

Old-Growth Forests in the Southwest and Rocky Mountain Regions Proceedings of a Workshop

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Old-Growth Forests: What Do We Know About Their Ecology and Management in the Southwest and Rocky Mountain Regions?¹

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This paper reviews the science and management of old-growth forests and summarizes discussions among 30 participants at a workshop in Portal, Arizona, March 9-13, 1992.

Concepts of old-growth forests -- the perceptions, values, definitions, characteristic features, ecological functions, and landscape importance -- vary widely. Because concepts are complex, scientists, resource managers, and the public will continue to bring old growth into clearer focus as knowledge is gained. Regardless of the concepts chosen for viewing old growth, on an ecological basis old-growth forests represent a stage in forest development characterized by certain structural, functional, and compositional features.

Managers are concerned with how much old growth exists, where it is, and what condition it is in. Improved inventory procedures are needed, including both remote-sensing technology and conventional on-the-ground procedures. Where will tomorrow's old growth be found, and how soon will younger stands attain old-growth conditions? Pathways of forest succession into old growth are poorly known for most forest types. We need better knowledge about how disturbances such as fire, insects, forest diseases, exotic organisms, pollution, and changing climate affect old growth and forest succession.

Allocation is another problem for planners. How much old growth is enough? How many stands should be old growth at any given time, what are the sizes and shapes of the stands, and how should they be distributed over various forest habitat types? How should old-growth stands be connected by forest corridors, and how are their functions modified by their setting? These are difficult but researchable questions. Lacking clear answers to these questions, should managers find clues from pre-European settlement forests? Is it reasonable to attempt to restore forests to their natural conditions? Or have changes since settlement precluded returning to earlier conditions?

In this paper, we review our knowledge of the influence old-growth stands on biogeochemical cycles and the roles of wildlife, decomposer organisms, cryptozoans of logs and snags, and other kinds of "hidden diversity." To what extent are the legacy of old trees and other genetic reserves in old-growth forests carried into the future? We know little about how present old-growth influences the development of future forest generations.

We conclude by looking at some tools for old-growth management. How can managers use fire or silviculture to assure future old-growth supplies, while at the same time meeting present and future extractive demands? Can younger stands be "treated" to hasten their development into old growth, or can existing old growth be altered without seriously compromising old-growth value?

INTRODUCTION

This volume of papers, given at a workshop on old-growth forests, represents much of what is known about old-growth forests of the central and southern Rocky Mountains and Southwest. This summary paper reviews the current state of knowledge available to

guide forest management and presents the most research needs. It is not our intent in this summary article to review the literature. Rather, we refer to specific papers in this volume for relevant literature on individual topics.

Old-growth forests in the central and southern Rocky Mountains and Southwest have important biological and social values. Certain ecological characteristics of old-growth forests are unique, and because of these features such forests provide a necessary component in the forest landscape. Important biological values of old growth include habitat for a variety of animal and plant species, biodiversity and pools of genetic resources, and long-term biological records of climate. Old-growth forests also are valued for supplying economically important forest products, recreational experiences, and cultural (spiritual) heritage. Of these, perhaps the most

¹ Summary paper of the Old-Growth Forests in the Rocky Mountains and Southwest Conference (Portal, AZ, March 9-13, 1992).

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compelling mandate for old-growth conservation is its role as habitat for organisms which, over evolutionary time, have become dependent upon old-growth conditions.

Many geographic areas in the Rocky Mountains and Southwest have experienced a sharp decline in virgin forest in the landscape, and in some forest types, old-growth forest has been reduced to a fraction of the amount existing before settlement. Nonetheless, there is a tremendous opportunity for retaining or enhancing biological features unique to old-growth ecosystems. In Europe and Asia, in the rainforests of Brazil, and in the eastern United States, many forest areas have been either exploited through intensive and often repeated harvest or impacted by deterioration in air and soil quality to the point that the existence of old-growth forests in a historical condition is nearly impossible. That point has not yet been reached in the central and southern Rocky Mountains and Southwest, but threats to old-growth forests in the landscape are real and substantial.

Perceptions of Old Growth

An issue surfacing repeatedly at the workshop and elsewhere is the application of the term "old growth." The subjective "feel" of what constitutes high quality old-growth forests varies tremendously among individuals and may differ from scientifically determined ecological conditions that characterize old growth. It is important to recognize these differences because they represent the range of expectations placed upon forest lands by the various viewers and users.

