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Old-Growth Forest Structure in Eastern Oregon and Washington

Abstract

Old-growth forest structure is an important issue in managing for forest health and productivity in eastern Oregon and Washington. Old-growth forest structure is estimated to be as little as 3% of presettlement levels; what remains is in isolated patches and is at risk of loss from less frequent but more severe fires. Low-elevation ponderosa pine and Douglas-fir stands are more densely stocked with increased fuel, and often represent compositional shifts to more lodgepole pine and grand fir. The changes are attributed to changes in natural disturbance regimes as a result of management of fire, grazing, timber harvest, wildlife, insects, and disease. Treatments that can accelerate development of old-growth forest structure include thinning to accelerate growth on residual stems, returning fire to fire-dependent ecosystems, and maintaining large trees and snags. These methods have risks: prescribed fire may not mimic frequency and severity of historical fire, thinning may activate dormant stem decay, increased connectivity may increase susceptibility to stand-replacement fire, insects, and pathogens. Models for multiple species and interactions of treatments, insects, and disease are not available.

Introduction

Foresters and economists often have viewed old-growth forests in terms of financial maturity and have prescribed a series of silvicultural activities to achieve an orderly conversion of old stands to young stands to maximize vigor and productivity. More recent perspectives involve expanded silvicultural objectives and greater understanding of plant ecology and ecophysiology, and consider old-growth stands as developmental stages with attendant pathways and structural and functional aspects that are achieved when trees grow in the absence of external disturbances (Oliver 1981, Oliver and Larson 1990, Moir 1992). For dendrochronology, emphasis is on tree age (Swetnam and Brown 1992), while for wildlife habitat, structure may be more important (Reynolds and Linkhart 1992, Thomas et al. 1993). Historical and current relationships between wildlife species and key old-growth habitats in eastern Oregon and Washington are discussed by Wisdom et al. (2000). O'Hara et al. (1996) suggested "old forest" should be used to avoid the strong social rather than ecological construct. This synthesis narrative emphasizes the development, distribution, role of natural disturbances, treatment strategies, and existing decision tools for manipulation of old-growth forest structure with emphasis on the key conifer tree species occurring in eastern Oregon and Washington.

Individual trees, growing on relatively good or protected sites, may obtain ages in excess of 250 years for *Abies* species, 500 years for *Picea* species, and 1200 years for whitebark pine (*Pinus albicaulis* Engelm.) (Franklin and Dyrness 1973, Perkins and Swetnam 1996). Initial attempts to define old-growth forest structure in western Washington and Oregon and in California by ecological functionality resulted in broad criteria for tree species, crown size and closure, number of canopy layers, and the presence and size of snags and down logs (USDA 1986). Recent work to describe old-growth forest attributes for forest ecosystems of eastern Oregon and Washington are based on structural features such as the number of large trees, number of snags, amount of down woody material, number of tree canopy layers, the native shrub or herb component, and the amount and size of tree or canopy gaps (USDA 1993). These broad criteria fail to consider variations among common site characteristics that influence plant species composition, however, and thus assume an equivalent capability across all sites supporting the same climax tree species.

