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Chapter 10

Old-Growth Forests of Southern New England, New York, and Pennsylvania

Peter Dunwiddie, David Foster,
Donald Leopold, and Robert T. Leverett

Many old-growth forests in southern New England have been overlooked by ecologists and foresters until very recently. Some visually impressive "virgin" stands have occasionally been described in the literature, but these reports are few. This lack is especially remarkable in light of the number of old-growth forests that have been identified in recent years. The failure to recognize these forests may have a number of causes, including a widespread perception that this region had been altered to such an extent that no old-growth forests remain. Pronouncements by noted ecologists such as Egler (1940) that such forests could not be found in Massachusetts no doubt contributed to the sentiment that searching for old growth was pointless. Another cause may have been a misconception that old-growth forests are aesthetically pleasing stands of large trees, with sparse undergrowth and a homogeneous, park-like structure. Much recent work in old-growth forests has greatly broadened this image to include a diversity of sites and species of considerable age but often less spectacular dimension than previously recognized.

In this chapter we focus on the old-growth hemlock and northern hardwood forests of southern New England, New York, and Pennsylvania. An increasing number of studies is documenting the extent, distribution, composition, appearance, and dynamics of these forests. This work provides the basis for our review. However, other forest types in this region are also receiving greater scrutiny of their old-growth characteristics. Work by Cogbill and others (see Chapter 9) is providing important information on some of the northern forests of spruce, fir, and hemlock. Other studies by Abrams and colleagues (Abrams and Downs 1990; Mikan, Orwig, and Abrams 1994) have drawn attention to the antiquity of some of the mixed oak forests of Pennsylvania. Old-growth examples of other forest types in this region may also be recognized as our understanding of these communities becomes more complete.

Old-Growth Hemlock-Northern Hardwood Forest Remnants

Forests of the Northeast have been severely impacted and greatly reduced in extent since European settlement began in the 17th century. Widespread land clearance for agriculture led to a severe reduction of forest cover through the 1700s and peaking in the mid-19th century, when less than 50% of the region remained forested. Intensive logging and fuelwood cutting occurred on the remaining woodlands, and by the mid-19th century the general poor state of the forest led to conservation efforts to reclaim cut-over woodlands (e.g., Emerson 1846). With the decline of northeastern agriculture the area of second-growth forest has increased tremendously, but modern population growth and suburban spread place new pressure on forested regions to provide housing and recreation, as well as wood products.

As a result of this history of intensive land use, all but a tiny fraction of the original forest area has been dramatically transformed across the Northeast. Southern New England has changed the most. In Rhode Island not a single stand of old-growth forest remains as far as is known, whereas Connecticut is believed to have only 40 to 80 hectares (Davis 1993). To the north, Massachusetts retains close to 200 ha of old growth (Dunwiddie 1993), and southern Vermont and New Hampshire contain a few hundred to a thousand hectares. New York has faired far better. The Adirondack preserve is by far the most significant old-growth area in the Northeast. Established through public acquisition in 1885, it is believed to contain upward of 81,000 ha (Ketchledge 1992) of old-growth forest, and perhaps as much as 200,000 ha (B. McMartin, personal communication). The second largest remaining area of old-growth forest is found in the Catskill mountains and includes over 24,000 ha of mostly upland spruce-fir forest that escaped logging due to inaccessibility and low economic value (M. Kudish, personal communication). Other New York sites such as the Reinstein Woods of Buffalo will likely add 1,000 hectares (Kershner 1993). Pennsylvania has several dozen tracts of old-growth forest amounting to 2,400 to 3,200 ha (Davis 1993). Two areas, Cook Forest and the Allegheny National Forest, contain nearly half of this total; other sites tend to be small (20 to 80 ha) and widely scattered.

Early Efforts to Document Old-Growth Sites

With all but a tiny fraction of old-growth forest gone, recognition of isolated stands becomes a real problem. Consequently, it is instructive to examine early studies as references for identifying other old-growth sites.

