the differences between natural and anthropogenic disturbances? For example, does it incorporate structural legacies that provide continuity from one stand to the next? What is the rationale for the quantity and type of legacies, if any, in the plan?
- How much does the plan simplify forest stand development? For example, does the plan account for multiple development pathways?
- Does the plan address spatial planning of structural units? Does it consider the pattern, juxtaposition, and connectivity of habitat types across the landscape? Does it evaluate the consequences of alternative patterns in terms of the life-histories and population viabilities of particular species, and the operation of natural processes?

### Questions to consider: Older forests are less susceptible to catastrophic disturbances than younger forests

1. Does the management prescription for one problem (e.g., fire risk, pathogens) inadvertently create other problems? For example, do management plans account for the soil compaction, erosion, and increased fire risk from logging residues, and other effects associated with intensive silvicultural activities? Has the plan accounted for the full range of relevant disturbances that will impact the forest in preparing its planned activities?
2. Does the plan account for potentially unstable terrain?
3. Does the plan account for the effects of reduced root strength on landslide frequency? Does the plan account for the effect of timber harvesting on slope stability? Does the plan account for the effect of vegetation/tree/stand age on slope stability?

4. Does the plan specifically account for historical patterns as well as recent and future changes in riparian and floodplain forest structures and landscapes?

### Questions to consider: Not all species and habitats are of equal concern

- Does the plan specify which wildlife species the prescriptions intend to benefit? Are the species rare or threatened, or are they weedy species that can get along in a variety of habitat conditions? In the case of rare or threatened species, how does the plan provide specifically for their needs? Are species dependent on or closely associated with late-seral forests accounted for in the plan?
- What habitats is the plan designed to create or protect? Are these common or rare in the region? Are protected habitats of adequate size and connectivity to meet the needs of the most demanding native species?

### Questions to consider: Roads dramatically alter forest ecosystems

1. Does the management prescription account for the ecological effects of the road construction and maintenance activities associated with carrying out such activities?
2. Have alternatives to road building been considered? How does the plan attempt to address the effects of roads? Does the plan call for obliteration and revegetation of roads no longer needed for management?
3. Does the plan identify and maintain (or create) roadless areas and low road-density watershed as refuges from human activity?

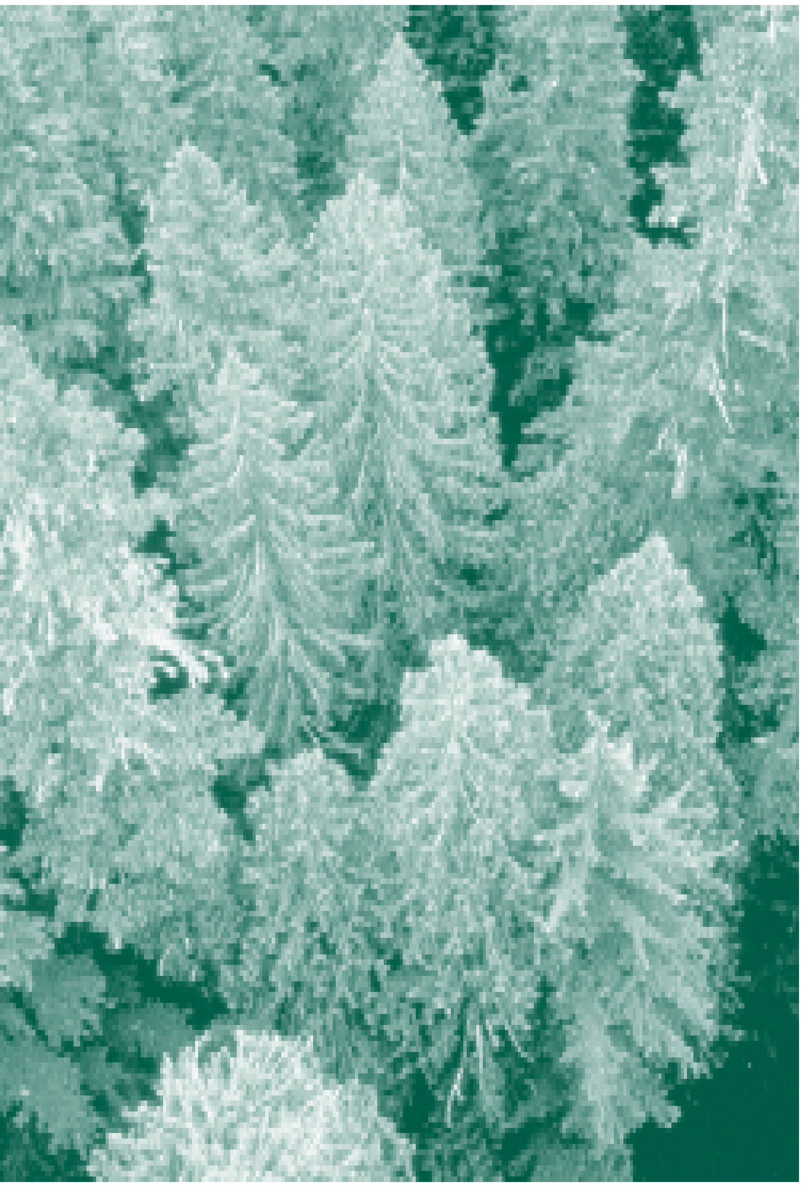
### Questions to consider: Regional context is critical to ecologically-based forest management

1. Does the plan look beyond the boundaries of the planning area and consider historical and regional context? For example, does the plan consider the history of habitat change in the broader region and strive to protect or restore habitat types and species which have declined most in the region since European settlement?
2. Has the plan used adequate spatial and temporal scales for meeting its internal objectives? (For example, does it consider what is occurring on adjacent land as well as what might occur on those lands in the future?)
3. Does the management plan consider broad, regional strategies for conservation, and work to further those strategies? For example, does the plan seek to link protected areas within the plan boundaries to other such areas established or proposed within the region or adjacent regions? Does the plan contribute to conservation strategies for wide-ranging species (e.g., forest carnivores), whose conservation must be accomplished on vast spatial scales?
4. Has the plan sought to minimize habitat fragmentation? In what ways?

### Questions to consider: Forest reserves are an important component of ecological management

1. Does the management plan evaluate the need for reserves by looking at the regional and landscape context of lands covered in the plan? Does the management plan call

for the creation of reserve areas as part of its strategy to conserve forest and wildlife diversity? If not, how has the plan established a margin of safety, should the management prescriptions not meet their stated objectives? If yes, have the reserves been designed to meet specific conservation objectives? What is the control area for the grand experiment with nature?



### Questions to consider: General planning considerations

1. After having articulated its objectives, does the plan follow through on accomplishing those objectives?

2. Does the plan use the best available scientific information from all relevant disciplines, including wildlife biology, fisheries science, ecosystem ecology, conservation biology, landscape ecology, and hydrology? Have independent scientists been consulted to review the plan, and have their recommendations been taken to heart?

3. Does the plan explicitly acknowledge uncertainty and risk, and account for these factors by incorporating appropriate margins of error?

4. Does the plan incorporate adaptive management that provides opportunities to learn from, and makes real changes based on, management experiences? Is the design for adaptive management scientifically rigorous?

5. Does the plan include a credible monitoring program that will provide useful information for adaptive management? Is a mechanism provided to assure that the monitoring program is well funded and will continue in perpetuity?

6. Have sources and levels of risk been identified and fully disclosed? Have options for reducing risk been considered and disclosed? Has a framework for decision-making or a rationale for coping with risk been articulated?

# Scientific Panel on Ecosystem Based Forest Management — Bios

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