Stand Development and Silviculture in Bottomland Hardwoods[1]

J. Steven Meadows[2]

INTRODUCTION

Silviculture for the production of high-quality timber in southern bottomland hardwood forests involves the application of environmentally sound practices in order to enhance the growth and quality of both individual trees and stands. To accomplish this purpose, silvicultural practices are typically used to regulate stand density, species composition, and stem quality to promote the growth and development of high-value stands. To be successful, the hardwood silviculturist must understand the process of stand development--how even-aged, mixed-species stands develop and change over time, especially with respect to species composition and stand structure. If silviculturists know how hardwood stands develop and mature under natural conditions, they are better able to predict the effects of various silvicultural manipulations in these stands.

Successful management of mixed-species stands, such as most southern bottomland hardwood forests, requires specific knowledge about each of the species in the stand: (1) biological requirements, not only for regeneration, but also for future growth and development; (2) pattern of growth over time, such as slow vs. rapid early growth; and (3) silvical characteristics, especially shade tolerance and flood tolerance. These three critical characteristics of a species collectively determine the competitive ability of that species. In addition, differences in the competitive abilities of the various species found in a given stand determine the future development of that stand. The hardwood silviculturist must recognize and understand these relationships to better understand how different stands develop under different conditions to produce the structure and species composition that exist in a given stand today.

GENERAL STAGES OF STAND DEVELOPMENT

Oliver (198 1) proposed that the process of stand development in even-aged, mixed-species stands can be divided into four broad stages: (1) stand initiation, (2) stem exclusion, (3) understory reinitiation, and (4) old growth. Much of the following discussion, unless otherwise noted, has been adapted from Oliver (198 1).

Development of an even-aged, mixed-species stand begins after some type of major disturbance, either natural or human-induced. The disturbance must be severe enough to kill or remove most living trees in an area large enough to promote the development of an even-aged stand. Thus, most of the trees in the new stand will develop in the absence of competition from surrounding, undisturbed trees.

Stand Initiation Stage

After a major disturbance removes the existing stand, tree species begin to reoccupy the area with stems originating from one of three sources: (1) existing stumps and roots, (2) seeds, or (3) advance regeneration. These new individuals grow and develop, gradually utilizing more and more of their available growing space until, at some point in time, one or more of the environmental factors necessary for growth become limiting (i.e., their available growing space is completely utilized). In most situations, light is the first environmental factor to limit growth (this occurs at the time of crown closure). Following a major disturbance, species that exhibit a pattern of rapid early growth thereby gain at least a temporary competitive advantage over species that exhibit a pattern of slow early growth.

This period from the initial invasion of the site by new individuals until the site is fully occupied and environmental factors become limiting is referred to as the stand initiation stage. Duration of this stage varies widely and depends on a number of factors, but in the Southern United States, a new stand fully occupies the site generally within about 10 to 15 years following a major disturbance.

---

[1]Paper presented at a Workshop to Resolve Conflicts in the Conservation of Migratory Landbirds in Bottomland Hardwood Forests; 1993 August 9-10; Tallulah, LA.

[2]USDA Forest Service, Southern Forest Experiment Station, Southern Hardwoods Laboratory, Stoneville, MS 38776

Stem Exclusion Stage

Once new individuals in the stand fully utilize their available growing space and one or more environmental factors become limiting to growth, the next stage of stand development begins. This is referred to as the stem exclusion stage in which new stems cannot become established in the developing stand. Because crown closure has occurred, environmental conditions on the forest floor are not conducive to the establishment of new individuals.

Because the available growing space in the stand is now fully utilized, intense competition among the existing stems begins to occur. In mixed-species stands, the competitive abilities of the various species present determine how the different species respond to this intense competition. Inherent early growth rate and shade tolerance are the two primary determinants of the competitive ability of an individual species during this stage of stand development. Because the various species in the developing stand have different early growth rates and different shade tolerances, there may be large differences in the abilities of the species to respond to this competition. The end result is a vertical stratification of individual trees and species in which one, or possibly several, species eventually become dominant and suppress the growth of the other species in the stand. This process of vertical stratification may be illustrated through the following scenario.