The Colebrook Study

In 1913, G. E. Nichols published his excellent study of the Colebrook tract, a 120-ha virgin forest in northwestern Connecticut. With the advent of portable sawmills in the late 19th century and improved transportation, many previously inaccessible old-growth stands were logged. The Colebrook tract was one of the last stands in southern New England and was studied by Nichols to document the old-growth forest before it was destroyed. He considered the logging of this stand a calamity, and his deep frustration with the loss of the Colebrook tract is apparent in the poignant quote included in the Introduction to this book.

Colebrook was a hemlock-northern hardwood forest dominated by hemlock *(Tsuga canadensis)* and beech *(Fagus grandifolia)* and including sugar maple *(Acer saccharum)*, yellow birch *(Betula alleghaniensis)*, northern red oak *(Quercus rubra)*, white ash *(Fraxinus americana)*, American basswood *(Tilia americana)*, black cherry *(Prunus serotina)*, black birch *(Betula lenta)*, red maple *(Acer rubrum)*, and eastern white pine *(Pinus strobus)*. Small areas of American chestnut *(Castanea dentata)* occupied upland slopes and, along with the hemlocks, were the largest trees. The chestnuts were remarkably fast-growing, measuring more than 130 centimeters in diameter at breast height (cm dbh) and no older than 150 years old. Hemlocks were much slower growing, with mature specimens averaging nearly 90 cm dbh and about 275 years old. Maxima for this species were recorded to be 150 cm dbh and 350 years old. The beech were smaller and younger than the hemlocks, reaching 85 cm dbh and 225 years. Northern red oaks and sugar maples were 250 to 300 years old and up to a meter in diameter. Scattered white pines exceeded 35 m in height.

Nichols made many useful observations about the structure and composition of the forest that provide a baseline for comparison with modern stands:

1. In low-lying areas hemlock comprised up to 75% of the stems. Understory hemlocks were suppressed, with trees 12 to 14 cm dbh aged 100 to 150 years old. Growth of these saplings rapidly accelerated if released from shady conditions.
2. All age classes were represented by most species, suggesting a stable forest composition.
3. Hobble bush *(Viburnum alnifolium)* and Canada yew *(Taxus canadensis)* were identified as indicator species of mature woods and noted as generally absent in second-growth forests.

4. Important structural indicators of old growth included scattered large logs, nurse logs, and heart rot on larger trees.
5. A diverse association of bryophytes formed a rich ground cover and extended up the tree trunks to a height of 24 m on some hardwoods, particularly sugar maple and beech, but were completely absent on hemlock.
6. Soils were undisturbed and contained a thick humus layer (5 to 30 cm thick).

In comparisons of the Colebrook tract with adjacent second growth, Nichols's primary observation was the "xerophytic proclivity of second-growth tracts." Yew, hobble bush, and striped maple *(Acer pennsylvanicum)*, common in the old growth, were sparse or absent. Pin cherry *(Prunus pensylvanica)*, black huckleberry *(Gaylussacia baccata)*, and blueberry species (*Vaccinium* spp.) were much more abundant in second growth, but mesophytic herbs like twisted stalk *(Streptopus roseus)*, painted trillium *(Trillium undulatum)*, and wood sorrel *(Oxalis acetosella)* were uncommon. Paper birch *(Betula papyrifera)*, white pine, and hickory species (*Carya* spp.) were dominant trees in second-growth forests, together with prolific stump-sprouters like red oak and chestnut. Nichols's observations and particularly his description of old-growth indicators provide one of the best early baseline studies for the hemlock-northern hardwood association of southern New England.

The Allegheny Forest Studies

For about a decade during the late 1920s and '30s, scientists at the Allegheny Forest Experiment Station of the U.S. Forest Service conducted a number of studies in the hemlock and northern hardwood forests of northwestern Pennsylvania (Lutz 1930, Morey 1936a, 1936b, Hough 1936, Hough and Forbes 1943). These authors explicitly acknowledged the incalculable value of the information gleaned by studying forests undisturbed by human activities, and tried to apply this information to silvicultural practices. Hough and Forbes, for example, made detailed comparisons between the ecology of old-growth and second-growth forests in order to understand "the profound changes which the white man has brought about." These studies addressed forest susceptibility to natural disturbance such as fire, wind and ice storms, insect infestation, and animal damage and the ways in which soils, topography, local climate, and varying intensities of natural and human disturbance interact to produce an extremely diverse array of forest types.

