Forest Stand Structure and Development: Implications for Forest Management[1]

Kevin L. O'Hara[2]

A general premise of forest managers is that modern silviculture should be based, in large part, on natural disturbance patterns and species' adaptations to these disturbances. An understanding of forest stand dynamics is therefore a prerequisite to sound forest management. This paper provides a brief overview of forest stand development, stand structures, and disturbance regimes and discusses the implications of applying this information to forest management in the Sierra Nevada. It focuses on three forest types that comprise the bulk of the managed land base: mixed conifer, ponderosa pine, and red fir forests.

In forest stands in all regions of the world, similar stand development processes occur in highly different ecosystems (Oliver 1992). Most descriptions of stand development characterize it as a progression through stages toward an older forest, possibly an old forest, in the absence of disturbance. Disturbances, from human or other causes, can move stand development backward or forward in the process, depending on their type, severity, and timing. As a result, stand development is best characterized as a multidirectional, chaotic process, and a given stand structure can originate from a number of different pathways. From a forest management perspective, this implies that there are a variety of ways to create a stand structure, providing some flexibility in designing silvicultural treatments.

Present forest structures in the Sierra Nevada are the result of a range of disturbances. These include a wide variety of fire regimes, wind patterns, insects, pathogens, and past timber harvest practices, such as high-grading performed in various ways under the guise of "selective" cutting, seed tree harvesting, and, more recently, plantation management. These disturbances and the subsequent regrowth of forests have created a highly diverse series of landscapes and a high level of diversity within those landscapes.

Time-Space Disturbance Continuum

Seymour and others (2002) state it is believed that, in forests in the northeastern United States natural disturbances occur over larger areas as the interval between disturbances increases. Comparing natural disturbances to timber harvest practices, clearcut harvesting usually occurs at shorter disturbance intervals than those typical of natural disturbance events of similar size (20 ha). Shelterwood harvest treatments, because they affect a smaller area, represent a spatial-temporal process that is closer to the norm. Selection treatments are generally within the normal range. Although Western forests experience larger-scale disturbances, these events can occur within the same area at frequent intervals. Nevertheless, the implication that small-scale disturbances naturally occur more frequently than larger-scale disturbances probably holds, in principle, for Sierra Nevada forests as well as other Western conifer-dominated forests.

---

[1] This paper was presented at the Sierra Nevada Science Symposium, October 7-10, 2002, Kings Beach, California.

[2] University of California, Department of Environmental Science, Policy, and Management, Berkeley, CA 94720.

If one accepts the principles that natural disturbance severity, frequency, and spatial extent are related (albeit with some exceptions) and that forest management practices might be pushing the limits of system resilience by directly or indirectly causing more frequent and severe disturbances than would naturally occur, how can forest management be modified to fall more in line with the natural temporal-spatial dynamics of disturbances in the Sierra Nevada? One alternative is to extend rotation lengths for even-aged silvicultural systems. Rotations in California range from 50 to 80 years, or more on slower-growing sites, and are restricted on State and private lands to 50 years or more by California forest practice regulations. Rotation lengths have typically been determined by the point at which mean annual volume increment (MAI) is maximized or the point at which financial returns are maximized. Longer rotations would have lower volume productivity or lower financial returns. A recent examination of patterns of MAI in thinned coast Douglas fir (*Pseudotsuga menziesii* var *menziesii*) in the Pacific Northwest indicates that MAI does not peak as early as previously believed and, in many cases, shows no sign of reaching a maximum in either cubic or merchantable (board foot) units (Curtis and Marshall 1993). Earlier mistaken assumptions regarding the maximization of MAI in thinned Douglas fir stands were attributed to a poor understanding of height growth patterns in Douglas fir, a species with a prolonged height growth pattern, and a poor understanding of the effects of thinning on volume increment. The implication is that rotation lengths could be extended for these forests without any appreciable loss in volume productivity. It is likely that similar results are possible in Sierra Nevada conifers because these species possess similar, prolonged height-growth rates. If similar patterns do occur and if longer rotations were widely adopted in the Sierra Nevada, this would lead to major changes in the distribution of stand structures over broad scales and an increase in the number of stands containing old forest features.

Uneven-aged silviculture also offers opportunities for management strategies that incorporate a more natural distribution of temporal-spatial disturbance patterns. However, this does not include the traditional form of single-tree selection silviculture that relied on very minor disturbances and used negative exponential diameter distributions to guide the selection of target structures. Instead, the creation of simpler two- or three-aged stand structures is recommended, as these require less frequent entries, provide sufficient light resources for regeneration of shade-intolerant species, and more closely represent the effects of natural disturbance processes (O'Hara 1998).

The formation of relatively large gaps for regeneration or group selection represents another alternative to traditional single-tree selection. This method is suitable for management of shade-intolerant species and mimics natural dynamics of Sierra Nevada ecosystems by representing the small cleared patches formed by natural disturbances, such as mixed-severity fires, insects, or pathogens.

