Stand Characteristics:

Vertical Structure and Crown Closure

By Gro Flatebo

DEFINITION

Vertical structure is the extent to which plants are layered within a stand. The degree of layering varies with forest type and is determined by the arrangement of growth forms (trees, vines, shrubs, herbs, mosses, lichens, and liverworts), by the distribution of different tree species having different heights, diameters, and crown characteristics, and by trees of the same species but of different ages and sizes. The extent to which vertical structure varies within the stand determines the degree of vertical diversity. *Crown closure* is the degree to which the overstory foliage fills the growing space. Stand density as well as growth form, leaf type, and other crown characteristics affect crown closure.

IMPORTANCE TO BIODIVERSITY

In many forest types, vertical structure provides a range of habitats used by different organisms. Forests that are well stratified will generally support a greater array of plant and animal species as compared to forests in which most of the vegetation is concentrated in one layer. Lack of vertical structure can have negative effects on species that rely on specific layers of vegetation for food and cover. Crown closure is a major determinant of the amount of light, precipitation, wind, heat, and other factors that penetrate the canopy and reach the forest floor. The resulting macro- and microclimatic conditions affect the diversity of organisms that occur.

GOAL

Maintain an adequate representation of diverse vertical structures and degrees of crown closure in forest types that are naturally characterized by a variety of foliage layers and crown closures.

BACKGROUND AND RATIONALE

The degree of development of vertical structure is a result of a stand's stage of development, stand disturbance history, age structure, site productivity, and species composition. Maine's forests usually develop several layers of foliage – an overstory, understory, shrub layer, and ground or herb layer (Figure 1).

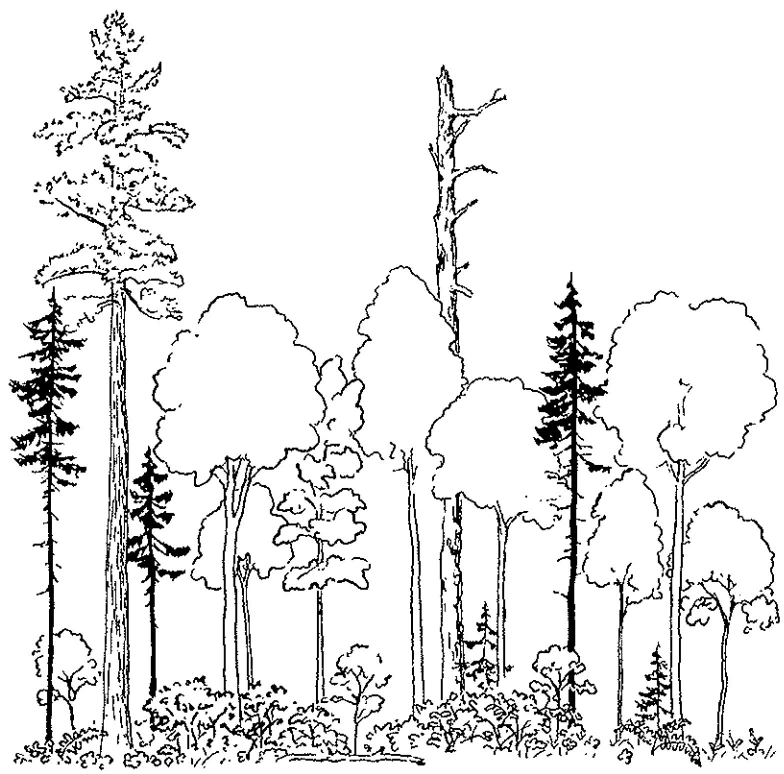


Figure 1
Vertical structure in a forest is determined by the presence or absence of foliage layers from the ground to the upper canopy. The degree of crown closure influences the development of understory, shrub, and ground vegetation layers.

Vertical Structure and Crown Closure

In an even-aged stand, a forest canopy forms about 10 to 20 years following disturbance. As the canopy closes, vegetation on the forest floor begins to thin and die out and species composition changes. During the initial stages of crown closure, the canopy is dense and little light reaches the forest floor. After several decades, as subdominant trees in the crown die, more light reaches the forest floor and plants can survive in the understory. As the base of the living canopy rises, more light reaches the forest floor and plants can invade and survive. The implications of these stages on biodiversity are outlined in Table 1.

Vertical structure is limited in early- and mid-successional stands. However, some common wildlife species thrive in these stands where a dense layer of ground vegetation provides protection from weather and predators, easily accessible food, and seasonally important food. Ungulates, such as white-tailed deer, as well as many other mammals, birds, and invertebrates use these stands (DeGraaf et al. 1992).

Later successional stages feature an older, more developed canopy that is taller and has more vertical structure. This translates into greater foliage-height diversity, more canopy gaps, greater foliar biomass, and greater leaf-surface area that provide a variety of habitats that are used extensively by birds, small mammals, epiphytes, and invertebrates. As canopy heights increase, vertical profiling and selective use of the canopy by birds increases. For example, raptors use trees above the canopy as nesting or roosting sites; hawking and sallying species favor open sites in the upper canopy where there is greater maneuverability; foliage gleaners focus their foraging on leaves recently exposed to sunlight; and trunk-gleaning species favor lower, older portions of the canopy where furrowed bark is more abundant (Sharpe 1996). The live and dead branches and generally rougher bark of large trees host a myriad of invertebrates, epiphytes (mosses, lichens, and liverworts), and microbial organisms.