The study of stand development (stand dynamics) considers changes in stand structure through time and the interaction of structure and disturbance factors or events. Within the last several decades, a large body of work across many ecosystems has contributed to a greater appreciation for the potential of multiple pathways of stand development leading to old-growth stand structure rather than mono-directional change (succession) leading to a single and stable stand structure or condition (climax) (McIntosh 1999). In addition there is greater recognition of the competitive advantage often held after disturbance by individual or groups of plants (cohorts), and the role of various forms and intensities of disturbance (Johnson et al. 1994, Means 1982, Oliver and Larson 1990). O'Hara et al. (1996) presented a structural classification of seven classes potentially applicable to all western forest ecosystems that includes vertical, horizontal, and quantitative structure components; two classes describing old-growth forest structure differ primarily on the number of cohorts and strata present. Throughout eastern Oregon and Washington, presettlement ponderosa pine (*Pinus ponderosa* Laws.) and some low-elevation Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western larch (*Larix occidentalis* L.) stands often developed with open, multi-aged structures (Barrett 1979, Tesch 1981, Agee 1993). A common management objective has been to convert these multiaged stands to even-aged stands. Documented developmental patterns for these even-aged stands that relates existing structural characteristics to future characteristics often incorporate incremental and total stem height and diameter growth, stand growth, changes in volume, and accumulated mortality, and represent competitive interactions from different stem densities portrayed at various levels of growing stock (Tesch 1981, Larson 1986, Cochran and Barrett 1999, Cochran and Seidel 1999, Cochran and Dahms 2000). In contrast, O'Hara (1996) studied ponderosa pine stands with multiple cohorts and found that similar developmental patterns of cohort structure developed across broad regions, growing space was used more efficiently by stands with multiple cohorts, and growing space was used disproportionately by large trees.

Developmental patterns for other species are not as well refined; Cochran and Dahms (2000) reported on the response of even-aged lodgepole pine (*Pinus contorta* Dougl.) at two sites maintained at five different levels of growing stock, while Muir (1993) examined the patterns of stand structure resulting from natural and human-induced disturbances in lodgepole pine stands of western Montana. Developmental patterns for grand fir (*Abies grandis* Douglas ex D. Don) have emphasized regeneration stages (Seidel and Cochran 1981). Less is known of developmental patterns for species of eastern Oregon and Washington with more limited distribution such as limber pine (*Pinus flexilis* James), sugar pine (*P. lambertiana* Dougl.), western white pine (*P. monticola* Dougl.), incense-cedar (*Calocedrus decurrens* (Torrey) Florin, Pacific yew (*Taxus brevifolia* Nutt.), Engelmann spruce (*Picea engelmannii* Parry), subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), mountain hemlock (*Tsuga mertensiana* (Bong. Carr.), and whitebark pine (Arno and Hoff 1989, Tomback et al. 1993).

Declines from historical levels in the overall extent of old-growth forest structure of eastern Oregon and Washington are well documented, and area may be as low as 3% of presettlement levels (Bolsinger and Waddell 1993, Everett et al. 1994, Karr and Chu 1994, Hann et al. 1997). Decline can be attributed to changes in natural disturbance regimes resulting from active management programs for fire, grazing, timber, wildlife, and pest control (Johnson et al. 1994, Oliver et al. 1994).

Disturbance and Old Growth

Forests of eastern Oregon and Washington have a long history of natural and human-induced disturbance. At the landscape scale, early settlers at the beginning of the 20th century witnessed open forests of ponderosa pine and Douglas-fir with widely spaced trees, few if any down logs, and little litter and woody undergrowth (Languille et al. 1903, Wickman 1992, Bonnicksen 2000). The structure of stands, as suggested by early settlers' journals, was a seemingly uniform park-land of widely spaced medium to large old trees and continuous herbaceous undergrowth (Agee 1994, Naumburg and DeWald 1999). This old-growth forest structure before the 1900s was substantially the result of frequent low-intensity fires that thinned stands from below by killing small-diameter stems through a combination of cambial and root damage and crown scorch, consumed litter and down wood, opened stands to increased sunlight, and led to vertical stratification of fuels (Saveland and Bunting 1988, Agee 1990, Agee 1993). Fire may also have reduced or eliminated stems in the lower crown strata that were infected with dwarf mistletoe (*Arceuthobium spp.*) (Barrett 1979). Frequent, low-intensity surface fires are generally thought to be characteristic of presettlement conditions throughout the distribution of ponderosa pine (Kilgore 1981). Recent work in the Black Hills of South Dakota and Wyoming, however, suggests that in addition to periodic, low-intensity surface fires that hold open-canopy forests in a relative state of equilibrium, more infrequent catastrophic disturbance characterized by large, stand-replacing fires may have maintained large, contiguous patches of old-growth forests in a state of "nonequilibrium" (Shinneman and Baker 1997). Natural fire intervals in old-growth ponderosa pine forests ranged from 4 to 11 years in central Oregon (Bork 1984, Morrow 1986), 7 years on the east slope of the Washington Cascades (Everett et al. 2000) and averaged 10 years across the Blue Mountains (Hall 1980) and 11 years in the southern Blue Mountains (Heyerdahl 1997). With effective fire exclusion, understory tree density in the remaining old-growth ponderosa pine and low-elevation Douglas-fir forests has increased, stand composition has been altered to include more lodgepole pine and grand fir on some sites, and stands are at greater risk of stand-replacement disturbances (Mutch et al. 1993, Agee 1994). Fuel accumulations in old-growth ponderosa pine forests now rarely resemble those of presettlement forests, and tree mortality is affected by season of fire, fire severity, fine-root biomass, and tree vigor (Swezy and Agee 1991).

