Health of Oak Forests in the Southern Appalachian Mountains

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Southern Appalachian forests cover about seventy per cent of the land area in the region and are renowned for their complexity of composition. The single most common type is oak forest which comprises over half of the forested area (SAMAB 1996). They do not stand alone, but are imbedded in a complex and varied landscape. Oak forests of the Southern Appalachian Mountains are host to myriad pathogens and insect pests whose effects at the individual tree scale range from benign to lethal. While the health of oak forests is certainly affected by these biotic agents, their mere presence does not define forest health.

Forest ecosystem health is a term coined relatively recently which has rapidly evolved from a utilitarian emphasis on the capability of landscape to fulfill society's management objectives to an acknowledgement of the importance of ecosystem function. Kolb and others (1994) propose that healthy forest ecosystems have the following attributes:

- the physical environment and biotic resources to support productive forest cover;
- resistance to and/or the ability to recover from catastrophic change;
- equilibrium between supply and demand of essential resources (i.e. water, nutrients, light, growing space); and
- diverse seral stages and stand structures that provide habitat for native species and essential ecosystem processes.

They further state that forest ecosystem health is assessed at a landscape scale (rather than tree or stand scales) and cannot be evaluated in a social vacuum. The diversity of objectives that people hold for Southern Appalachian forests make this evaluation the subject of considerable debate. This

Table 1.

Comparison of Southern Appalachian forest composition, structure, disturbance characteristics, and values perspective

Pre-1900	Current
Composition: American Chestnut	Composition: Oak
Relatively Complex Age Structure	Cohorts 80-100 Years Old
Sparse Understory	Dense Understory
Widely Spaced, Large Diameter Overstory	Dense, Small Diameter Overstory
High Disturbance (Farming, Logging, Fire)	Low Disturbance (Fire Suppression)
Small, Dispersed Human Population	Large, Urbanized Human Population
Forest Utilization Perspective	Ecosystem Protection Perspective

paper aims to evaluate the health of oak forest ecosystems in this region from this perspective.

Historical Context

Southern Appalachian forest landscapes evoke images of the primeval forest in many people today. Indeed, most vegetation components in these forests have been present in varying mixtures and distributions for at least 58 million years (Delcourt and Delcourt 1981). However, the only thing constant about these landscapes has been change. Advancing and retreating ice sheets, drought, flood, wind, and fire all served to shape forest composition and structure in the absence of people.

People have been important change agents since arriving in the region some 9,000 years ago (Hudson and Tesser 1993), but the human frame of reference for forest ecosystem change extends back for perhaps a few centuries, at most. In this context, the types and sequence of human-influenced disturbances since the middle of the 19th century have resulted in Southern Appalachian forests that bear little resemblance in terms of composition and structure to any that has existed during the previous period of human habitation. These human-influenced disturbances include the widespread use of fire, first by native people and then by European settlers; land clearing and agriculture followed by abandonment of marginally productive lands; widespread and sometimes abusive logging to supply fuel and building materials to a growing nation; industrialization and concurrent urbanization; and the institution of aggressive fire suppression.

Perhaps the most profound ecological disturbance of all occurred with the introduction to North America and spread of *Cryphonectria parasitica* (Murrill) Barr, the fungus pathogen that causes chestnut blight. While it causes only minor direct effects on a few oak species, it has caused unequaled impacts on oak forests that are still manifest today. American chestnut (*Castanea dentata* (Marsh.) Borkh.) was the most important hardwood tree in Southern Appalachian forests. Estimates of composition at large landscape scales ranged from 25 to 50 percent (Ashe 1911, Buttrick 1925). Originat-

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ing in Asia, the chestnut blight pathogen was first detected in the Bronx, New York in 1904. The pathogen spread rapidly, since native chestnuts lacked co-evolved disease resistance. By 1940, chestnut blight had killed 50-99 percent of the American chestnuts throughout its botanical range. The tree persists today as sprout growth from residual root systems but usually attains diameters of only a few centimeters and rarely flowers before succumbing again. As chestnuts died, newly available growing space was quickly occupied by other species already positioned in the mid- and understory by earlier disturbances such as repeated fire and logging. Chestnut replacement was variable, but typically oak species (*Quercus Montana* Willd., *Q. rubra* L. and *Q. velutina* Lam., in particular) increased (Korstian and Stickel 1927). These changes occurred over a very short time span on millions of acres in the Southern Appalachian Mountains. State-federal cooperative fire control programs, public land acquisition to form national forests and parks, and lower rates of harvest compared to previous levels resulted in oak forests which have aged relatively free of disturbance for 70 to 90 years. These forests are contrasted with those found around the time of European settlement (table 1). Current characteristics make them vulnerable to a stress-mediated disease known as oak decline, which is affecting landscapes throughout the Southern Appalachians. The disease is both an indicator of, and a contributor to, compromised ecosystem health.

