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Environmental Threats to the Health of Montane Forests of Northwestern Virginia

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ABSTRACT

Recent studies of forest decline have raised the question of how environmental stressors interact to affect the health of forest ecosystems. I provide an overview of the major environmental stressors on the health of montane forests in northwestern Virginia, and suggest that additional information on factors affecting forest health would enhance future studies of forest ecology.

INTRODUCTION

Recent studies of forest decline have raised the question of how environmental stressors interact to affect the health of forest ecosystems. While in the past the emphasis has typically been on "single biotic or abiotic primary-causal-agent diseases" (Manion 1981), it appears that many disease syndromes observed today (at least in natural ecosystems) may in fact be caused by combinations of causal agents that interact in various ways to produce the symptoms observed.

In this paper I present an overview of the major environmental factors affecting the health of montane forests in northwestern Virginia, and suggest that additional information on the distribution and importance of environmental stressors affecting forest health would be a valuable contribution to both studies of disease syndromes and forest ecology in general.

METHODS AND MATERIALS

Sources

Most of the data used in this study comes from published literature, most notably Brown (1986), Garner et al (1989), Huber et al (1987) and Smith and Tirpak (1989). Where necessary, the available data is supplemented by information based on interviews with National Park Service and USDA Forest Service personnel and by personal observations during field excursions through the area. Most of the forest composition and tree damage information is based on the fifth USDA Forest Service Forest Inventory and Analysis (FIA) survey of Virginia, conducted during 1984-1985.

Approach

I divided the types of factors affecting forest health in northwestern Virginia into three types: non-anthropogenic factors, anthropogenic factors, and fire. Non-anthropogenic factors include competition, weather, insects, diseases, browsing, and senescence. Anthropogenic factors include air pollution, real estate and industrial development in forested areas, and anthropogenically-induced climate

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change. Fire is treated as a separate case because it can result from either natural causes or by human activities.

The Study Area

The area under consideration is the Northern Mountains region of Virginia as defined by the USDA Forest Service (Bechtold et al 1987, Brown 1986). The region is composed of Alleghany, Augusta, Bath, Botetourt, Clarke, Craig, Frederick, Highland, Page, Roanoke, Rockbridge, Rockingham, Shenandoah and Warren Counties (Brown 1986). Most of Shenandoah National Park and the George Washington National Forest and some of the Thomas Jefferson National Forest lie within the study area.

There were 2.5 million acres of timberland in the region as of 1985. Of that, approximately 10% of the stands were classified as softwood types and 90% as hardwood types (Brown 1986). The major forest cover types are shown in Table 1. The more important species (or species groups as defined in Huber et al 1987) are shown in Table 2. Only those species which made up at least 1% of the region's total tree population are considered.

DISCUSSION

Non-Anthropogenic Factors[1]

The major non-anthropogenic factors affecting forest health in the region are: 1) competition and site conditions; 2) weather; 3) insects; 4) fungi and other pathogens; 5) overbrowsing; and 6) senescence.

Suppression and stagnation as a result of strong competition and/or poor growing sites is a major cause of damage in many softwood and hardwood species in the region, affecting over 5 percent of the trees in the sapling size class (Huber et al 1987).[2] Softwood species are more seriously affected, with over 10 percent of the saplings affected in Virginia pine, pitch pine and table mountain pine.

Weather (excluding lightning), is a major cause of damage in all species except white and chinkapin oaks, hickories and Virginia pines (Huber et al 1987). Trunk and branch breakage due to wind and ice, and visible damage (frost cracks, winter burn, etc.) from temperature extremes are typical examples of weather damage.

Weather events, such as serious droughts, can help trigger diebacks, especially in trees growing in unfavorable sites. Dieback, while affecting all hardwoods, is a major cause of damage only in larger-size oaks (Huber et al 1987).