For example, species with rapid early growth rates (pioneer species) typically dominate the stand initially. Other, more persistent species, although present in the stand, grow slowly during these early stages, and, in fact, are often overlooked as a component in the developing stand. As this period of intense competition continues and the stand develops further, the growth rates of the early dominants slow down, mortality increases, and these pioneer species begin to gradually lose their dominance in the stand. As a result, the more persistent species eventually overtake the pioneers, become dominant, and suppress the growth of the other species in the stand. At this point in the development of the stand, these pioneer species, initially dominant, are now overtopped by the eventual dominant species. If these pioneer species are intolerant of the shaded conditions they now encounter, they will die and gradually cease to be a component of the stand. On the other hand, if these initially dominant species can tolerate some shade, they may remain alive for many years, but will grow slowly as long as the overstory remains intact. Under these conditions, these species will still be present in the stand, but will constitute only a minor component of the mature stand.

The important point is that the species that will eventually dominate the mature stand generally is **not** the species that was largest or most numerous in the early stages of stand development. Other species usually dominate the stand at first, but are eventually overtaken as the stand continues to develop. In fact, in many cases, the species that eventually dominates the mature stand may be infrequent in number during the early stages of stand development and may even be overlooked as a component of the stand, until it finally begins to overtop its competitors.

Understory Reinitiation Stage

As this stratified stand develqps towards maturity, the overstory will gradually begin to break apart as scattered individuals die. The openings thus created in the overstory allow sunlight to reach the forest floor, creating favorable conditions for the development of new stems, or advance regeneration, in the understory. Thus begins the understory reinitiation stage of stand development. Understory reinitiation may begin relatively early or relatively late in the life of the stand, depending on the shade tolerance of the overstory species and the frequency of minor disturbances within the stand. Individual stems may remain alive in the understory as advance regeneration for very long periods of time, possibly as long as 30 to 35 years for some bottomland oaks. However, in most circumstances, advance regeneration of oaks and other moderately intolerant species can only be expected to live for about 5 to 10 years in a shaded understory.

Old-Growth Stage

Understory reinitiation may occur continuously within a stand over a long period of time, providing a gradual transition to the old-growth stage. This transition occurs as the mature overstory breaks up slowly through the death of individual trees. The advance regeneration in the understory immediately adjacent to the dead tree is thus released, and these younger individuals gradually grow into the canopy. If this process continues throughout the stand over a long period, the result will be the formation of an uneven-aged, multistrata, old-growth stand composed of individuals of widely differing ages and sizes. However, very few stands ever reach this last stage of development because another major disturbance generally occurs first, sending the stand back to the stand initiation stage.

Consequently, the old-growth stage is only rarely attained, especially in areas subjected to relatively frequent major disturbances, and is generally not perpetuated for long periods.

STAND DEVELOPMENT IN RED OAK-SWEETGUM STANDS

Much of the evidence supporting Oliver's (1981) description of the four general stages of even-aged stand development comes from his own research in mixed oak-maple-birch stands in central New England (Oliver 1978) and in mixed conifer stands in western Washington (Stubblefield and Oliver 1978, Wierman and Oliver 1979).

The vertical stratification process that Oliver (1978) found in oak-maple-birch stands in central New England is of particular interest. During the first 20 years of development in these stands, red maple and black birch (sweet or cherry birch) were much more numerous and grew faster than northern red oak, even though the oaks would eventually dominate the stand. Somewhere around age 17 to 20 years, the red oaks caught up to the maples and birches in total height. From then on, the oaks eventually outgrew the maples and birches and formed a dominant canopy above them. By the time the stands were 60 years old, northern red oak was clearly the dominant species, and most of the maples and birches had either died or were relegated to subordinate positions in the stand. Diameter growth of these species was greatly suppressed by overtopping oaks. These smaller understory trees could easily be mistaken to be younger, late-invading stems. However, Oliver (1978) showed that these understory trees are, in most cases, the same age as larger, overstory trees. In fact, many mixed-species stands that appear to be uneven-aged because of a wide range of tree sizes within the stand may actually be even-aged stands with this multilayered structure resulting from the vertical stratification process.