Site productivity relates to vertical diversity in that it can affect the rate of succession. Better-quality sites compact seral stages into fewer years, and vertical diversity will develop sooner on better sites than on poorer sites (Crawford and Frank 1987).

Coniferous overstory inclusions of hemlock, spruce, fir, or pine can provide feeding, nesting, and winter shelter opportunities that are otherwise not available in hardwood stands. Likewise oak, beech, and other

Table 1

Features of biodiversity at four stages of stand development. (Adapted from Oliver and Larson 1996).

Stand Development Stage	Stage Age (depends on site quality)	Coarse Woody Debris (Spies 1997)	Vertical Structure	Plant Species Diversity	Animal Species Diversity
Stand Initiation Site Conditions	10 to 30 years depending on disturbance type	Variable to plentiful	Simple	High	High[1]
Stem Exclusion	20 to 80 years	Variable, plentiful if decay-resistant trees in initial stand	Simple	Low	Low
Understory Reinitiation	60 to 150 years	Little, few inputs	Becoming more complex	Medium	Medium
Shifting Mosaic or Old Growth	150 years +	Plentiful	Complex	High	High[2]

[1] Vertebrate and invertebrate species adapted to open habitats.

[2] Fewer common species than in the stand initiation phase. Typically, species use large dead trees, deep multi-layered canopies, deep forest soils, or organic matter.

hardwoods in conifer stands can provide foraging and nesting sites as well as mast. Wildlife use of overstory inclusions increases as the trees increase in size (DeGraaf et al. 1992).

A range of tree sizes will foster a greater diversity of wildlife species. For example, some bird species, such as the redstart and brown creeper, prefer small trees, while others, such as great blue heron, osprey, and owls, require larger trees.

The plant species within a stand influence vertical structure through their growth forms, crown characteristics, and leaf type (i.e., broad-leaved deciduous versus needles). These characteristics, together with stand density, determine how much light penetrates the forest canopy to reach the understory and forest floor to support other vegetation layers.

As a general rule, even-aged forests have little vertical structure and uneven-aged forests have more vertical structure (Hunter 1990). Forest stands under even-aged management cycle between the stand-initiation stage, stem-exclusion stage, and the understory-reinitiation stage. More recently, some stands are being harvested midway through the stem-exclusion stage (Seymour 1992). Even-aged forest management can simplify forest structure by fostering a younger forest with less vertical structure.

Uneven-aged stands have several age classes of trees and consequently several layers of foliage. Some of the vertical diversity in Maine's uneven-aged forests results from horizontal patchiness of vegetation. Small natural disturbances, such as windthrow, ice damage, and mortality from insects and disease, create gaps in the canopy that foster younger trees and increase the overall diversity of the stand. Three general silvicultural approaches are available to enhance vertical structure in even- and uneven-aged stands (Franklin et al. 1997):

1. **Longer rotations** – Extending the time period between harvests allows structural elements to develop naturally within the stand. These include a range of tree sizes and ages as well as vertical structure. However, if used without structural retention (see 2.), the value of longer rotations will be more limited as important structural features do not occur until late in the rotation.

2. **Structural retention** – Trees are left on site after a harvest or thinning to retain structural elements as a legacy for the new stand. In essence, retention brings multi-aged characteristics to even-aged systems. This strategy can support greater biodiversity (compared to stands of the same age without retained structure), maintain refugia for organisms and processes in harvested areas, enhance connectivity of the managed landscape, and structurally enrich the next forest stand. Retained structures include living trees of various species, sizes, and conditions as well as standing dead trees and fallen logs. Retained structures can be dispersed throughout the stand or be aggregated in clumps.

   Retained patches of forest provide a broader variety of stand structural elements than individual trees retained across the harvested area. They offer undisturbed forest-litter layers, multiple layers of vegetation, and more stable microclimatic conditions. Trees dispersed across the site can provide habitat for species that are strongly territorial or that require specific structures such as cavity trees. Their value for biodiversity increases as the stand surrounding these trees matures.

3. **Structural enhancement** – Silvicultural treatments can enhance the development of vertical structure in forests. For example, thinning accelerates understory development and succession while moving the stand into the understory reinitiation

stage (DeBell et al. 1997). Frequent and light thinnings, creating snags and openings in the canopy, can enhance vertical structure in a stand, as can choosing trees to leave during thinning to increase species diversity and variation in tree size. A shelterwood cut done over several stages will create a range of ages within the stand, especially if several overstory trees are left after the final overstory removal.