Insects are widespread in the forests of the region but, at least until recently, caused visible damage to only a small percentage of trees. At the time when the data reported in Huber et al (1987) were gathered (1984 and 1985), only hardwood borers, which primarily affect red/black oaks (northern red, scarlet, southern red, and black oaks) and maples (red, silver, and sugar maples), and terminal shoot and

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1 Statistics based on data from Huber et al. (1987) are for the entire state of Virginia instead of the region of concern in this paper. However, the species (or species groups) discussed in this section are among the more important members of the region's forest communities as defined earlier.

2 The size classes (after Huber et al. 1987) are as follows: Sawtimber (≥ 9.0 inches DBH for softwoods, ≥ 11 inches DBH for hardwoods); Poletimber (≥ 5 inches DBH but smaller than sawtimber size); Saplings (1 to 5 inches DBH).

TABLE 1. The major forest cover types in northwestern Virginia (after Brown, 1986).

Forest type	Total Acreage	Percent of Region's Total Timberland
Oak-Hickery	1,702,000	67%
Oak-Pine	284,000	11%
Chestnut Oak	226,000	9%
Virginia Pine	94,00	4%
Pitch Pine	60,000	2%
Table Mountain Pine	43,000	2%
White Pine-Hemlock	43,000	2%

TABLE 2. The more important trees species (based on the number of live trees) in northwestern Virginia (after Brown, 1986).

Common Name	Scientific Name	Percent of Region's Tree Population
Red and silver maples	*Acer rubrum*, *A. saccharinum*	13%
Blackgum	*Nyssa sylvatica*	12%
Chestnut oak	*Quercus prinus*	10%
Hickory	*Carya* spp.	7%
Scarlet, southern red and black oaks	*Quercus coccinea*, *Q. falcata*, *Q. velutina*	6%
Virginia pine	*Pinus virginiana*	4%
White and chinkapin oaks	*Quercus alba*, *Q. muehlenbergii*	4%
Eastern white pine	*Pinus strobus*	4%
Northern red oak	*Quercus rubra*	3%
Yellow popular	*Liriodendron tulipifera*	2%
Black locust	*Robinia pseudoacacia*	2%
Pitch pine	*Pinus rigida*	2%
Sugar maple	*Acer saccharum*	1%
Table mountain pine	*Pinus pungens*	1%
Eastern hemlock	*Tsuga canadensis*	1%
Ash	*Fraxinus* spp.	1%

stem borers, which primarily affect hickories, were major causes of damage to trees in the region.

The incidence of damage from bark beetles may have been under-reported in Huber et al (1987) because, as the authors pointed out, death of the tree generally occurs within a few years of infestation by the beetles, and dead trees would not have been counted in the forest survey.

The gypsy moth has been appearing in increasing numbers and has begun to defoliate thousands of acres in the area, particularly in the northern and eastern portions (such as the Blue Ridge). Most of the area falls within the area where 51-75% of the timber is susceptible to defoliation by gypsy moths (Huber et al 1982). The long-term effects of the gypsy moth on forest composition in the region are unknown.

Fungi and other pathogens have had major impacts in the region in the past. The chestnut blight has virtually wiped out the American chestnut, which had been a major component of the forests in the region. Most chestnut sprouts in the area are infected to some extent.

All species groups display a significant number of form defects due to unknown causes, at least in the smaller size classes (Huber et al 1987). Basal defects are prevalent only among hardwood species, except for some oaks and yellow poplar. It is probable that fungi and other pathogens are involved to some extent in the processes leading to these defects. Form and basal defects may also give some indication of the stress level faced by the forests in the region, at least by suggesting the prevalence of damaging agents.

Portions of the region are subject to overbrowsing by white-tail deer. This is especially apparent in protected areas such as in Shenandoah National Park, where a striking browse line can be observed from many areas along Skyline Drive. The overbrowsing problem is primarily restricted to forests within one mile of human development (David Haskell, Shenandoah National Park, *personal communication*).