Consider three contrasting forest scenarios discussed at this conference. These scenarios are described to illustrate that the issue of old-growth quality is very complex. First is a mature Engelmann spruce/subalpine fir ecosystem found low on a north-facing slope near the riparian zone (Fig. 1). This forest has multiple canopy layers, a number of large trees (some of which are in poor health), a number of snags and large down logs, and a few very old stumps. Second is a ponderosa pine forest having relatively few very large, old trees intermixed with many smaller trees in several additional canopy layers (Fig. 2). Large and small down logs occur, but there are no signs of prior harvest or other silvicultural intervention. Third is a small stand of very old limber pine trees on a rocky outcropping with little soil (Fig. 3). The trees are only a few meters tall and are widely spaced.

These stands may be viewed very differently by various individuals. The spruce/fir stand may be rated by most viewers as the highest quality old-growth forest of the three described because of the complex



Figure 1. Mature Engelmann spruce-subalpine fir stand in the San Juan Mountains, Colorado.

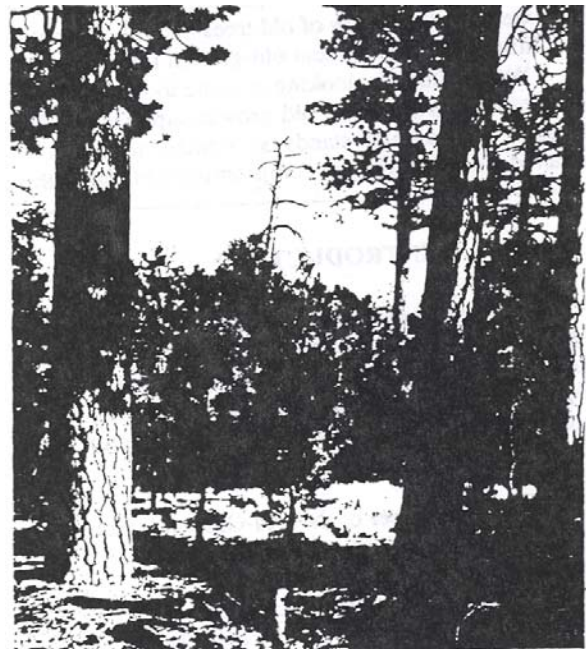


Figure 2. Old ponderosa pine with saplings filling in a small meadow. From the Monument Canyon Research Natural Area, New Mexico.



Figure 3. Limber pine trees 1,500 years old near Red River, New Mexico (photo by Ann Lynch).

stand structure, numerous big trees, and the large amount of dead and down material. However, a close examination may reveal that the oldest trees are only 200 years old and hardly approach the maximum age or size supported on that site. Furthermore, the dead and down material may have resulted from normal thinning as the stand matured and not from the decline of the oldest trees in the stand. Thus from a stand development view, the stand may barely qualify as old growth at all. Such a stand may satisfy a viewer's perception that "large" means "old," and it may well meet wildlife needs for a diverse stand structure, but ecologically the stand may not even be old growth.

The ponderosa pine stand has majestic old trees and no signs of disturbance. Many viewers might judge this stand to be ideal old growth because of the relatively high tree density and multiple canopy layers plus the presence of large old trees and dead and down logs. Yet this stand may be a far departure from the classic old-growth ponderosa pine forest of pre-European settlement times, because fire suppression has allowed the development of several younger age classes of trees and the accumulation of dead material on the forest floor (Covington and Moore, this volume).

The limber pine stand meets few viewers' expectations for an old-growth forest. The trees are

very small and widely spaced, giving the stand little "feel" that it is old growth. Yet these trees may exceed

1,500 years in age and the stand is truly an ancient forest (Swetnam, this volume).

Researchers and managers of all disciplines interested in old-growth forest structure and function, as well as individuals and groups attaching significance to old forests perceived to be old growth, must strive to adhere to scientifically credible terms and concepts. Doing so will help reduce conflicts over the many and often conflicting goals that old forests are expected to serve. In this regard, it is important that hidden agendas be addressed clearly and openly. While issues such as maintaining roadless areas, providing habitat for threatened or endangered species, sustaining the economic viability of a community through timber harvest, and honoring the cultural heritage of forests are very important, it is also important to apply those issues to old-growth forests only when the issues are appropriately linked specifically to the old-growth condition. By being clear about definitions and goals, it may be possible to limit conflict and misunderstandings and better resolve resource management problems, especially when forest lands are expected to meet goals that may not involve the requirement for true old-growth conditions.

