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Report NE-339

Analysis of Forest Health Monitoring Surveys on the Allegheny National Forest (1998-2001)

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Abstract

Describes forest vegetation and health conditions on the Allegheny National Forest (ANF). During the past 20 years, the ANF has experienced four severe droughts, several outbreaks of exotic and native insect defoliators, and the effects of other disturbance agents. An increase in tree mortality has raised concerns about forest health. Historical aerial surveys (1984-98), Forest Inventory and Analysis plot data collected in 1989, and FHM plot data collected 1998-2001 were analyzed to compare disturbed and undisturbed areas. Tree mortality and crown dieback levels were compared between undefoliated areas and areas defoliated by cherry scallopshell moth, elm spanworm, and gypsy moth. American beech mortality was compared inside and outside the beech bark disease killing front. This study illustrates the value of an intensified grid of P3 plots and demonstrates the integration of aerial survey and plot data.

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Cover Photos

Clockwise from top left: Allegheny Reservoir, by Janeal Hedman, USDA Forest Service; *Cladonia coniocraea*, courtesy of Yale University Press; Logan Falls, by Greg Porter, USDA Forest Service; Gypsy moth larva, by John H. Gent, USDA Forest Service, www.forestryimages.org.

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Executive Summary

Current Forest Conditions

- Current conditions on the Allegheny National Forest (ANF) have been shaped largely by timber removals at the turn of the 19th century, the decline and subsequent rebound of populations of white-tailed deer, multiple-use management by the USDA Forest Service over the past 75 years, and disturbance events that have occurred during the past 15 years.
- Nearly half of the forest land in the ANF consists of the mixed upland hardwoods and Allegheny hardwoods forest types.
- Black cherry and red maple are the most abundant tree species on the ANF.
- A summary of even-aged hardwood stands throughout the ANF revealed an overall inverse J-shape diameter distribution which usually indicates uneven-aged stands. The abundance of smaller diameter stems results from the following: 1) the diameter distribution in older stands (80 to 100 years) is an inverse J shape because faster growing species rapidly outgrew slower growing species. Thus, the diameter distribution is stratified by species growth rate; and 2) in younger stands that originated during the past 40 years, species low in food preference to deer or that are resilient to repeated browsing make up a large proportion of small-diameter stems.
- For most species, the average number of standing dead trees is greater on the ANF than for other forested portions of Pennsylvania.
- Average conditions across the ANF easily meet suitable and optimal habitat requirements for the Indiana bat.
- Overstory tree species richness is higher in the stem exclusion and understory reinitiation categories than in the stand initiation category.
- Because black cherry is abundant in all stand-size categories, this species probably will increase in dominance on the ANF over the next century.
- Due to the overwhelming abundance of non-oak regeneration, little oak forest likely will be sustained over the long term both in areas where timber harvesting occurs and is prohibited.

Disturbance Processes

- The frequency of defoliation by the cherry scallopshell moth was significantly related to the percentage of black cherry basal area in stands.
- The number of years of defoliation by the cherry scallopshell moth was significantly associated with the percentage of standing dead black cherry. Crown dieback of black cherry increased with years of defoliation by cherry scallopshell moth, though the relationship was not statistically significant. Managers should consider suppression activities following a defoliation episode so that tree damage can be mitigated should another defoliation event occur.

- The frequency of defoliation by the elm spanworm was significantly associated with the proportion of black cherry in stands.
* There was a tendency for greater levels of host crown dieback and tree mortality in stands defoliated by elm spanworm.
- The frequency of defoliation by gypsy moth was significantly related to the percentage of oak basal area in stands.
- The percentage of standing dead American beech was more than twice as great inside than outside the killing front of beech bark disease.
- Most of the basal area of standing dead sugar maple was on upper slopes but mortality was greater in defoliated than in undefoliated areas regardless of slope position. Crown dieback of sugar maple also was higher on defoliated than undefoliated trees regardless of slope position.