Hough and Forbes noted important differences between the tree species found in old-growth and second-growth areas. Cut-over areas tended to have less hemlock, beech, and sugar maple, and more black cherry, yellow birch, red maple, and black birch. Furthermore, the degree to which the original forest was logged tended to accentuate these differences. Clearcutting and repeated logging especially favored short-lived species such as pin cherry, quaking aspen *(Populus tremuloides)*, and red maple.

The Allegheny forest studies represent an important effort to understand the historical conditions that control species mixes in old-growth forests. For example, important differences were recognized between the white pine-hemlock stands in Cook Forest as opposed to the hemlock forests at East Tionesta Creek in the Allegheny National Forest. Like many stands of white pines, the former is primarily even-aged, dating to one catastrophic event, a fire in 1644. In contrast, the Tionesta forests are comprised of multiple cohorts of hemlocks that developed over many years in response to complex interactions of climate, substrate, reproduction, and minor disturbance events. In another example, Hough and Forbes noted that forests that had been subjected to multiple fires tended to lose late-successional species such as hemlock, beech, and sugar maple.

These studies in northwestern Pennsylvania confirmed the diversity of the old-growth forests of the region and focused attention on the importance of the myriad of disturbance factors. These natural forests are very dynamic and are subject to wide temporal and spatial variations in composition. While providing a comprehensive overview of the range in forest types and histories, these studies also developed baseline data for subsequent investigations of old-growth forest dynamics on the Allegheny Plateau (Whitney 1984).

The Pisgah Study

In 1922 Harvard University purchased a tract in the Pisgah Mountain area of southwestern New Hampshire in order to preserve an old-growth forest threatened by logging. R. T. Fisher, director of the forest, had been studying the Pisgah area since 1910 in an effort to understand the history and dynamics of natural vegetation and to develop an ecological system of silviculture. Specific consideration was given to comparison of old-growth and second-growth forests and to contrasting the development of forests following natural wind, fire, and insect damage with those following cutting or agricultural abandonment (Griffith et al. 1930, Fisher 1933, Cline and Spurr 1942).

Pisgah included both conifer- and hardwood-dominated forests. The most majestic stands were old-growth white pine and hemlock in which emergent white pine, up to 130 cm dbh and 50 m in height, rose above a dense canopy of somewhat smaller hemlocks, which attained ages of up to 380 years. However, the strongly ecological approach of the researchers led them to recognize that natural forests were not necessarily dominated by old trees. Even-aged stands of red oak, beech, and white birch were common on the uplands and were ascribed to natural fires in the 18th century. Open stands of hardwoods and pitch pine *(Pinus rigida)* occurred on rocky outcrops and were described as virgin, despite the lack of obvious old-growth characteristics. Moreover, even the oldest stands, dominated by hemlock, white pine, and hardwoods, were interpreted as having developed following broad-scale disturbance and were thought to have changed dramatically in composition and structure through time.

The dynamic character of the natural forests is aptly summarized by Fisher in the forward to the Cline and Spurr study:

> The primeval forests, then, did not consist of stagnant stands of immense trees stretching with little change in composition over vast areas. Large trees were common, it is true, and limited areas did support climax stands *(or pre-climax stands)*, but the majority of the stands were in a state of flux resulting from the dynamic action of wind, fire and other forces of nature. The various successional stages brought about, coupled with the effects of elevation, aspect, and other factors of site, made the virgin forest highly variable in composition, density, and form.

This understanding of the dynamic nature of forest ecosystems had a major impact on subsequent ecological studies in New England (Raup 1956, Henry and Swan 1974, Bormann and Likens 1979, Hibbs 1983, Foster 1988) as well as on the development of silvicultural approaches to managing forest ecosystems (Spurr and Cline 1942, Gould 1960). It also played a major role in the intact survival of the Pisgah tract. In 1938 most of the old-growth forest at Pisgah was uprooted by a hurricane on September 22. Much of the region was logged to reduce fire hazard in the largest salvage operation in U.S. history, but A. C. Cline, director of the Harvard Forest, argued persuasively that the Pisgah forest should be spared and allowed to remain in its natural condition. His argument was based on three notions: (1) The damage from the hurricane merely represented nature repeating its history of infrequent disturbance, (2) the value of the forest and the site lay in the absence of human impact, not the age or size of the trees, and, consequently, (3) the site now represented an invaluable opportunity to follow the natural dynamics of forests. Salvage did not take place in the Pisgah forest, and it currently forms the heart of the largest state park in New Hampshire. Meanwhile, studies of the ongoing dynamics of the stand indicate that the current vegetation is markedly different from any previously documented on the site (Foster 1988).