DEFINING OLD GROWTH

The process of defining old-growth forests has been difficult because of the range of issues related to the old-growth condition. Because of this confusion, no single value has been universally accepted as the defining characteristic of old-growth forests. For example, in silviculture, forest ecology, and ecophysiology, the successional pathways and structural and functional aspects of stand development may be critical in definitions of old growth (Moir, and Kaufmann, this volume). In dendrochronology, the presence of very old trees may be the most important feature (Swetnam, this volume). For animal habitat, stand structure may be highly important (Reynolds, this volume), and for planning purposes, an easily applied forest structure/composition/age classification may be necessary (Mehl, and Lowry, this volume). For spiritual value, the presence of large trees and the lack of obvious human disturbance may be critical (Kramer, this volume).

Definition versus Characterization

In some cases the term "old growth" has been used in ways that distort or at least blur the ecological basis for distinguishing old growth from other stages of

forest development. Thus stands having features similar to those of certain old-growth forests, including multiple canopy layers with mature trees and considerable amounts of dead and down material, may be incorrectly termed old growth because they lack *old* trees. Stands having large trees that are not old may be perceived as old-growth stands even when the trees have not reached an old age for that site. Alternately, stands having old trees that are not large may not be perceived as old growth when they really are.

Another difficulty in characterizing "old growth" stems from applying strictly structural concepts in perceiving old-growth forests, when functional concepts also are important (Kaufmann, this volume).

Functionally, old-growth ecosystems are characterized by having a component ("cohort") of old trees that have a biochemistry of secondary metabolic products, some of which may provide high resistance to insects and disease. Relative to younger trees, the oldest trees have approached their maximum size and have nearly ceased height growth, and the tree crowns may be in various stages of decline. On average, the rate of production of new biomass is offset by mortality and respiration, and net productivity of the ecosystem is near zero. These functional aspects provide important additional constraints as to which forest stands qualify for the old-growth designation and which do not.

A final difficulty in old-growth characterization is deciding the extent to which old growth should resemble primeval or presettlement conditions. Livestock grazing, fire suppression, and logging have brought about substantial changes in most western forests, so much so that current forest conditions may be, decidedly "unnatural" from an evolutionary point of view. Where this is the case, certain species dependent upon presettlement ecosystem structures and functions may be at risk. Thus from a biological conservation perspective, contemporary "old growth" conditions may be inadequate habitat in many western forest types. Under these circumstances, ecological restoration treatments (e.g., elimination of exotic species, reintroduction of native species, prescribed burning, thinning, snag or down tree creation) may well be necessary for providing critical habitat (Covington and Moore, this volume).

As a step toward better understanding of old-growth ecology and management, scientists in the U. S. Forest Service and in universities and other agencies have gone to considerable effort in recent years to develop a general definition for old-growth forests. Given some of the confusion regarding how the term "old growth" is used, it seems worthwhile to present the definition developed by the U. S. Forest

Service and approved by the Chief of the Forest Service, and to discuss how it applies specifically in the Rocky Mountains and Southwest.

Agency Generic Definition

The Generic Definition (USDA Forest Service 1990) is as follows:

Old-growth forests are ecosystems distinguished by old trees and related structural features. Old-growth encompasses the later stages of stand development that typically differ from earlier stages in several ways including tree size; accumulations of large, dead, woody material; number of canopy layers; species composition; and ecosystem function.

Workshop attendees suggested that for certain forest types, most notably ponderosa pine that historically was influenced by frequent fire, this definition is somewhat restrictive, particularly regarding the accumulation of coarse woody debris, number of canopy layers, and species composition. The group suggested the following **General Definition for Old-Growth Forests in the Central and Southern Rocky Mountains and Southwest**:

Old-growth forests are ecosystems distinguished by old trees and related structural features. Old growth encompasses the later stages of stand development that typically differ from earlier stages in structure, composition, function, and other attributes.

This definition is broad and workable for communication, but the definition does not permit us to recognize old-growth stands. For this we turn to structural characteristics, which in turn reflect functional ecosystem processes. The group suggested slight rewording of the old-growth description to make it more appropriate for the central and southern Rocky Mountains and Southwest. The reworded Description is:

Structural features that characterize old growth in the central and southern Rocky Mountains and Southwest vary widely according to forest type, climate, site conditions, and disturbance regime. Old growth is characteristically distinguished from younger growth by some *but not necessarily all* of the following attributes:

- **Large trees for species and site.**
- **Wide variation in tree sizes and spacing between trees.**
- **Relative to earlier stages, high accumulations of large, dead standing and fallen trees.**
- **Decay in the form of broken and deformed tops or bole and root rot.**
- **Multiple canopy layers.**
- **Canopy gaps and understory patchiness.**

"Old" is not necessarily virgin or primeval. Structure and function of an old-growth ecosystem may be influenced by its stand size and landscape position. Given sufficient time, old growth can develop following human or natural disturbances, such as logging or wildfire.