Additional Forest Health Indicators

Lichen Communities

- Fifty-two lichen species were sampled on the ANF. Lichen species that are sensitive to pollution are uncommon on the ANF.

Down Woody Material

- Duff accounted for 64 percent of down woody materials (by weight) on the ANF.
- The weights of duff and 100-hr fuels were higher on plots in Pennsylvania outside the ANF.
- The weight of 1,000-hr fuels was higher on plots within the ANF than on other forested plots in Pennsylvania outside the ANF.

Vegetation Diversity

- In all, 540 species were sampled in surveys of understory vegetation on the ANF. Another 184 specimens remain unidentified or partially identified; some of these may be additional species.
- Forty nonnative species were identified on the ANF.

Ozone Bioindicator Plants

- Nearly half of the plants sampled for ozone (O^3) damage (44.6 percent) showed symptoms (generally less than 25 percent of leaf area with damage) of O^3 injury in 1998. By contrast, less than 25 percent of the sampled plants showed injury symptoms in 2000, and less than 8 percent showed symptoms in 1999 and 2001.
- Blackberry had the most O^3 damage as 40 to 60 percent of the sampled plants showed symptoms of injury (generally less than 25 percent of leaf area) in 1998-2000.

Introduction

In this report we present information collected and analyzed over a 4-year period as part of a forest health assessment of the Allegheny National Forest (ANF). An interim assessment, "*Forest Health Conditions on the Allegheny National Forest (1989-1999): Analysis of Forest Health Monitoring Surveys*" (Morin et al. 2001), was a compilation of aerial pest surveys and data collected from inventory plots over the first 2 years of the 4-year assessment. The current report includes results for all Forest Health Monitoring (FHM) plots established throughout the ANF as well as the full suite of forest health indicators, e.g., lichen communities, soils, down woody materials, ozone bioindicator plants, and vegetation, which were not included in the 2001 report.

The national FHM program was initiated by the USDA Forest Service in 1990 to monitor, assess, and report the status of and trends in forest health across the Nation. Methods were developed to collect data on forest health indicators such as tree mortality, damage, and growth, regeneration, crown condition, plant diversity, vegetation structure, ozone, lichens, down woody debris and fuel loadings, and soil chemistry. These indicators were included in the forest health assessment for the ANF. Also analyzed in this assessment were pest data collected during aerial surveys. ANF personnel collected data at an intensified spatial resolution so that information could be summarized at the National Forest scale.