Major insects associated with old-growth ponderosa pine forests include the pandora moth (*Coloradia pandora* Blake), the western pine beetle (*Dendroctonus brevicomis* LeConte), the turpentine beetle (*D. valens* LeConte), and the mountain pine beetle (*D. ponderosae* Hopk.). Old-growth ponderosa pine forests are subject to defoliation from pandora moth whose larvae consume the previous year's needles (Furniss and Carolin 1977). Reconstruction of a 622-year record of 22 individual outbreaks in 14 old-growth stands indicated two quasi-cyclical time series of 18 to 24 years and 37 to 41 years between outbreaks (Speer et al. 2001). Mortality from western pine beetle in old-growth ponderosa pine stands occurs at low levels unless regional droughts affect tree vigor across entire watersheds; the scattered distribution of large trees with insufficient vigor to produce adequate oleoresin exudation pressure to protect the tree results in low snag densities (Barrett 1979, Hessburg et al. 1994). Historically, mountain pine beetle probably was not associated with old-growth ponderosa pine stands, but with fire exclusion, small-diameter ponderosa and lodgepole pine stems have increased stand densities dramatically, and these densely stocked small-diameter stems can support populations of mountain pine beetle (Hessburg et al. 1994, Olsen et al. 1996).

Comandra rust (*Cronartium comandrae* Pk.) may be locally significant in old-growth ponderosa pine forests. This disease invades the fine twigs and main branches, eventually causing a canker in the bole and crown mortality above the canker (Childs 1968, Filip 1977). Top-killed trees may survive many years, eventually developing a resin-soaked, case hardened snag that persists for decades.

Since the turn of the century, the structure of most old-growth ponderosa pine forests has changed as a result of widespread selective timber harvesting that started with the first European settlers and greatly accelerated after World War II (Bergoffen 1976, Mowat 1961). Harvest cutting in ponderosa pine was initially designed to capture the mortality and reduce the risk of additional mortality caused by western pine beetle by removing up to 95% of the volume (Mowat 1948, Mowat 1961, Dolph et al. 1995). These stands often regenerated naturally with high densities of small-diameter stems; competition between the young cohort and the few remnant old stems often can be severe and can lead to mortality of the old trees (Dolph et al. 1995).

Landscapes dominated by mixed-conifer stands of Douglas-fir, grand fir, Engelmann spruce, and subalpine fir throughout eastern Oregon and Washington are characterized by mixed-intensity, mixed-severity disturbances that occur infrequently. Fire regimes are in the order of several decades to more than 100 years and, because these forests develop multiple layers of tree canopies with complete fuel ladders, fire is easily transported into upper canopy crowns and may become a stand-replacement event. Lodgepole pine, ponderosa pine, western white pine, and western larch are dominant seral species in these ecosystems. Landscapes supporting Douglas-fir and grand fir throughout much of eastern Oregon and Washington are highly complex in response to changes in climate, geomorphology, topography, and soils. Thus patches of old-growth forests dominated by grand fir or Engelmann spruce may best be described as unconnected fire "refugia" within a matrix of younger, more recently disturbed forests (Camp et al. 1997).