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The Southern Appalachian Field Trip approaching a high-elevation Quercus rubra *forest during the Third International Oak Conference.*

Oak Decline Biology, Incidence, and Effects

Oak decline is a disease of complex etiology affecting physiologically mature trees. It involves interactions between long-term predisposing stress, such as that caused by climate or site productivity; short term inciting stress such as that caused by drought or spring insect defoliation; and contributing organisms of secondary action such as armillaria root disease (caused by *Armillaria mellea* (Vahl. Ex Fr.) and perhaps other *Armillaria* spp.) and the two-lined chestnut borer *(Agrilus bilineatus* Weber). The temporal sequence of these three groups of factors is important in the ultimate expression of oak decline.

Predisposing factors such as climate and site productivity determine the onset of physiologic maturity. This is the point in tree's life history where critical levels of physiologic processes such as water transport efficiency, translocation efficiency, and the balance between photosynthesis and respiration are reached (Hyink and Zedaker 1987). Inciting stress factors such as extended drought or spring defoliation by insects or late spring frost alter carbohydrate chemistry in physiologically mature trees. This change in carbohydrate chemistry stimulates *A. mellea*, a ubiquitous saprophyte in oak forests, to become an aggressive pathogen, which further compromises water relations (Wargo 1974). Twigs and branches in the upper crown die back progressively over a period of years in an effort to accommodate an impaired root system. The two-lined chestnut borer is attracted to stressed oaks and, together with root disease, kills them (Wargo 1977). Most killed trees exhibit dieback evidence that can be dated back 2-5 years. Analysis of radial growth increment has revealed differences between healthy and decline oaks of the same species and age class that date decades earlier (Tainter and others 1990).

The pattern of oak decline on the landscape varies with initial stand species composition, stand age structure, decline severity, mortality incidence, and the duration of decline before inciting stress is eased. Patches of mortality can range from a few trees in stands with diverse species composition and age structure, to several hundred hectares on landscapes with a more uniform composition of physiologically mature red oaks defoliated repeatedly by the non-native gypsy moth (*Lymantria dispar* L.).

Widespread incidence during the mid 1980's in the southeastern U.S. reflects the coincidence of physiologic maturity of oak cohorts on a regional scale that developed after chestnut blight and fire control and extended regional drought. Inventories have estimated oak forest types cover about 7.1 million hectares (17.4 million acres) in the Southern Appalachian Mountains

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Table 2

Area and incidence of oak decline in the Southern Appalachian Assessment Area by ownership class - (SAMAB 1996)

	Host Type	Vulnerable		Affected		
Owner	Hectares	Hectares	% Host	Hectares	% Vulnerable	% Host
National Forest	1,293,926	904,035	70	223,447	25	17
Other Public	169,722	101,166	60	23,655	23	14
Private	5,597,415	2,836,592	51	447,232	16	8
Total	7,061,064	3,841,793	54	694,364	18	10

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in parts of six states. About 54 percent of this area was classified as vulnerable to oak decline damage with oak decline incidence estimated on 0.7 million hectares (1.7 million acres) (SAMAB 1996). National forests had a disproportionate oak decline incidence compared with other ownerships (table 2).

Habitat impacts of oak decline were interpreted by Oak and others (1988) to include both detrimental and beneficial changes, depending on the wildlife species of interest. Structural changes included creation of small to large canopy openings, reduced canopy density, short-term stimulation of understory species, potential increases in cover type diversity, and increased denning and cavity nesting sites. Long-term shifts in tree species composition can occur where competitive oak reproduction is absent or in short supply. The new forest now taking shape has fewer oaks, lower oak diversity, and more shade-tolerant species that are less valued by wildlife. Mast production potential was estimated to be 41% lower than if decline were absent and was projected to be 58% lower within 5 years. These projected reductions will persist for a long time because residual oaks are themselves prone to future decline episodes and competitive oak reproduction for replacement of dead overstory oaks is lacking. This has consequences for wildlife species that depend on acorns for food, especially in view of the fact that chestnuts, once a mainstay, are no longer available.

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John Palmer and Guy Sternberg study a stunted, high-elevation Quercus rubra *(red oak) forest during the Southern Appalachian Field Trip.*

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Oak Society members prepare to examine a typical Southern Appalachian oak forest during the Southern Appalachian Field Trip.

Southern Appalachian Forest Health Assessment

The four criteria set forth by Kolb and others (1994) for health forest ecosystems will serve as the standards against which relative health of Southern Appalachian oak forests will be judged.