Another key aspect of vertical structure, referred to as crown closure, is the degree to which the overstory foliage fills the growing space. It affects the amount of sunlight reaching the various layers of the forest. Crown closure also affects the amount and pattern of precipitation within the canopy and reaching the forest floor, as trees intercept the moisture and redistribute it through stem flow, throughfall, or evaporation. The canopy also affects the amount of heat, moisture, and snow cover near the forest floor. Greater degrees of crown closure are generally related to deeper litter layers and a darker, cooler, moisture microenvironment on the forest floor—conditions important for some amphibians, invertebrates, small mammals, plants, and fungi. Lesser degrees of canopy closure are often essential to regenerate intolerant tree species. In hardwood forests, cuts leaving less than 70 square feet of basal area may result in changes in forest-floor microclimate with consequent effects on species composition, e.g., regeneration of intolerant species such as raspberries (Barrett et al. 1962). Under full canopy closure, animals are less subject to extremes in temperature, solar radiation, windspeed, humidity, rain throughfall, snow accumulation, and predation.

Different wildlife species are adapted to differing crown closures and structures as part of all of their habitat requirements. DeGraaf (1992) estimates that 35 species of New England wildlife use habitats with minimum canopy closure (less than 15%), as can be found in old pastures, recent clearcut stands, and some shelterwood or seed-tree cuts; 50 species use habitats with partial canopy closure (15% to 70%), as can be found in clearcuts, open shelterwoods, sugarbush stands, and low-density pine stands (partial-canopy conditions can be short-lived, with an overstory filling in after several years); and 43 species use closed-canopy habitats (70% or greater closure) such as uneven-aged hardwoods, and in even-aged stands where stocking is maintained at these levels.

Crown roughness is another feature of vertical structure. Crown canopies are relatively smooth in even-aged stands, rougher in mixed-species stands, and roughest in uneven-aged stands.

CONSIDERATIONS

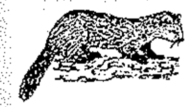
- Landowner objectives will guide whether and how much timber is left for structural retention within a stand. In even-aged systems, structural retention of trees can increase harvest and regeneration costs, decrease income for landowners and loggers, create safety issues for woods workers and affect the regeneration of intolerant species (Hanson and Hounihan 1996).
- In even-aged systems, the overall timber quality of trees retained in clumps after overstory removal may be low. Trees in the center of the clump will be slow-growing with small diameters and limbs. Trees growing on the edges of the clumps become tapered with large limbs on one side and a tendency to become wolf trees (Oliver and Larsen 1996).
- New stands are typically not at risk from diseases and pests spreading from older trees retained in the stand. The retained trees are much older and have a different set of insect pests than the younger, managed component of a stand (Franklin et al. 1997).

- Repeated thinnings, if too light, can encourage the development of a mid-story of shade-tolerant species that shade out understory plants, reducing the amount of forage available to ungulates and other animals.

RECOMMENDED PRACTICES

General

- Avoid thinning a stand in only one stratum, as it may reduce stand vertical structure and species richness, especially in even-aged, stratified stands of mixed species.
- During thinning operations, retain trees that will increase species diversity and variation in tree size in the stand. When possible, strive to keep the lower, mid, and overstory layers approximately equal in foliage volume (Crawford and Frank 1987).
- Irregular shelterwood harvests help enhance vertical structure by creating two-story stands. Three-stage shelterwood cuts create more vertical structure than two-stage shelterwood cuts (Crawford and Frank 1987). After regeneration has established, retain some shelterwood trees to produce large overstory trees and a multi-layered stand.
- Maintain softwood inclusions in hardwood stands and hardwood inclusions in softwood stands.
- Crown thinnings create an open canopy that enhances the development of herb and shrub layers and promotes the development of deeper crowns, maintaining plant-species richness and vertical diversity (Hunter 1990). Carefully choose trees for removal so as not to decrease tree-species diversity.
- Retain a variety of vertical structures over the landscape, i.e., some stands with closed canopies and a sparse understory, some with open-crowned canopies of intolerant trees with an understory of tolerant saplings, and some with foliage evenly distributed among all vegetation layers. A significant portion of the landscape should be managed for uneven-aged structure (Hunter 1990).



Even-Aged Management

- Retain some overstory trees during harvest. The number or percent of trees retained will depend on landowner objectives and the conditions of the stand, but from a biodiversity standpoint the more trees retained the better. Where possible leave several large trees (> 12″ dbh) following harvesting or thinning. Combine patches of trees with individual trees dispersed across the site to gain the ecological benefits of both. In clearcuts of greater than 10 acres, patches are preferable to dispersed trees (Woodley and Forbes 1997).
- When removing overstory trees, some deep-rooted trees, such as white pine, American beech, and red oak, can be retained as individuals dispersed across the site; shallow-rooted species, such as red spruce, may need to be left in clumps (Seymour 1992).
- Retained patches should be representative of initial stand conditions in terms of species composition and diameter distribution, and provide intact forest understories and soil organic layers. Patches can be oriented around potential snag trees.
- Leave trees that can naturally degrade into snags and standing deadwood, such as trees damaged by natural disturbances or previous harvests (i.e., broken tops, scarred boles, or lightning strikes). However, some healthy large trees that are not hollow or damaged should be retained. They ensure a healthier genetic and structural composition for the future stand as well as potential snags.