While there has been some concern expressed that old-growth forests in the Rocky Mountains and Southwest are different from those in the Pacific Northwest, the definition and description published in 1990 as slightly refined here are appropriate in both geographic regions *if properly applied*. For example, only some of the descriptive elements above may be appropriate. The accumulation of large amounts of dead and down material and multiple canopy layers may be significant characteristics of some forest types (e.g., old-growth spruce-fir). But in presettlement old-growth ponderosa pine stands, the frequency of fire contributed to open stands of large trees having little dead and down material and perhaps only one canopy layer (Covington and Moore, Harrington and Sackett, this volume). Similarly, very old limber or bristlecone pine trees may develop in highly stressful sites and reach only a few meters in total height, but for those sites the trees are large.

Variables in the Characterization of Old Growth

Missing from the old-growth definition and description above is any mention of specific tree age or size, or density of old trees in the stand. While initial attempts to inventory old-growth forests have required the development of preliminary quantitative descriptions for each forest type (Mehl, this volume), it is clear that certain features of old-growth stands vary depending on site productivity and geographic location. Within a forest type, old-growth stands may be found in a number of habitat types and across a wide range of physiographic settings (Robertson, this volume).

Thus the characteristics defining the old-growth condition, particularly those involving tree size, age,

stand density, canopy structure, and the accumulation of dead materials, may be very different among sites and habitat types within a forest type. This precludes a strict use of "minimum" characteristics in old-growth definitions when "old growth" is meant to include all forest stands meeting ecological criteria for this stage of forest development.

Two particularly pressing research needs are to determine how presettlement forest conditions varied among forest types, habitat types, and site conditions, and to clarify how the minimum criteria should vary accordingly. Such research requires an extensive field data base including samples from a matrix of site/habitat combinations. In the absence of such a data base and analysis, it is nearly impossible to determine the criteria to be used in the inventory and management of old-growth forests in the landscape without either excluding a number of true old-growth stands on poorer sites or including marginal old-growth stands on better sites. It may be possible, if the data base is large enough, to develop a classification model in the form of a key for old-growth conditions that accounts for variation in old-growth characteristics among habitat types and sites.

OLD GROWTH QUALITY

Many of us have been conditioned to believe that stands of big trees are old growth, when biologically such stands may not be good examples of late developmental stages for the forest type in its specific site condition. Some of us believe that signs of human disturbance such as skid roads and stumps seriously weaken the quality of an old-growth stand, when from an ecological point of view such evidence of disturbance may have little to do with the structural and functional features characterizing old growth or its value as animal habitat. A recreationalist seeking time in a pristine forest, or an individual seeking spiritual value, may be disturbed by rotting stumps in an old-growth forest but may be satisfied by an unroaded and undisturbed mature forest not meeting old-growth criteria. Some people may view a pine forest having multiple canopy layers and many down logs as ideal old growth, while from an ecological view such forests reflect significant disturbance in the form of fire exclusion.

We propose that the approach to old-growth definition in the previous section is the most appropriate one in many cases because it is ecologically sound and it is useful in decision-making processes regarding the inventory and management of old-growth forests in the landscape. We recognize that other values also are important, and we suggest, in

keeping with earlier remarks in this paper, that other terminology or concepts be used when dealing with wildlife habitat, visual or spiritual issues, etc., that in some cases may not require old-growth conditions to be present.

Disturbance and the Issue of Quality

Evidence of prior disturbance may affect how observers view an old forest. Some old-growth stands may have survived many centuries with no human intervention and with little change in history of biotic or abiotic disturbance. The question of disturbance is not a simple one, however. Many stands have no evidence of prior silvicultural activities, but fire has been effectively removed as a natural process during most of this century, and in some cases insect or disease control treatments have been applied. Thus large areas of presumably undisturbed forest have, in fact, taken on a structure quite different from what might have existed had natural disturbance regimes not been interrupted.

Many ponderosa pine forests, for example, historically had fire return intervals of less than every decade. But since the beginning of this century, fires have been excluded almost completely, with the result that new age groups of trees and considerable amounts of dead material exist in stands that otherwise might have had the classic, park-like appearance with numerous grassy openings characteristic of presettlement times. Fire suppression has resulted in much higher numbers of trees per area and the loss of most openings. And when fires occur, they often are of such intensity that the entire plant community is replaced.