Current Efforts to Document Northeastern Old Growth

The renewed interest in identifying and studying old-growth forests, coupled with the difficulty of differentiating old second growth from true old growth, has generated numerous definitions for old growth based on structural, compositional, historical, and edaphic criteria. It is increasingly apparent that a careful stating of assumptions about old growth is critically important to permit cross comparisons and to ensure that conclusions are scientifically defensible. It is equally important that general assumptions and specific criteria be continually scrutinized and revisited.

As one example, Hunter (1989) poses general age and disturbance criteria in the form of a series of questions that can be used to craft definitions appropriate to specific forest types:

Age Criteria

1. Has the forest reached the age at which species composition is relatively stable, and few successional species such as paper birch and white pine are present?
2. Has the forest reached the age at which the average net annual growth is near or at zero?
3. Is the forest significantly older than the average interval between large-scale natural disturbances?
4. Have the dominant trees reached their average life expectancy?
5. Is the forest's current annual growth rate below the lifetime average annual growth rate?

Disturbance Criteria

1. Has the forest ever been intensively cut?
2. Has the forest ever been converted to a different land use?

Hunter would first apply the age and disturbance criteria and then fine-tune to forest type considering forest structure, development, and disturbance history. In this way he leaves room for selective application of the criteria. For example, a fire-successional white pine stand could be included by relaxing age criteria No. 1, particularly in regions where fire is a part of the long-term history.

Though Hunter's criteria can provide helpful guidelines in identifying old-growth forests in different areas, there is still considerable room for disagreement on precise definitions and how they should be applied in specific sites. Depending on the information available, the purposes of the investigator, and the scales at which the forests are studied, widely different delineations of old growth can be defended. As the following review illustrates, current studies of old-growth forests in the Northeast have addressed these issues in different ways.

Old-Growth Forests of the Adirondack Park

Leopold et al. (1988) investigated 10 old-growth stands in New York's Adirondack Park to map locations and to sample vegetation. The study relied on criteria for identifying old-growth forests in Maine (Maine Critical Areas Program 1983): (1) a minimum homogeneous area capable of continuously supporting a forest stand, (2) a minimum percentage of individuals of the maximum age of the dominant tree species, (3) lack of human influence, and (4) evidence of regeneration. These criteria were used to establish the following stand characteristics for the study: heterogeneous structure that includes a mosaic of canopy gaps of varying sizes with corresponding woody debris (logs and snags) and tree regeneration; an intact, undisturbed ground layer with no evidence of logging, clearing, planting, exotic species, or other human influence; minimum acceptable size of eight hectares; and minimum stand age of approximately half the average maximum life span of the dominant tree species. These criteria did not completely exclude human influences, i.e., the study definition of old growth did not require "virgin conditions." The study looked at forest structure and composition, disturbance regimes, disturbance agents, and protection status in 4 of the 14 forest types (Reschke 1990) recognized in the Adirondack Forest Preserve: hemlock-northern hardwoods, beech-maple mesic, spruce-northern hardwood, and mountain spruce-fir forest. Data collected included stem density and basal area by size class and species. The project also summarized age, diameter, and height data from studies at widely varying locations in the Northeast.

Like the old-growth forests of the Allegheny Plateau, Pisgah, and Colebrook tracts, those in the Adirondacks are highly variable in composition and characteristics across and within the forest types. For example, basal areas of live and dead standing stems differed markedly between forests. The largest total basal area, 53 m^2ha^{-1} (20% of which is dead), occurred in the hemlock-northern hardwood forest type, compared to 38 m^2ha^{-1} (2% dead) in the beech-maple mesic forest, 35 m^2ha^{-1} (21% dead) in the spruce-northern hardwood forest, and 47 m^2ha^{-1} (35% dead) in the mountain spruce-fir forest. The last forest is noteworthy in that there were more dead standing red spruce than live ones (110 vs. 78 stems ha^{-1}).