Clatterbuck and Hodges (1988) observed a similar pattern of development in cherrybark oak-sweetgum stands on minor riverbottom sites in central Mississippi. In these stands, sweetgum initially dominated the less numerous oaks. In fact, the presence of the young oaks was not readily apparent in the developing stand, such that the casual observer might have predicted that oaks would not constitute a major component of the mature stand. However, in much the same pattern that Oliver (1978) observed in oak-maple-birch stands in New England, Clatterbuck and Hodges (1988) noted that the initially shorter cherrybark oaks were able to outgrow and eventually surpass the sweetgum stems at about age 20 to 25. In fact, by the time the stand was 30 to 32 years old, the oaks were significantly taller than the sweetgum stems and were able to expand their crowns above the sweetgum stems. By age 55 to 60, these stands exhibited a two-tiered canopy in which cherrybark oak clearly dominated the upper canopy and sweetgum occupied the lower canopy.

Both of these studies describing similar patterns of development in mixed-species hardwood stands used a combination of chronosequence and stem-analysis techniques to evaluate development in those stands (Clatterbuck and Hodges 1988, Oliver 1978). The chronosequence procedure assumes that measurements performed in many stands on similar sites, but at different ages, closely approximate the results obtained through successive measurements of one stand over many years.

Fortunately, Johnson and Krinard (1,976, 1983, 1988) followed the development of two similar stands of red oak-sweetgum on bottomland sites in southeastern Arkansas since their inception in 1956-57. Through long-term monitoring of permanent plots, they found a pattern of stand development very similar to that reported by Oliver (1978) and by Clatterbuck and Hodges (1988).

For example, through the first 9 years of development on the Saline River site, sweetgum, river birch, and American hornbeam dominated the stand, both in number and size of stems. However, between the ages of 9 and 29, river birch experienced very high mortality and essentially dropped out of the stand. American hornbeam maintained relatively high density but lost its dominance and was relegated to an understory position. Sweetgum, however, experienced only a relatively slight reduction in density and maintained its dominance within the stand. Red oaks were far less numerous than these three initially dominant species, almost to the point of being inconspicuous during the early stages of stand development. However, as river birch mortality increased, American hornbeam growth rates decreased, and red oak growth rates increased. Consequently, the oaks gradually developed into a larger component of the stand. By age 29, most of the red oaks seemed to be on the verge of exceeding the sweetgum stems in total height and, thereby, beginning to dominate the stand. Johnson and Krinard (1988) predicted that red oak would eventually clearly dominate both stands.

In the study reported by Clatterbuck and Hodges (1988), cherrybark oak began to dominate sweetgum at age 20 to 25, whereas Johnson and Krinard (1988) found that red oak had not quite begun to dominate sweetgum even after the first 29 years. The reason for the difference in the timing of this critical stage in stand development may be that the cherrybark oak-sweetgum stands in Mississippi developed on oldfield sites, whereas the red oak-sweetgum stands in Arkansas developed on cut-over sites. Both woody and herbaceous competition is greater on the cut-over sites, thereby suppressing the early growth of the red oaks and slowing the progression of stand development on that site.

SILVICULTURAL IMPLICATIONS

Knowledge of the way stands develop and change over time will enable silviculturists to better understand the specific biological system with which they are dealing. With knowledge of the pattern of natural changes in stand structure, species composition, and dominance, silviculturists can more effectively manage hardwood stands.

Specifically, for even-aged red oak-sweetgum stands in the South, the silviculturist should know that red oak, even though it is few in number and relatively inconspicuous in young stands, will eventually outgrow the more numerous and initially dominant sweetgum and will form the dominant canopy of the mature stand. Concerns expressed by many foresters about the apparent lack of red oaks in young mixed hardwood stands are, in many cases, unfounded. Because of this pattern of development in red oak-sweetgum stands, land managers should be wary of prematurely concluding that their sites are not regenerating to oak. Even as few as 60 free-to-grow oaks per acre, adequately distributed, may be enough to ensure the eventual development of an oak-dominated stand (Clatterbuck and Hodges 1988).