Ecologically, many forested areas that now exist should be considered disturbed by fire suppression even though no other signs of human disturbance are found. Little is known, however, about how various observers and users of forest lands view fire suppression and other signs of human disturbance (such as evidence of silvicultural activities) as impacts on the quality of old-growth forests.

OLD-GROWTH FORESTS IN THE LANDSCAPE

Landscape Issues

Old-growth forests historically constituted a significant component of the landscape mosaic, providing an array of features not found in forests at other developmental stages. Many very important questions are being asked about old-growth forests in the landscape. Some of these questions have been addressed above, such as why old-growth forests are

needed and how they are recognized. Numerous other issues emerge when Forest Plans are appealed or subject to revision or when the ecology of old-growth forests is considered:

- How much old growth is enough?
- How serious is the impact of various management practices upon fragmentation, and how is fragmentation measured?
- Are old-growth forests found more frequently in some plant associations than in others?
- How large should old-growth stands be, and how should they be buffered by mature forests *or by* corridors that connect to other old-growth patches? Are the concepts of corridors and distribution useful in a naturally fragmented landscape?
- What organisms do patches and corridors serve?
- How do different alternatives in Forest Plans affect biological diversity within patches and the overall landscape diversity?
- What were the structure, composition, and geographic/topographic forest patterns (which included old growth) during presettlement times?
- How has fire suppression (or other broad-scale changes) during the last century affected old-growth conditions for wildlife habitat, epicenters of insects or plant pathogens, or the propagation of large-scale disturbances?
- How are ecological processes different in old-growth forests compared with other stages of development?
- How can the transitions into and out of the old-growth state be evaluated?
- What is the role of old growth in the development of subsequent forests on a site?

It is noteworthy that the important management questions also are priority research questions. Scientists and managers attending the workshop suggested that cooperation of researchers and managers is essential when dealing with landscape issues. Because of the large scales of space and time that are relevant for landscape processes, it is necessary that science and management cooperate in making scientifically sound management decisions while being aware that experimentation to answer a number of landscape questions may not be practical. The most

likely contribution of science to management at a landscape scale will be the development of appropriate ecosystem models that can be used to assist managers with landscape issues.

Biodiversity

Old-growth forests are considered by scientists and managers to be an important component of biological diversity, or "biodiversity," which is the richness and distribution of different forms of life in an area. The contribution of old growth to biodiversity occurs at all spatial scales. In the landscape, old-growth stands provide structural and functional contrasts to younger forests. The number of old-growth forest stands and their sizes and arrangement in the land contribute to landscape diversity. Scientists need to test various measures of landscape diversity for usefulness to forest managers. A research problem is to relate measures of landscape diversity to how landscapes are functioning in terms of various treatments and outputs such as water yield, nutrient cycling, recreation visitor days, or wildlife population levels.

Old-growth forests may be the preferred habitat for certain microbes, fungi, bryophytes, and higher plants (Romme et al., this volume). They are known to be the preferred habitat for a number of vertebrate species, such as martens, flammulated owls (Reynolds, this volume), or animals requiring tree cavities for reproduction. Animal populations of species preferring old growth are limited not only by the size of old-growth stands, but also by the number and arrangement of stands in the landscape. However, research lags far behind the manager's need to know about minimum viable populations, as illustrated for example by the Mt. Graham red squirrel on the Coronado National Forest in Arizona.

Much of the diversity within old-growth forests is associated with the numerous detrital and other heterotrophic food webs (e.g., metabolism based upon respiration rather than upon photosynthesis). Old-growth stands are rich with fungi and other microorganisms (such as nitrogen-fixing bacteria associated with rotting wood). These in turn support myriads of cryptic (hidden) micro-arthropods and other invertebrates in intricate food webs. Many small mammals include fungi in their diet; furthermore, their fecal pellets may function as mycorrhizal inoculum or fertilizer for germinating seeds. Several carnivores, such as woodpeckers, plethodonid salamanders (Scott, this volume), certain kinds of hymenopterans (e.g., bees, ants, wasps), or roaming black bears cap these

food webs. This diversity is more complex in old-growth forests than in younger stands in part because of the numerous kinds and amounts of chemical energy accumulated in wood and litter. For example, decaying wood is an important microsite governing ectomycorrhizal activity in forest soils (Larsen et al., cited in Moir, this volume).

