Multiaged Systems in the Central anc

Silviculturists must be able to assess and control levels of growing stock for the specific structural objectives that arise from new social goals. In the central and southern Rockies, few if any forest types particularly lend themselves to classic uneven-aged selection systems; instead, stand density index is used to implement a broad range of structural objectives, from even-aged to multiaged. Using this index to manage stands is relatively simple and therefore constitutes a practical alternative for unconventional multiaged systems.

By James N. Long

Social values associated with forest resources are always subject to change (Koch and Kennedy 1991). The shifts are reflected in forest management objectives and even in interpretations of what constitutes sustainable forest management, and they affect choices of silvicultural systems. The pressures for change in the way forests are managed are particularly strong in the central and southern Rockies, where more than 75 percent of commercial timberland is controlled by various agencies of federal, state, local, and tribal governments (Long 1995).

Stand-level objectives *must* be made explicit before they can be translated into silvicultural practice. The development and subsequent implementation of most stand management objectives can be expressed in terms of physical structure and species composition. Structure and composition are not, of course, independent, since species composition can directly or indirectly influence structure, and vice versa. For example, a tolerant species like subalpine fir is more likely to contribute to vertical structure and is more likely to become established in a stand already exhibiting some vertical structure (Daniel et al. 1979; Parker and Long 1989). Species composition is often an important stand-level objective because it may be a strong determinant of timber values and also directly influence conservation values. In mixed-conifer forests in northern Arizona, for example, aspen may account for only 12 percent of the total basal area but 88 percent of the host trees for cavity-nesting birds (Li and Martin 1991). And structure is often even more important, since it appears to influence avian habitat independently of the plant community species (e.g., Rice et al. 1984; Reynolds et al. 1992; Delong et al. 1995).

Disturbance and Diversity

A common assumption is that appropriate elements of ecosystem and landscape structure and function will be maintained within the approximate range of natural disturbance (Galindo-Leal and Bunnell 1995). For this reason, it has been suggested that the best strategy for maintaining diversity at both the stand and the landscape level is to mimic natural disturbance regimes—specifically, to employ management strategies reflecting the range of sizes, frequencies, and intensities of the historical disturbance regime (Covington and Moore 1994; Roberts and Gilliam 1995).

Put another way, silvicultural systems that contribute to "spatial and temporal diversity of resources and environments will be most effective in maintaining plant species diversity" (Halpern and Spies 1995). In managed forests, reproduction methods are analogous to the natural coarse-scale disturbances that periodically reinitiate succession. Reproduction methods, in fact, represent a gradient of disturbance intensities that strongly influence composition and structure. Disturbances that remove all or none of an overstory result in single-age class stands; disturbances that remove varying amounts of an overstory result in multiaged stands.

Resource objectives should not dictate silvicultural systems or prescriptions. Rather, the silviculturist should have flexibility in designing systems to create and maintain the desired species compositions and stand structures (Long et al. 1986). A very broad range of stand structures and species compositions can be created with several systems (Matthews 1989; Oliver 1992). The discussion about even-aged, multiaged, and uneven-aged systems is, or at least should be, a discussion of structural objectives. These terms represent a variety of potential structures, some

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of which will meet a given set of objectives better than others. Nontraditional reserve-tree silvicultural systems, for example, may provide a great deal of the structural complexity of uneven-aged systems while minimizing some of their operational difficulties (Long and Roberts 1992).

The Density Index

Given specific structural objectives derived from broad stand management goals, the silviculturist must have a way to assess and control levels of growing stock. None of the major forest types of the central and southern Rockies require management under a classic uneven-aged selection system—indeed, few if any forest types in the region particularly lend themselves to it. The spruce-fir type, for example, is characterized by stand-replacing disturbances by fire and spruce beetle outbreaks at very long intervals of 200 to 300 years. Between those catastrophic disturbances, windthrow, fires of moderate severity, and mortality associated with endemic populations of spruce beetle create mosaics of patches ranging from less than 0.5 acre to greater than 5 acres. The result is an irregular stand structure that is far from "balanced," and any silvicultural system based on natural disturbance must incorporate such diversity. The BD*q* method—B, the residual basal area; D, the maximum retained diameter in the residual stand; and the *q* factor—is simply not appropriate for the range of irregular stand structures demanded by most management objectives.