In old-growth Adirondack forests, canopy hardwoods are 200 to 300 years old and up to 100 cm dbh; conifers may be somewhat older (200–400 years) and taller (20–50 m). These values led the authors to conclude that a minimum stand age of 200 years can be used as one criterion for defining old-growth forest stands in this area. In reviewing historical data, however, they also concluded that red spruce had been the dominant canopy species in all forest types in much of the western Adirondacks before logging.

Leopold et al. noted that disturbances in northeastern forests range from mortality of one to a few canopy trees to catastrophic disturbance that destroys much or all of the overstory and can alter soil and other community characteristics. A particular forest type or region may experience a continuum of disturbances, and through time this imposes a mosaic of overlapping patches on the landscape. The structure, composition, and distribution of the species comprising these patches reflect the complex interactions of disturbance regimes of different scales with the ecological tolerances of each species. Some species in old-growth forests may be largely self-replacing, such as hemlock and basswood; yellow birch requires a canopy gap to become established, whereas white pine may replace itself only after a catastrophic disturbance.

Three forest disturbances—fire, herbivory, and beech bark disease—have only recently shaped old-growth forests in the Adirondacks. In the late 1800s and early 1900s fires were prevalent only during the period of heavy logging and transportation of logs by locomotives. Heavy browsing by white-tailed deer in the past few decades has likely affected these forests much as deer have in Pennsylvania, especially where hemlock was once abundant in the regeneration layer (Whitney 1984). Such high levels of deer browsing on hemlock and other preferred species could greatly shift the canopy dominance to American beech. However, this species is being devastated throughout the Northeast by beech bark disease. The effects of the disease are most striking where large beech trees recently occupied significant portions of some old-growth forests—e.g., at Ampersand Mountain. Forests in the Adirondacks will need a few hundred more years to hide the scars of fires that occurred earlier this century. The long-term effects of heavy deer browsing and beech bark disease on old-growth forest structure and composition may prevent these forests from ever resembling presettlement conditions.

Two other Adirondack studies deserve mention. In the 1970s, Roman (1980) studied the extensive old-growth forests in the Five Ponds Wilderness. Roman's study is significant because it is based on 71 vegetation plots (generally 0.1 ha) that were located throughout the area, and does not focus necessarily on where the largest trees were. Soils and topographic data also were collected from each plot. Roman's data, although not widely available, are the best quantitative depiction of old-growth forest structure and composition in relation to environmental factors and natural disturbance in the Northeast.

Woods and Cogbill (1994) analyzed old-growth forest vegetation in plots used by Leopold et al. (1988), plus additional plots in eight stands not previously sampled. Total live basal areas (stems >5 cm dbh) ranged from 24 to 63 m^2ha^{-1}, the higher values occurring in hemlock-dominated stands. Canopy densities were from 420 to 1,880 stems ha^{-1}. Nearly all stands had individuals >200 years old, based on ring counts from cored trees.

Old-Growth Forests in Massachusetts

Dunwiddie (1993) examined possible old-growth forests in Massachusetts that had been identified by R. Leverett. Thirteen sites totalling approximately 142 ha were found in the Berkshires that met the criteria Dunwiddie used to define old growth: (1) a minimum stand size of four to five hectares, (2) dominant trees of an age >50% of the maximum for the species, (3) minimum evidence of human influence or other catastrophic disturbance, and (4) evidence of tree regeneration, especially of late-successional species. Other commonly cited old-growth characteristics that were considered included single and multiple tree-fall gaps, pit and mound microtopography, undisturbed soils, standing snags and fallen logs in various states of decay, and uneven tree age structure. Dunwiddie collected data from 26 0.1-ha study plots in the 13 old-growth Berkshire sites, including species composition, structure, basal area, density, ages, and heights of selected trees, as well as on dead snags, fallen wood, and understory composition.