At the genetic level, old-growth forests may harbor genotypes of species adapted to later stages of forest development and thus different from their genetic cousins in younger forests. Considerably more work is needed, however, to elaborate upon this theme. Indeed, the difficulty facing forest managers and researchers is that so little is known about the requirements of most of the species in old-growth ecosystems. Although animals such as Northern goshawks or Mexican spotted owls may symbolize old-growth dependency, knowledge about the breadth of ecological and habitat tolerances is often lacking even for them.

Research also is needed on the manner in which the biodiversity of old-growth forests contributes to the functional health of forests that follow. This has important implications in residue management and other practices that provide a structural link between successive forest generations.

Ecophysiology of Old-Growth Trees and Stands

The behavior of old-growth forests with regard to the carbon, nutrient, and water resources is understood in a general sense, but many specific questions have not been answered. It is known that at the late developmental stage we refer to as old growth, the net productivity of the ecosystem approaches zero and may even become negative. This means that newly produced biomass is offset, on average, by heterotrophic respiration plus mortality of individual trees or tree parts such as foliage, branches, and roots. It is also believed that as trees age, they not only experience a decrease in productivity in the form of reduced leaf area and growth, but they also undergo certain changes in secondary product metabolism resulting in biochemical changes in plant composition that may be related to increased resistance to insect or disease attack.

Many of the details of these processes are not understood for each forest type, nor is it clear exactly how the ecophysiological characteristics of old trees can be used to judge when a mature stand reaches old-growth status or when an old-growth stand deteriorates to the point it no longer functions as an old-growth ecosystem. It seems clear, however, that a stand does not qualify for the old-growth status if none of the oldest trees have reached the conditions in which

general vigor is being lost and no structural and functional changes accompanying longevity and senescence processes are occurring.

It is also obvious that some conditions required for achieving old-growth status can occur in stands that have had prior silvicultural treatment (including harvest), and it may be possible to influence, through silvicultural intervention, the development and persistence of the old-growth condition. Recent analyses of the growth history of old lodgepole pine trees has shown that trees presently having low leaf area and approaching mortality grew more rapidly during their first 100 years, compared with neighbor trees of the same age, height, and bole volume but currently having high leaf area (Kaufmann, this volume). This suggests that trees growing rapidly early in the life of the stand became the first trees reaching old-growth status. The trees growing slower initially but surviving to old age now extend the time during which the old-growth status occurs.

How this applies to even-aged stands of other forest types or to uneven-aged conditions is not known. It seems reasonable, however, to suggest that manipulation of stands early in their development may have considerable influence over their old-growth characteristics, and careful treatments may improve the character and longevity of old-growth stands. This is discussed more below.

Forest Development and Synchrony of Old-Growth Characteristics

Forest community development is both a stochastic and a deterministic process. The incidence and intensity of stand-altering events such as fire, climatic fluctuations, windthrow, insect attack, disease outbreak, regeneration success, stress-induced mortality, and other biotic and abiotic variables are highly unpredictable. The developmental trajectory by which forest communities reach the old-growth condition may vary widely within forest types both within and across geographic regions. Consequently the desirable features of old-growth stands may not peak at the same time in different environments, and considerable latitude is required in classifying stands. This is why, in the old-growth description given earlier, only some of the descriptive characteristics can be expected to occur simultaneously. Furthermore, certain characteristics are not equally expressed for all forest types. For example, the accumulation of coarse woody debris and development of multiple canopy layers are important for old-growth spruce/fir forests, but perhaps the best examples of old-growth ponderosa pine would be the rare cases in which fire has continually limited the accumulation of coarse woody debris and the development of younger age classes of trees.

Relatively little is known about the range of successional pathways that can lead to old growth, nor is much known about how the different paths affect the quality of the resultant old-growth stands. It is important to understand that the old-growth condition is temporary. While stand-replacing disturbances may be very infrequent in some locations, eventually they are likely to occur. Some of the highest-quality old-growth stands, such as the Engelmann spruce/subalpine fir old-growth forest in Bowen Gulch near Rocky Mountain National Park in Colorado, may have had no significant disturbance for many centuries, but such stands are the exception rather than the rule, and even for those stands there is no assurance that a major stand replacement disturbance will not happen in the near future.

Seral stands can acquire old-growth characteristics and can be classified as old growth. Seral stands are expected to be transient, provided conditions are appropriate for stand structure and composition to change. However, climax stands also are transient when considered at more comprehensive scales of space and time, and there is little reason to distinguish between seral and climax forest communities when evaluating the old-growth condition. The likelihood of more rapid loss of old-growth characteristics may be higher in some seral stands (e.g., aspen), however, and this may be a factor in determining the role of seral old-growth stands in landscape management.