The age of the forests in the area is increasing (Brown 1986). The frequency of declines may increase due to senescence alone, or as a result of increasing susceptibility of older trees to environmental stresses (Franklin et al 1987, Manion 1981, Mueller-Dombois 1987).

Anthropogenic Factors

The major anthropogenic factors either affecting or having the potential to affect the health of forests in the region are: 1) air pollution; 2) development; and 3) climate change.

Air pollution may affect plants either directly by damaging plant tissues (e.g. Paparozzi and Tukey 1984) or indirectly through mechanisms such as interfering with the cold hardening process (Friedland et al 1984) or by altering the soil chemistry, leading to the increase of elements like aluminum to phytotoxic levels (Ulrich et al 1980).

Most of the region falls in the area labelled as facing minimal risk to the effects of wet deposition of acidic pollutants (Buikema et al 1988), however, areas of moderate risk occur along the Blue Ridge and on higher portions of the ridges to the west. Typically, the pH of rainwater is not low enough to cause acute toxic effects to foliage. However, potential effects on forest ecosystems due to soil-mediated processes cannot be ruled out. Gaseous ozone (and some other photochemical oxidants) occurs in concentrations high enough over most of the eastern United States to cause foliar injury to sensitive species, inhibit photosynthesis, alter carbon allocation and affect mycorrhizal associations (Garner et al 1989, Gilliam et al 1989).

Pollutants in the environment typically occur in mixtures. It has been demonstrated that pollutants in mixtures, such as sulfur dioxide and ozone, may act synergistically, resulting in increased toxic effects on vegetation beyond those predicted on the basis of each pollutant occurring in isolation (Carlson 1979, Chappelka et al 1985, Chevone et al 1986, Garner et al 1989, Mansfield and Freer-Smith 1981).

Forests at higher elevations (> 1,000 meters) may be especially susceptible to damage from pollutants in cloud water and fog. The area experiences heavy fogs at least 60 days per year (Barchet et al 1988), with the frequency increasing with altitude. Sigmon et al (1989) found that cloud water averaged four times more acidic than precipitation at Shaver Hollow in Shenandoah National Park. Under those conditions the concentrations of pollutants are more likely to reach levels comparable to those that cause visible injury to plants in laboratory and greenhouse studies.

Stagnation events caused by high-pressure systems over the region may result in an increase in the concentration of air pollutants in the region, resulting in acute toxicity effects. While stagnation events often occur over the entire region, it is likely that the forests in the smaller valleys in the western part of the region would be most affected.

Although much of the timberland in the region is protected on public lands, the loss of forested land (in addition to agricultural land) is still a cause of concern. According to Brown (1986), urban and related uses claimed 50% of the acreage diverted from timberland during the period from 1977 to 1985. My personal observation is that there has been increasing development pressure on the forest and rural land in the northern part of the region. Development pressure in the area will probably fluctuate periodically depending on the health of the real estate market, especially in the Washington, D.C. metropolitan area.

There is the potential for drastic disruptions of the forest communities if global warming occurs. Several climate models predict an increase in temperature and in the frequency of drought in the southeastern United States (Urban and Shugart 1989). Such changes could make the climate of northwestern Virginia more suitable for species with a higher temperature and drought tolerance and lead to decreased productivity in the region's forests. Changes in the region's climate may also influence the disturbance regime (including fire frequency and magnitude) as well as the activity of insects and pathogens (Smith and Tirpak 1989, Woodman and Furiness 1989).

Assuming the projections for increased temperature and drought frequency are correct, the forest communities of the region could experience a northward migration of species (Urban and Shugart 1989). An analogous shift would occur along an elevational gradient as well, with upper and lower distribution limits migrating higher on mountain slopes for many species. Indeed, some montane community types that are limited in extent in the region, particularly spruce-fir communities on the higher elevations in the Blue Ridge and Ridge and Valley Provinces, could disappear entirely (Woodman and Furiness 1989). If the climate warms faster than forest species can extend their range northward in response, many species may become extinct (Zabinski and Davis 1989). The potential for local extinction will be much higher in fragmented habitats.