The Massachusetts old-growth sites were dominated by hemlocks, northern hardwoods, or a mixture of the two types, and occurred primarily on steep slopes in relatively inaccessible locations where they escaped the extensive logging that cleared most of the forests. Total live basal areas (stems >10 cm dbh) ranged from 24 to 52 m^2ha^{-1}. As in the Adirondacks, highest values occurred in hemlock-dominated stands, where hemlock accounted for 75% of the basal area and 71% of the stems. Basal areas of old-growth forests in Massachusetts were similar to values from the Adirondacks and New Hampshire, and about 23% higher than values from second-growth forests growing in nearby sites. The basal area of standing dead snags in Massachusetts old growth averaged 9% of the total (live and dead) in all forest types; the proportion was highest (27%) in northern hardwood and hemlock-northern hardwood forests. Stem density of canopy trees ranged from 190 to 670 stems ha^{-1}, with highest densities in hemlock forests. These values, as well as the density of large trees, were lower in the Massachusetts old-growth forests than in similar Adirondack forests. Hemlocks were the oldest trees; some ring counts were >300 years, and ages may exceed 400 years in some individuals with rotten centers. Sugar maples in the 200- to 250-year age range were encountered in several plots.

In addition to the 142 ha described by Dunwiddie, Leverett has found an additional 40 ha with similar characteristics at 13 other sites in Massachusetts. Isolated small pockets (<4–5 ha) of old-growth forest in central and eastern Massachusetts may add another 6 to 10 ha to the total. Application of less stringent definitions of old growth could increase these estimates by 800 to 1,200 ha. For example, large acreages that appear to have received little human disturbance, but which contain few old trees, often exist contiguous to those sites identified by Dunwiddie. He speculated that trees >200 years old (especially hardwoods) appear to have a high probability of falling on the steep sites in the Berkshires, resulting in the sparse density of old stems in many areas.

Old-Growth Forests in the Allegheny Plateau

Important recent studies have been carried out in old-growth forests of northwestern Pennsylvania. Runkle (1981, 1982) studied gap formation and regeneration of old growth in the Eastern U.S., including 75 gaps in Tionesta Scenic

Area. Here, about 0.5% of the land surface is converted to new tree-fall gaps each year, which is low relative to other old-growth forests in the East (Runkle 1985). However, Runkle (1985) points out how forests in this region are affected more by large-scale disturbances.

One such disturbance happened in May 1985 when a powerful tornado hit the Tionesta area and flattened about 400 ha of old-growth forest, including toppling 99% of the canopy trees (Peterson and Pickett 1991). Peterson and colleagues (e.g., Peterson and Pickett 1990, 1991; Peterson and Campbell 1993) have investigated the immediate effects of this catastrophic disturbance on the vegetation at Tionesta and subsequent response of the vegetation to the microtopography created by the uprooted trees.

Whitney's (1984) study of the trees in the old-growth forest at Heart's Content is valuable because it examines vegetation changes based on plots established in 1929 by Lutz (1930) and remeasured in 1978. Whitney's data clearly show that heavy deer browsing (since probably the 1930s) has had a profound influence on the size-class distribution of stems in this stand. For example, with the exception of beech, the smaller size classes of trees once common in the understory (e.g., hemlock and birch) had been eliminated by 1978. Bjorkbom and Larson (1977) showed similar dramatically adverse effects by deer on the vegetation at Tionesta.

Whitney (1990) also examined the vertical and horizontal patterning of the old-growth forest at Heart's Content. His results show a large-scale patterning related to soil drainage, which segregates beech-hemlock-white pine-dominated areas from hemlock and yellow birch areas, and a smaller-scale patterning that separates small areas of hemlock from yellow birch.

Old-Growth Forests of Southern New Hampshire

Several authors have characterized the composition of old-growth northern hardwood forests in this region. Leak (1973, 1987) has provided valuable information on basal areas and species composition at several sites. Carbonneau's (1986) survey of 12 old-growth sites provides some of the most detailed information published for this region. Based on samples from 400-m^2 plots, she concluded from size-class data that many of the stands were most likely all-aged. She also emphasized the importance of small-scale disturbances in structuring these forests.