In areas where low-intensity fires had been frequent before settlement, the absence of fire during most of this century has resulted in very different developmental trajectories for stands. From an ecological perspective, some old-growth characteristics may still have developed, but the forests represent a new kind of old-growth condition. The degree to which novel stand conditions might be classified as old growth depends on the role of functions or conditions such as biodiversity, ecosystem health, and stability. To answer this question correctly, information is needed both about the ecological impacts (especially on biodiversity) of the altered developmental trajectory and the willingness of old-growth forest users to accept a modified type of old-growth forest.

MANAGING OLD-GROWTH FORESTS

The Baseline of Comparison

The issue of whether or not to use management techniques to affect the amount and quality of

old-growth forests, and whether any intervention is permissible at all, must be evaluated against the changes that have already occurred in all forests since settlement by Europeans. All old-growth forests have been impacted by man, whether or not the effects are obvious. The most apparent impacts in the central and southern Rocky Mountains and the Southwest involve timber harvest in ponderosa pine, which has sharply reduced the acreage of old-growth forests, and fire exclusion, which has altered the structure of old-growth stands that historically had frequent low-intensity fires.

Other impacts also have occurred. For example, the pattern of old-growth forest distribution in the landscape has been changed dramatically since presettlement times, with much of the remaining old-growth forest now relegated to less accessible areas and perhaps to less-productive sites. The atmospheric concentration of CO₂ has increased 40 % since the mid-1800's, and this may have far-reaching effects on the development and stability of old-growth stands. And there have been order-of-magnitude increases in atmospheric deposition of certain chemicals containing nitrogen, sulfur, etc., into forest ecosystems.

Given the variety of past, present, and future impacts, an important question, in those situations where managing for old-growth qualities is appropriate, is the baseline of comparison. From a biodiversity standpoint, presettlement conditions may be the most desirable baseline, because those conditions represented the natural system in all its detail and complexity (Covington and Moore, this volume). Yet over the near term, presettlement conditions may be difficult to restore on any extensive basis, because of the major impacts timber harvest and human community development have had in forested areas. It may not even be possible to restore presettlement old-growth conditions on any spatial scale, because of the unknown impacts of increased CO₂ in the atmosphere and increased atmospheric deposition of chemicals.

Thus the question of old-growth management and the issue of selecting an appropriate baseline requires increased knowledge about changes that have occurred since settlement impacts began and the degree to which present physical and chemical environments affect old growth and other ecosystems. These are difficult issues, and it is likely that old-growth management decisions often will have to be made with inadequate knowledge of the ecological and environmental consequences. It is important that all management decisions, and even the decision *not* to intervene with the normal ecosystem processes, be done with clear understanding of the scientific knowns and unknowns.

Silvicultural Treatment

It was suggested earlier that, given enough time, it is quite possible for old-growth conditions to develop in stands where prior human disturbance had occurred. For example, a subalpine forest may have old lodgepole pine trees in various stages of decline, with a significant stand component of Engelmann spruce and subalpine fir that has developed after harvest near the turn of the century. Such stands may have a complex structure and considerable amounts of coarse woody debris, but also skid roads and very old stumps. The oldest trees in these stands, chiefly lodgepole pine, were left during the earlier harvest, and presently they help the stand meet some old-growth criteria.

While for certain uses past or future disturbance is not considered acceptable, there may be important situations in which silvicultural intervention is highly desirable to improve the quantity, quality, distribution, or duration of old-growth forests in the landscape. An example is ponderosa pine along the Front Range in Colorado, where old-growth stands are scarce. It may be possible and desirable to enter such stands and alter the structure, age distribution, and amount of coarse woody debris to favor the development of old-growth features. Such an effort could be part of a program to restore some of the desirable qualities of the ecosystem (biodiversity, etc.) that had existed before settlement, harvest, and fire suppression so drastically altered the landscape.

Reintroducing Fire

It is clear from discussions above that fire suppression since settlement of the West has had major effects on forests. It was the conclusion of the workshop participants that fire be used in forest ecosystem management because historically it has been a very important ecological process in most, if not all, forest types in the central and southern Rocky Mountains and Southwest. There are several forest types in which fire is a critical natural element in the forest landscape, and the effects are reasonably well-understood. There are other types, however, for which relatively little is known regarding the impacts of fire, although it is known that total fire suppression in the landscape is unrealistic.