Bark beetle outbreaks are likely responsible for much of the mortality in old-growth forests of mixed conifers; the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.) can develop large populations in diseased or weakened trees and move out to attack and kill nearly all the Douglas-fir stems in a stand (Seidel and Cochran 1981, Hessburg et al. 1994). Herbivory by western spruce budworm (*Choristoneura occidentalis* Freeman) and Douglas-fir tussock moth (*Orgyia pseudotsugata* McD.) occurs periodically in mixed-conifer stands containing grand fir and Douglas-fir (Swetnam et al. 1994, Wickman et al. 1994, Swetnam et al. 1995). These insect outbreaks historically resulted in little overstory mortality except from lower canopy strata and those trees of low vigor. Defoliation and reductions in canopy cover, along with improved mineral cycling, may actually stimulate radial growth of grand fir and Douglas-fir (Wickman 1986, Mason et al. 1997). Recently, western spruce budworm and Douglas-fir tussock moth outbreaks have become more extensive and more intense as host availability has increased (Wickman 1992). Tree mortality and eventual conversion of standing dead to down logs in these old-growth forests, along with new seedling establishment, appears to follow similar patterns after disturbances that have vastly different durations (Youngblood and Wickman, *In press*). Stem decays, especially decay caused by the Indian paint fungus (*Echinodontium tinctorium* (Ell. et Ev.), may be present in old-growth forests that contain grand fir and subalpine fir as host species (Aho et al. 1987, Hessburg et al. 1994).

Lodgepole pine is normally a short-lived seral species, replaced by a number of more shade-tolerant conifers. On infertile pumice deposits in south-central Oregon, it may develop an edaphic climax lacking replacement by other tree species. A slow-moving fungus that decays tree boles, infrequent fires, and mountain pine beetles combine to maintain at least two cohorts in stands (Geiszler et al. 1980). Old-growth whitebark pine is often killed when mountain pine beetle populations develop in lower-elevation stands of lodgepole pine and spread upward (Arno and Hoff 1989), or may be replaced by subalpine fir in the absence of fire. The introduced white pine blister rust (*Cronartium ribicola* J.C. Fisher ex Rabh.) may also infect and kill whitebark pine.

Management Effects

Forest health and productivity treatment strategies for old-growth forests involve recognition of site conditions, early detection of events or agents of disturbance, protection of specific sites, and accelerated development of old-growth characteristics by restoring natural processes. Treatment strategies that maintain, enhance, or accelerate old-growth forest conditions will likely vary until there is common agreement on conditions and attributes that characterize old-growth forests. Recent work in identifying and mapping potential disturbances with GIS capability indicated little change from historical levels of insect and disease hazard at the subbasin scale, yet considerable variation in hazard at the watershed scale where large changes in vegetation structure have occurred (Lehmkuhl et al. 1994). A moratorium on harvesting in late-successional and old-growth forests in eastern Oregon and Washington in addition to a moratorium on harvesting any tree of any species older than 150 years with breast-height diameter of 20 inches or larger was recommended by a scientific panel charged by Congress to assess conditions in forests of eastern Oregon and Washington (Perry et al. 1995). Daterman (1994) outlined key components for short-term approaches to protecting old-growth forests, especially the need to develop measures to prevent further bark-beetle-caused mortality of the larger trees in old-growth forests. More long-term methods may involve implementing silvicultural prescriptions to reduce the hazard of insect-caused mortality at the stand scale and extend treatments across entire landscapes (Mason and Wickman 1994). Restoring natural processes to maintain or enhance development of old-growth forest structure was the basis for many of the ecosystem management activities assessed across the Interior Columbia Basin, including management activities to improve both the area (extent) and connectivity of old-growth forests by returning fire to fire-dependent ecosystems, maintenance of large residual structures, and stocking control to promote development of similar structures (Quigley et al. 1996).