Implications of Old-Growth Studies

The results and conclusions of the studies cited above leave little doubt that old-growth forest ecosystems of the Northeast include a great diversity in species composition, age structure, and disturbance history. Climate, soil composition, fauna, and small- and large-scale disturbance factors interact in determining forest composition and often preclude the establishment of a steady state mixture of late-successional species. Recent studies focusing on forest succession, stand dynamics, gap dynamics, disturbance regimes, and nutrient recycling are an outgrowth of attempts to unravel the myriad of processes and their interactions that shape the forest. Terms like "shifting mosaics" and "overlapping disturbance patterns" help to illuminate the dynamic nature of old-growth forests and to remind us that natural processes are at work at all levels. The result is an overlay of broad patterns and a plethora of exceptions to every rule.

Despite the large variety of conditions that shape individual stands, some attributes of old-growth forests are sufficiently widespread to allow for generalization. Within the hemlock-northern hardwood forest type, many canopy trees may reach ages of 200 or more years. Mature hemlocks are often 225 to 350 years old and approach 400 to 500 years in some stands. Sugar maple, beech, and yellow birch can all be expected in age ranges of 175 to 250 years. However, isolated stands may possess an abundance of hardwoods in the 250- to 350-year range, and occasionally trees in the 400-year age range can be found. Sizes of all species vary greatly with growing conditions. On the least favorable sites, diameters of the mature trees will range from 30 to 60 cm, and occasionally up to 120 cm on the favorable sites. Heights of dominant canopy trees vary from 15 to 25 m on poor sites and up to 40 m on good sites (occasionally 50 m for white pine).

From early descriptions of northeastern forests, one might conclude that none of the remnants surviving today match the splendor of the original growth. However, old-growth forests in several locations have remarkable specimens that match or exceed the size recorded in early studies. Hemlock diameters can exceed 120 cm, and heights of 43 m have been measured in several areas. Red spruce >70 cm dbh can be found in the Berkshires and the Adirondacks. Hardwoods are typically shorter, but some, such as yellow birch and white ash, occasionally reach 120–130 cm dbh. Perhaps the most impressive tree in the Northeast in terms of size is the white pine. A valuable timber tree, old-growth white pines are now mostly scattered and mere shadows of their former glory. Nonetheless, isolated stands of large trees can still be found, as in Cook Forest. Individuals occasionally exceed 50 m tall, and there are historical records of trees reaching 60 m. Diameters have been reported to approach 150 cm. Many of the large white pines that remain occur in relatively inaccessible river gorges and on steep sides of ridges. In some cases, old second-growth field pines have been mistaken for old-growth forests. Such was the case of a fine stand in western Connecticut known as the Cathedral Pines. Most pines in this stand blew down during a severe storm in 1989 (Patterson and Foster 1990).

Current Efforts to Locate Old Growth in the Northeast

Old-growth forest in the Northeast is currently being documented by scientists as well as by amateur and professional naturalists. The state Natural Heritage Programs have been a key repository of data, as well as an important source of funding for these surveys. The Forest Service tracks old-growth remnants in the White Mountain and Green Mountain National Forests of Vermont and New Hampshire. The Appalachian Trail Conference has identified about a dozen previously undocumented sites along the trail corridor in Vermont. The Massachusetts Audubon Society has helped map and describe some of the residual pockets of old growth in Massachusetts.

The most vigorous and persistent effort has been an ongoing project by *Wild Earth* that led to a publication summarizing known old-growth forests in the East (Davis 1993). Today *Wild Earth* continues to provide leadership and a focal point for articles and discussions about the role of eastern old growth, in cooperation with other conservation organizations.

One novel effort in northwestern Massachusetts employs the multi-spectral and textural signatures of remotely sensed digital imagery. Bertolette (1993) correlated the spectral signatures of known areas of old growth and has been applying this model to surrounding areas known to include old growth. The technique may be useful primarily in pinpointing likely sites for subsequent ground-truthing.

Surprising discoveries continue to be made as forests in forgotten corners are scrutinized by experienced eyes. A total of 30 old-growth stands have been recently documented in western New York (B. Kershner, personal communication), and 26 additional, albeit small, old-growth remnants have been identified in western Massachusetts (P. Dunwiddie and R. Leverett, unpubl.). The Adirondacks and Catskills hold the greatest promise for new sites. This stems from the early preservation of those regions and speaks to the necessity of long-term preservation.