In the central and southern Rockies, stand density index (SDI) is commonly used to assess and control growing stock for a broad range of stand structure objectives, including northern goshawk nesting habitat (Lilieholm et al. 1994), ungulate hiding cover (Smith and Long 1987), and a particularly complex structure for Mexican spotted owl habitat (Fiedler and Cully 1995).

Because the relative densities of individual stand components are additive, the density index is a robust, practical way to assess growing stock across the range of stand structures, from even-aged to multiaged, including irregularly structured stands (Long and Daniel 1990; Cochran 1992; Long 1996). Illustrations of the use of SDI in developing density management regimes have been published for even-aged (e.g., Long 1985), two-storied (Long 1996), and uneven-aged (Long and Daniel 1990; Fiedler and Cully 1995) stands.

How It Works

An example illustrates the use of SDI in regulating growing stock in a two-storied stand characteristic of a shelterwood-with-reserves system (Long 1995). A ponderosa pine stand in the Southwest has been regenerated using a uniform shelterwood. We now wish to retain six trees per acre (TPA) in the overstory; these reserve trees have a mean diameter of 18 inches. The understory consists of about 600 saplings per acre. We want to precommercially thin the understory so that at a future commercial thinning, these trees will be about 8 inches in diameter and the total stand SDI (overstory plus understory) will not exceed 270. This SDI target is about 60 percent of maximum SDI for Southwest ponderosa pine (i.e., 450) and should therefore prevent suppression-related mortality (Long 1985).

Calculations in this example are all simple variations on the basic SDI formula:

$$SDI = TPA \times (D/10)^{1.6}$$

where D is mean diameter. The task is to determine the number of understory trees to leave after the precommercial thinning.

Step 1: Estimate the future contribution of the overstory to total SDI. This requires estimating overstory D at the next entry. Assume, for example, that the average diameter of the reserve trees will increase by 4 inches and therefore be 22 inches when the understory is ready for the planned commercial thinning. Then the expected contribution of the overstory to total SDI is

$$SDI_{OV} = 6 \times (22/10)^{1.6} = 21$$

Step 2: Calculate the amount of total SDI allocated to the understory at the next entry. Given that we want a total SDI of 270, about 21 of which will be contributed by the overstory trees, the understory allocation is 249.

Step 3: Calculate the number of understory trees that should be left after the precommercial thinning. Given targets for the understory of SDI = 249 and D = 8 inches, we can calculate the appropriate TPA:

$$TPA_{us} = 249/(8/10)^{1.6} = 356\ TPA$$

The most tenuous assumption is the first step, the estimate of future overstory D. Fortunately, for systems involving relatively few overstory reserve trees, residual stocking in the understory is relatively insensitive to future overstory D. For example, if the reserve diameter increment were estimated to be 6 inches instead of 4, the desired residual understory stocking would be reduced to 351 TPA—a difference of only 5 TPA.

Although residual stocking in the understory is not very sensitive to diameter increment of the overstory trees, it is extremely sensitive to the number of overstory trees. Increasing the number of reserve trees from 6 to 20 TPA, for example, means that residual stocking of the understory after the precommercial thinning must be reduced to approximately 285 TPA, or a difference of 71 TPA.

Increasingly, management objectives are dictating stand structures other than those resulting from even-aged or classic uneven-aged silvicultural systems (O'Hara 1998). Additional research is needed to determine appropriate allocations of growing stock to the components of these unconventional multiaged systems. Nevertheless, SDI is proving to be a robust, practical alternative for assessing and controlling growing stock in various types of irregularly structured stands.

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