A related form of uneven-aged silviculture is currently known as "variable retention": individual trees or clumps of trees are reserved after harvest. The purpose of retaining these trees is to provide structure, future snags, and coarse woody debris to enhance wildlife habitat or improve the visual appearance of units harvested with even-aged methods. The resulting two-aged stands are essentially similar to the products of more traditional regeneration methods, such as seed tree with reserves or shelterwood with reserves. Reserve trees are trees retained through a subsequent rotation.

Data comparing the productivity of these forms of uneven-aged silviculture with that of even-aged systems are scarce. Current opinion assumes some loss in productivity with the more complex systems as well as greater financial costs. O'Hara (1996) compared LAI (leaf area index) and volume growth between even-aged and multiaged (two or more age classes) ponderosa pine (*Pinus ponderosa*) stands and found no differences. In follow-up work, Nagel and O'Hara (2002) found late-season water limitations in even-aged ponderosa pine stands that might contribute to a productivity advantage for multiaged stands. The greater economic costs associated with managing uneven-aged stands appears to be the result of more expensive harvesting and possibly more frequent stand entries.

Restoration

Restoring existing stands to reflect presettlement conditions or other standards is becoming a frequent goal of forest management in the Sierra Nevada. Among the most common objectives are restoration of old forests and enhancing stand structural diversity in younger forests. Restoration of old forest features generally entails reducing the stand density in younger stands to correspond with that of older forests. This accelerates growth rates and aids the formation of structural elements, such as lichens and mosses. Even old trees can respond positively to a thinning treatment. Latham and Tappeiner (2002) reported that older individual ponderosa pine, Douglas fir, and sugar pine (*Pinus lambertiana*) trees all responded with faster growth and greater vigor to additional growing space in southwest Oregon mixed conifer stands. Ultimately, more trees can be left as snags or coarse woody debris on the forest floor.

Other work in coastal Douglas fir has shown that old forest trees frequently grew in wide spacings, as evidenced by their rapid initial growth rates (Tappeiner and others 1997). These initial growth rates have in some cases exceeded those of the widest spacing trials. The implication is that these old forest trees initially grew with little competition and this contributed to their large size. It is not known whether this is also true for the Sierra Nevada, but the topic warrants further study.

Variable-density thinning is another method to increase stand-level variability such that stand structures may begin to reflect natural disturbance patterns more closely. This thinning concept applies to either precommercial or commercial thinning operations. Variable-density thinning simply applies different prescriptions to different parts of a stand so that some areas might be thinned heavily and others not thinned at all. The result is that some areas develop with wide spacing among trees and other areas of the same stand develop with heavier competition among trees. This method potentially influences the way stands are defined and characterized; they may be classified according to a common operation rather than a common structure.

Fuelbreaks are another restoration objective that at the stand scale attempt to restore fire-resistant structures but at the landscape scale serve as strategic impediments to catastrophic fires. Fuelbreak stand structures vary depending upon the pretreatment structure. For dense stands, a typical series of treatments is thinning to reduce density, followed by reducing ladder fuels, with a subsequent effort to reduce surface fuels. An objective of these treatments is often to prepare stands for prescribed burning to prevent future accumulations of fuels (Weatherspoon and Skinner 1996). In the case of the Herger-Feinstein Quincy Library Group Forest Recovery Act objectives in the northern Sierra Nevada, there is also the intent to eventually convert these stands to uneven-aged structures.

References

Curtis, R.O.; Marshall, D.D. 1993. **Douglas-fir rotations: Time for reexamination.** Western Journal of Applied Forestry 8: 81-85.

Latham, P.; Tappeiner, J. 2002. **Response of old-growth conifers to reduction in stand density in western Oregon forests.** Tree Physiology 22: 137-146.

Nagel, L.M.; O'Hara, K.L. 2002. **Diurnal fluctuations of gas exchange and water potential in different stand structures of Pinus ponderosa.** Trees– Structure and Function 16 (4-5): 281-290.

O'Hara, K.L. 1996. **Dynamics and stocking-level relationships of multi-aged ponderosa pine stands.** Forest Science 42, Monograph 33; 34 p.

O'Hara, K.L. 1998. **Silviculture for structural diversity: A new look at multiaged stands.** Journal of Forestry 96: 4-10.

Oliver, C.D. 1992. **Similarities of stand structures and stand development processes throughout the world—some evidence and applications to silviculture through adaptive management.** In: Kelty, M.J.; Larson, B.C.; Oliver, C.D., editors. The ecology and silviculture of mixed-species forests. Dordrecht, The Netherlands: Kluwer Academic Publishers; 11-26.

Tappeiner, J.C.; Huffman, D.; Marshall, D.; Spies, T.A.; Bailey, J.D. 1997. **Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon.** Canadian Journal of Forest Research 27: 638-648.

Weatherspoon, C.P.; Skinner, C.N. 1996. **Landscape-level strategies for forest fuel management**. In: Status of the Sierra Nevada, Vol. II. Davis, CA: University of California, Centers for Water and Wildland Resources; 1471-1492.