As for the more widespread community types in the region, there is likely to be a shift from oak-hickory to oak-pine to yellow pine community types (Urban and

Shugart 1989). Some areas facing severe drought stress (or increasing wildfire frequency) could even shift to an open savannah or even grassland community, although these would most likely be limited in extent in the region.

Fire

Fire is a complex phenomenon that warrants special treatment. Human and non-human factors can interact to affect the behavior of specific fires in various ways, and the relative importance of human and non-human factors in controlling the fire regime prior to European arrival cannot be assessed with any degree of certainty.

An average of 55 fires a year burn in the George Washington National Forest (Boyd Ritchie, George Washington National Forest, *personal communication*). Most fires range in size from one to 100 acres, and the average size of a fire in the George Washington National Forest is 11-14 acres. The fires are most widespread in mixed pine-hardwood stands, but can occur in any forest type. Most result from human activity.

Shenandoah National Park experiences from 1 or 2 fires in wet years to 6 to 10 fires during drought years (David Haskell, Shenandoah National Park, *personal communication*). Most fires are rather small, but about once in every 10 years a fire will burn at least 200 or 300 acres. As in the George Washington National Forest, most fires in the park are caused by humans.

CONCLUSIONS AND RECOMMENDATIONS

The montane forests of northwestern Virginia are subject to a myriad of environmental stresses. It is important to have an appreciation of the complex interactions between environmental stresses and forest communities, especially at times like these when the forests are facing periods of potentially drastic change.

We can not afford to evaluate the effects of a particular environmental factor on the health of forests without considering the interactions of that factor with other factors simultaneously affecting the forests. Trees affected by one stressor, such as an air pollutant, are more susceptible to attack and damage from another, such as bark beetles. Air pollutants, climate extremes, increased competition, and other diseases have all been shown to affect trees in this way (Franklin et al 1987, Manion 1981, Matson and Waring 1984, Shigo 1985, Wargo 1972, Waring 1985, 1987).

Increasing fragmentation of the forest cover from urban and rural development may result in a decrease in the area available for interior forest species, resulting in more stressful living conditions for these species and leading to increased susceptibility to attack from insects and diseases and to dieback and decline syndromes. Decreasing stand size may also render some stands susceptible to total destruction by larger-scale disturbances. If preservation of critical habitats is a priority, then management policies requiring forested buffers around critical habitats such as wetlands should be planned and implemented with this concept in mind.

As fragmented habitats may also inhibit the migration abilities of forested species, policies should be planned now in order to ensure that sufficient migration corridors exist should climate warming begin to affect the distribution of species in the region's forest communities.

More information on the distribution and magnitude of factors affecting forest health, gathered from observations made during field studies, is needed. I will use an example from my own research to illustrate how such information can be efficiently gathered in the field. I must point out, however, that the documenting stress levels in the forests is not the primary focus of my current research. The methods I describe are just ways that I can efficiently gather information on stress levels in addition to acquiring the primary data I desire.

I am measuring forest community composition in 20x50-meter quadrats on two mountains in the Ridge and Valley Province. In addition to measuring the diameter at breast height (DBH) of live trees, I also measure the DBH of standing dead trees. I also try to identify the dead trees. This information will provide some insight on how the community has been changing (or not) during recent years. I also note evidence of damage and evidence of potentially damaging agents (such as the presence of gypsy moth egg masses) on living trees as I measure them.

I also look for remaining signs of disturbance (such as fire, windthrow, or mass movements) which affected the stand in the past. This additional data, which doesn't add much to the time spent on a site, will help me understand how the present composition of the community has evolved.

Increased effort should be made to report such information in the ecological literature. More information, and/or more communication of such information among researchers, could be a great help in building our understanding of forest ecology in a constantly fluctuating environment.

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