The reintroduction of fire in landscape management is not easy. The buildup of fuels has reached such a level in many forests that any fire is likely to be so intense that the entire forest community will be replaced. Thus where fires historically were frequent enough to help maintain old-growth conditions, now fires may totally destroy the trees that

might otherwise have been protected by more frequent fires (Covington and Moore, Harrington and Sackett, this volume). Furthermore, human communities have developed in many forested areas that typically had frequent fires (particularly along the Front Range in Colorado), and both the accumulation of fuels and the presence of buildings severely limit prescribed burning in most situations. Intense fires in some cases even result in the destruction and replacement of the human community development.

The accumulation of fuels during the extended period of fire suppression has resulted in the accumulation not only of large amounts of coarse woody debris, but also in large amounts of litter beneath large trees. Thus far researchers have not been able to develop reliable techniques for using fire in ways that prevent lethal temperatures from developing at the base of trees as this accumulated litter burns, even when fire is used in cool, moist seasons of the year (Harrington and Sackett, this volume). Considerable research is needed to determine how fire can once again be made a more significant part of landscape ecology. It may be possible to achieve some of the structural effects resulting from fire by using silvicultural techniques not aimed at timber harvest. Research is needed on the potential for using silvicultural treatments to simulate the effects of fire.

Inventory Techniques

Inventories of old-growth forests and of forests that have potential for transition into the old-growth condition are extremely important in forest planning. It is critical that inventories are conducted using guidelines with a sound scientific basis. Presently, most inventory of old-growth forests is conducted using some type of scorecard, often with both quantitative and qualitative features (e.g., Lowry, this volume). This has been a useful interim approach, but considerable modifications are needed (Robertson, this volume). The main problem with existing approaches is that they almost totally exclude old growth on poorer sites, because the scorecards make use of minimum criteria relating to tree size and stand structure (Mehl, this volume). Furthermore, certain scorecards favor structural diversity that in some cases (e.g., ponderosa pine) should be considered a quality-reducing factor rather than a quality-enhancing factor, and little attention is given to functional features that distinguish old growth from other successional stages.

Several rating systems have been used to quantify dead material on the forest floor, but not all systems have been used to quantify all of the standing and down dead material important in characterizing old

growth. Convenient methods are needed to evaluate all portions of the accumulated dead materials in forest communities, including their states of decomposition.

Research also is needed to improve inventory techniques for detecting old-growth forests at the landscape scale. The scorecard approach has evolved on individual National Forests, often with major differences in criteria among Forests for distinguishing old growth in similar forest types. General guidelines are needed for conducting inventories over large geographic areas. This research requires not only increasing our understanding of how old growth varies among sites and habitat types within forest types (see discussion above), but also improving the technology for completing accurate inventories. The development of remote sensing techniques (Nel, this volume) holds considerable promise for conducting broad-scale inventories.

Ecological Knowledge for Management

Synthesizing current and future scientific knowledge into a format useable in natural resource management is a formidable task. The necessity for addressing the likely ecological consequences and environmental impacts of various management scenarios (including no action) at comprehensive spatial and temporal scales overwhelms conventional approaches for integrated resource analysis. A central conclusion of working sessions at this meeting was that spatial and temporal ecological modeling coupled with formulations of desired future conditions is needed to support analyses not only for old-growth management decisions but also for landscape management in general.

Additionally, we concluded that management experiments and demonstration areas at the landscape level would be necessary for testing hypotheses and developing models that can aid decision-makers in guiding both research and management. To accomplish these tasks, improved access to remote sensing technology, geographic information systems, process-based simulation models, and other advanced technologies is necessary both for researchers and for managers.

CONCLUSIONS

It is clear from the wide array of topics covered in this volume that although much is known about old-growth forests in the central and southern Rocky Mountains and Southwest, many important questions remain unanswered. It is the responsibility of researchers to address these questions, because without

adequate scientific answers, it is likely that serious mistakes will be made that could have long-term negative environmental and ecological consequences.

At the same time, it is the responsibility of forest managers to incorporate the most up-to-date scientific knowledge in making decisions about the management of forest landscapes to protect and enhance the unique values of old-growth forests. It is also important that scientists and managers acknowledge those areas in which scientific knowledge is inadequate, to proceed cautiously when that is the case, and to inform researcher leaders and interested members of the public of such problems.

Some of the changes imposed on the forest landscape since settlement began presently restrict management options in the near future. Yet we have a tremendous opportunity to turn the pattern of change into a more positive one. This can be done through appropriate integration of sound scientific principles into guidelines for managing forests in ways that meet both present and anticipated future needs. It cannot be done by science alone, or by management alone, or by overreacting to the demands of narrowly focused interest groups. Managing old-growth forests in the landscape requires a long-term landscape perspective supported by informed communication among scientists, resource managers, and the public.