The Future of Old-Growth Research and Protection

Interest in old-growth forests in the Northeast has appropriately focused on the identification and protection of the surviving fragments. A large number of old-growth stands have been identified over the last decade, and many groups are working to prevent these remnants from being logged or otherwise compromised by human activity. Though this inventory process will continue, it is likely that priorities will begin to shift as fewer large tracts remain to be discovered. Efforts to protect these old-growth sites must proceed aggressively, however, since they provide an irreproducible baseline for comparisons with disturbed forests. Without these stands as a point of reference, it is impossible to identify characteristic species, processes, or other attributes that may be unique to old-growth forests, and to assess the degree to which other sites have been altered.

It is abundantly evident from the fate of such old-growth forests as Tionesta and Pisgah, however, that the old-growth condition is not permanent. It may persist for hundreds of years, and possibly over a thousand for some stands, but eventually disturbances set back the clock of succession to a point that precludes the forest from being considered old, at least in the sense of the trees. Thus protection efforts must also focus on sites that may most readily assume many of the attributes of old-growth forests in the future. This recognition of the dynamic nature of these stands points toward several key areas on which future research in the Northeast should be focused.

Biodiversity

Preserving the diversity of organisms, habitats, and ecosystems in the Northeast in the future will require a thorough knowledge of these attributes in old-growth forests. A top priority, therefore, is to understand better the structural and compositional characteristics of old growth in this region. Most studies have focused on trees and neglected other forest strata. Surprisingly little work has been done on herbaceous species in the understory (Whitney and Foster 1988). It would be especially informative to focus as well on often-overlooked groups of organisms likely to occur in niches that may be unique or most prevalent in old-growth forests. For example, investigations of bryophytes, lichens, canopy and soil invertebrates, and fungi all may be particularly fruitful. Recent work by Cooper-Ellis (1994) in the Berkshires suggests a suite of bryophytes that may occur more frequently in old growth. Other studies are needed to determine whether old-growth forests in the Northeast have other structural or functional attributes that may distinguish them from second-growth forests, such as canopy structure, quantities and arrangements of dead wood, soil composition and structure, and nutrient cycling. Since many of these attributes are poorly known for second-growth forests as well, comparative studies among forests of different ages and types are important.

Ecological Roles

Future work is needed to identify and clarify the ecological roles of old-growth-forest attributes. It is not known, for example, whether features such as super-dominant white pines emerging from a hemlock canopy, unique bryophyte assemblages, or large accumulations of dead wood (should such attributes be identified) are components that are essential or important to the functioning of old-growth ecosystems.

Forest Dynamics and Disturbance Regimes

Much remains to be learned regarding the dynamics of old-growth forests. The ecological roles of disturbances of various scales, from individual tree-falls to widespread canopy blowdowns, in maintaining the biodiversity of these forests is poorly understood. Similarly, little is known about how old growth fits into the shifting mosaic of forests in pre- and post-settlement times—the distribution of forests of different compositions and ages across the landscape and through time in response to natural disturbances and changing human land use.

Threats

Current and future threats to old growth need to be identified. A host of diseases and insects, many of which have only recently appeared on the scene, are likely to significantly alter forests in the future. For example, the arrival of the hemlock wooly adelgid may dramatically restructure many hemlock-dominated old-growth stands in the Northeast (McClure 1991, 1992). Studies must be established to focus on the short- and long-term impacts of this and other threats to many components of old-growth forest ecosystems.

Forest Management

As forests in New England continue to regrow following 18th- and 19th-century clearance, many areas are increasingly assuming attributes of old-growth forests. It is important to understand what aspects of old growth will continue to be absent from these areas, as well as what aspects are readily restored. Studies are particularly needed to understand how various silvicultural practices in second-growth forests may be modified to sustain old-growth characteristics. Emphasis also must be given to determining how to best manage old-growth forests on the landscape. Priority areas include delineating adequate buffer zones, identifying compatible and incompatible uses, configuring protected areas that allow for natural disturbances of all scales, and designing forest preserves with appropriate corridors and zones to accommodate different uses while protecting old-growth attributes.

What is most critical is that we understand natural forest ecosystems, especially as they are embodied in stands of old growth, and how they differ from forests that have been significantly altered by human activity. To do that, we must preserve our irreplaceable old-growth remnants.

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