The eventual return, through active management, of fire as a disturbance event operating at presettlement frequencies may serve to restore many natural processes and protect large residual structures from stand-replacement fire, once existing fuel accumulations are reduced in low-severity, high-frequency fire regimes such as those of low elevation ponderosa pine and Douglas-fir (Mutch et al. 1993, Arno and Ottmar 1994, Mutch and Cook 1996, Covington et al. 1997). These goals may not necessarily be achieved mutually (Swezy and Agee 1991). The effect of burning on residual tree growth is not conclusive; limited work suggests that under some conditions, short-term growth reductions may occur (Landsberg et al. 1984, Peterson et al. 1994). The degree to which prescribed fire can be used to mimic historical fires in frequency and severity is not known, nor is there a clear understanding of the types of stand structures and their related values that can develop after prescribed fire (Youngblood and Riegel 1999).

In mixed-severity, mixed-frequency fire regimes such as those of mixed conifers, restoration of natural processes and protection of old-growth structure may not be possible through the reintroduction of fire. In some cases, fire exclusion or suppression since the beginning of the 20th century has been ineffective; in other cases, reintroduction of fire would result in complete stand replacement. In these systems, silvicultural methods of thinning for accelerating the development of large structures may be beneficial. Acceleration of growth on some stems requires stocking level control to eliminate the growth of competing trees; stocking level control may also reduce the hazard of some insect- and disease-related mortality by maintaining stands under a critical stand density, above which mortality may be serious (Cochran 1992, Cochran et al. 1994, Cochran 1998, Cochran and Barrett 1999, Cochran and Seidel 1999, Cochran and Dahms 2000). Retrospective studies of old-growth forest structure provide the best target for determining what were the historical ranges of densities and spatial patterns in any given area (Harrod et al. 1998, Harrod et al. 1999, Youngblood and Riegel 1999, Harris 2000). These strategies are not without some risk, however. Stocking control by thinning may activate dormant stem decay, leading to reduced growth, mortality, and fuel accumulation (Youngblood 2000). In some high-severity, low-frequency disturbance regimes, current management goals of increasing the amount and connectivity of old-growth forest structure may increase the risk of stand-replacement disturbances from insects, pathogens and fire in old-growth "refugia" stands (Camp et al. 1997).

When stands are deficient in trees with identified old-growth characteristics important for wildlife, such as living trees with decay, hollow trees, or dead snags (Bull et al. 1997), various artificial means of creating these features have been attempted (Parks et al. 1996). Treatments have included topping the tree with a chainsaw or explosives, girdling, and inoculations with decay fungi. While preliminary results appear promising, these actions are costly and may not produce the desired decay conditions.

Decision-Support Tools

Few integrated, widely useful, and easy-to-use tools for developing, managing, and protecting old-growth structure exist. Decision-support tools for application of fire are limited. Predictions of first order (the direct or immediate consequences) fire effects of prescribed and wildfire for duff and woody fuel consumption, mineral soil exposure, fire-caused tree mortality, and smoke production may be modeled by using FOFEM (Reinhardt et al. 1997). This model addresses only the direct effects of fire, however. Models of the cumulative effects of fire with other disturbance factors such as insects or disease are not available. Guides to prescription development for burning in low-elevation forests are available (Kilgore and Curtis 1987). Keane et al. (1990) developed a model of whitebark pine stand dynamics over 500 years that simulated fuel accumulations, tree establishment, growth, and mortality, and the effects of insect and disease.

Decision-support tools for thinning involve suggested stocking levels for specific species. In general, these are based on pure, even-aged stands (Seidel and Cochran 1981, Cochran et al. 1994, Cochran 1998, Cochran and Barrett 1999, Cochran and Seidel 1999, Cochran and Dahms 2000). Based on the work of Cochran et al. (1994), stocking guides for most tree species across most plant associations found in the Blue Mountains are now available (Powell 1999). Similar guides to allocating growing space among cohorts to control stocking in multi-aged stands of ponderosa pine (Cochran 1992, O'Hara 1996, O'Hara and Valappil 1995) may have wider applicability as more watersheds are managed under uneven-aged regimes.

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