1. Physical and biotic resources to support forest cover: Physical resources include soil, water, and air quality. There has been extensive coverage in the popular press concerning air quality issues in the Southern Appalachians and much speculation about the reduction of productive capacity of soil from the deposition of acidifying compounds in some media. Poor visibility days in summer due to surface ozone, other aerosols, and particulates are frequent and may be increasing. However, no evidence exists that soil productivity is being altered. Ozone is a regional pollutant of concern, causing foliar symptoms on sensitive trees (e.g. yellow poplar, eastern white pine, white ash, black cherry) in some localities, but oaks are relatively tolerant of ozone. Though soils are somewhat degraded in some places due to abusive early logging and on abandoned and afforested agricultural lands, the productive capacity to support forest cover remains.

While physical resources are mostly intact, biotic resources are incomplete. The historic and present status of oak in Southern Appalachian landscapes must be considered. Oaks were an important but subordinate component of historic forests. The elimination of American chestnut as a canopy species has elevated oaks to an unprecedented position as the most dominant species group. In this context, some biotic resources are lacking. There is hope for the future recovery of American chestnut through resistance breeding. However, many substantial hurdles remain, not the least of which will be social acceptance of the type, severity, and frequency of disturbance necessary to reintroduce the tree as an ecosystem component functioning in a manner similar to historic forests. Southern Appalachian forests are relatively unhealthy under this criterion.

2. Resistance to catastrophic change and/or ability to recover after catastrophe: The term catastrophic implies a sudden, extreme change. In their assessment of southwestern U.S. ponderosa pine forests, Kolb and others (1994) use the threat of pine bark beetles and subsequent stand replacing wildfire, both appropriately described as catastrophic change agents, to il-

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lustrate unhealthy conditions under this criterion.

Sudden and extreme may not be appropriate adjectives to describe the ecosystem changes taking place today in Southern Appalachian oak forests, but there is no doubt that oaks are decreasing in abundance and diversity in oak decline-affected areas and that this disease is having landscape-scale effects. The prevailing low disturbance regime is not permitting the replacement of dying oaks in many areas. Instead, oaks are being replaced by shade-tolerant mid-story species such as red maple, black gum, and sourwood. With over half of upland oak forests vulnerable in this area, it is also apparent that oak decline represents a significant continuing forest health issue. Whether one considers the reference condition to be the historic chestnut-oak-hickory forest, or the present mixed oak-hickory forest, the combination of chestnut blight, widespread oak decline, and incomplete oak replacement have resulted in new tree species mixtures that are less desirable to many wildlife species. Like the ponderosa pine illustration, changes in forest composition and structure are occurring over large landscapes that will be technically difficult, expensive, and socially unattractive to reverse. It is difficult to argue that Southern Appalachian oak forests are healthy under this criterion.

3. Functional equilibrium between supply and demand of essential resources: The pattern of oak decline occurrence on Southern Appalachian landscapes is normally ranges from small groups of trees to areas a few hectares in size. Under these conditions, the functional equilibrium between supply and demand of water, nutrients, light, and growing space is maintained. There are cases where outbreaks of defoliators such as the gypsy moth are a significant inciting factor in severe oak decline over large landscapes. The lack of co-evolved parasites and predators in North America makes for outbreaks that are prolonged and severe when compared with native defoliators. Thousands of hectares of severe oak decline mortality occurred during gypsy moth outbreaks the mid-1980's in northern Virginia national forests (Starkey and others 1995) that may have disturbed water relations, nutrient cycling, and light and growing space for desirable tree reproduction. However, Southern Appalachian forests overall are probably healthy under this criterion.

4. Diversity of seral stages and stand structures: Oak decline has always been part of the landscape, but it is unlikely that such a large proportion has ever been vulnerable simultaneously. The high proportion of forest area affected by or vulnerable to oak decline illustrates the relative homogeneity of Southern Appalachian oak forests and points to a lack of young, regenerating oak stands and oak stands with more complex age structures. While younger aged stands exist, oaks are not as heavily represented. The current trend in silviculture of upland oak forests is towards stands with more complex age structure, but maintaining an oak component requires direct attention and action. Southern Appalachian oak forests are probably unhealthy under this criterion.

Summary

Southern Appalachian oak forests ecosystems are judged relatively unhealthy by three of four criteria set forth by Kolb and others (1994). This is due primarily to fundamental changes in forest composition and structure since the introduction of chestnut blight and the

unprecedented place oaks have assumed in these disturbed forest landscapes. Cohorts of oak that replaced chestnut over large areas in the region are now reaching physiologic maturity and are subject to the stress-mediated disease known as oak decline. Forest cover will continue to persist, but as oaks decline and die, mostly non-oak species will exploit the newly available space resulting in a new forest with a smaller and less diverse oak component. Among the forces guiding the development of this new forest are fire suppression and social values that resist intentional forest disturbances providing for conditions suitable for oak self-replacement. Oaks will continue to be represented in the new forest, which will be less susceptible to oak decline, but some social values met by oak forests (e.g. some wildlife habitat components, economic value of timber) will be compromised.

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