COMMENTS AND AUDIENCE DISCUSSION

A lengthy discussion by the audience centered on the concept of old growth as presented here. In my presentation, it was stated that the old-growth stage of stand development, as defined by Oliver (1981), is only rarely attained and is generally not perpetuated for a long period, depending on the relative frequency of major disturbances. In fact, the “public” concept of an old-growth structure in a climax association of species probably does not exist. These contentions sparked a lively and thought-provoking discussion on the concept of old growth, particularly as it pertains to bottomland hardwood stands in the Mississippi Alluvial Valley.

The audience presented an alternative concept of old growth; i.e., that as an earlier seral stage is replaced by a later seral stage and a multilayered structure develops at least temporarily, this situation should be called old growth for that earlier seral stage. There was some agreement by the audience with this concept, but it was pointed out that this proposal did not satisfy the public conception of old-growth stands. Someone also stated that changes in hydrology (either natural or anthropogenic changes) and deviations from normal climate patterns may also contribute to accelerating the development of a multilayered structure, such that an affected stand could exhibit "old-growth” structure without truly being old.

After much discussion, the audience generally agreed that the public concept of old growth as a multilayered structure in a climax association may be unattainable in the Mississippi Alluvial Valley because of the young geologic age of most of the sites. In other words, the site itself prevents these stands from ever developing a climax association.

The audience then suggested abandoning the term “old growth” because the public concept of it is unattainable in the Mississippi Alluvial Valley and, therefore, the term does not apply to these bottomland hardwood ecosystems. Someone suggested that a more appropriate term would be “a multilayered structure with a diverse species composition.” This phrase embodies the characteristics of “old growth’ that are desirable for Neotropical migratory bird habitat.

This discussion did not resolve the issue of defining the concept of old growth as it pertains to bottomland hardwood forests in the Mississippi Alluvial Valley. That was not the point or even the potential benefit of the discussion. What the discussion did serve to do was to open up a lively dialogue within an audience composed of a diverse group of resource managers and researchers--foresters, ecologists, wildlife biologists, and fisheries biologists--with diverse objectives and opinions on how bottomland hardwood stands should be managed.

LITERATURE CITED

Clatterbuck, Wayne K.; Hodges, John D. 1988. Development of cherrybark oak and sweetgum in mixed, even-aged bottomland stands in central Mississippi, U.S.A. Canadian Journal of Forest Research. 18(1): 12-18.

Johnson, R.L.; Krinard, R.M. 1976. Hardwood regeneration after seed tree cutting. Res. Pap. SO-123. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 9 p.

Johnson, R.L.; Krinard, R.M. 1983. Regeneration in small and large sawtimber sweetgum-red oak stands following selection and seed tree harvest: 23-year results. Southern Journal of Applied Forestry. 7(4): 176-184.

Johnson, Robert L.; Krinard, Roger M. 1988. Growth and development of two sweetgum-red oak stands from origin through 29 years. Southern Journal of Applied Forestry. 12(2): 73-78.

Oliver, Chadwick Dearing. 1978. The development of northern red oak in mixed species stands in central New England. Bull. 91. New Haven, CT: Yale University, School of Forestry and Environmental Studies. 63 p.

Oliver, Chadwick Dearing. 1981, Forest development in North America following major disturbances. Forest Ecology and Management. 3: 153-168.

Stubblefield, George; Oliver, Chadwick D. 1978. Silvicultural implications of the reconstruction of mixed alder/conifer stands. In: Briggs, David G.; DeBell, Dean S.; Atkinson, William A., comps. Utilization and management of alder: Proceedings of a symposium; 1977 April 25-27; Ocean Shores, WA. Gen. Tech. Rep. PNW-70. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 307-320.

Wierman, C.A.; Oliver, C.D. 1979. Crown stratification by species in even-aged mixed stands of Douglas-fir/western hemlock. Canadian Journal of Forest Research. 9(1): l-9.