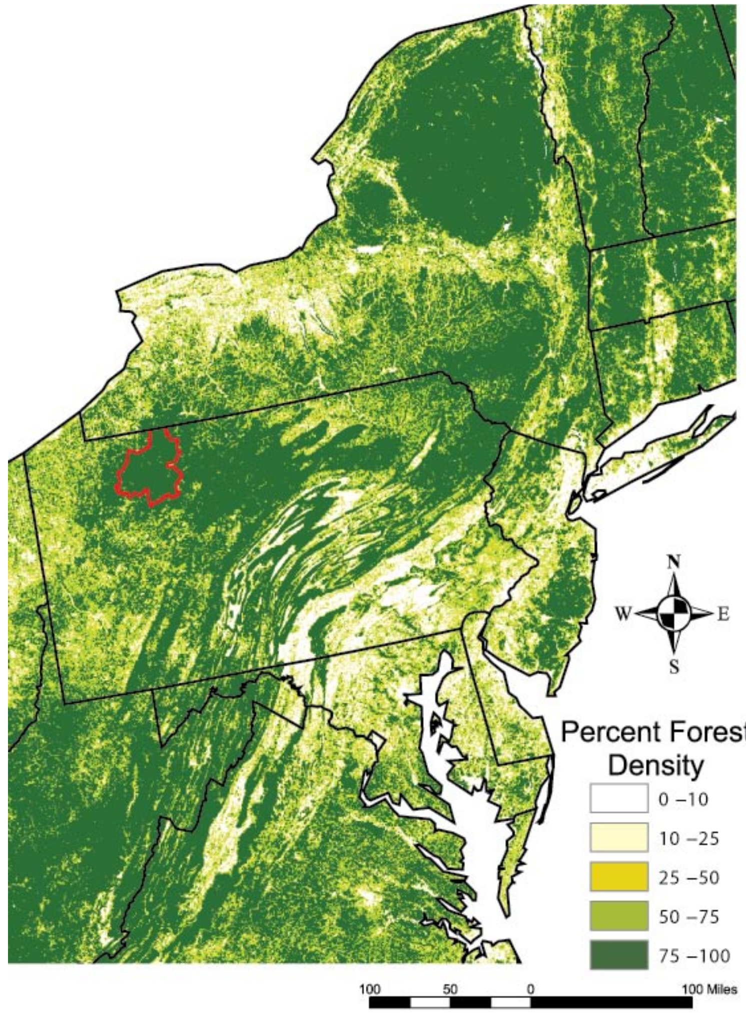

Figure 1.—The Allegheny National Forest in Pennsylvania overlayed on percent forested land (1-km grid cells--percent of each cell that is forest; NLCD data from Multi-Resolution Land Characteristics Consortium).

Objectives

The following issues were addressed in the assessment:

- Forestwide overstory and understory conditions.
- Tree-crown conditions as a reflection of tree and forest health.
- Tree mortality and relationships to possible causes.
- Habitat conditions for the endangered Indiana bat (*Myotis sodalis*).
- Pest-caused damage and relationships to forest conditions.
- Diversity and distribution of lichens.
- Soil characteristics and relationships to forest health.
- Down woody material and fuel loadings.
- Composition and distribution of herbaceous vegetation.
- Ground level ozone injury.

The aerial pest surveys and the data collection on forest health plots will continue so that current information on trends and change is available to planners.

Location

The ANF is located in northwestern Pennsylvania (Fig. 1) on the unglaciated portion of the Allegheny Plateau. The Forest comprises portions of Warren, Forest, McKean, and Elk Counties. The area within the forest

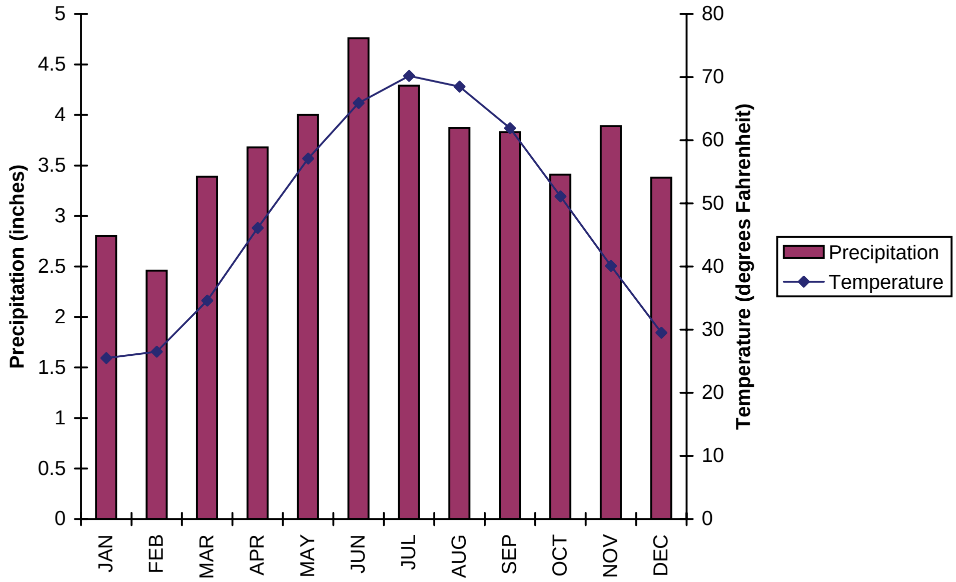

Figure 2.—Average monthly precipitation and temperature for Warren, PA, 1926-94, data from Pennsylvania State University, College of Earth and Mineral Science, Department of Meteorology.

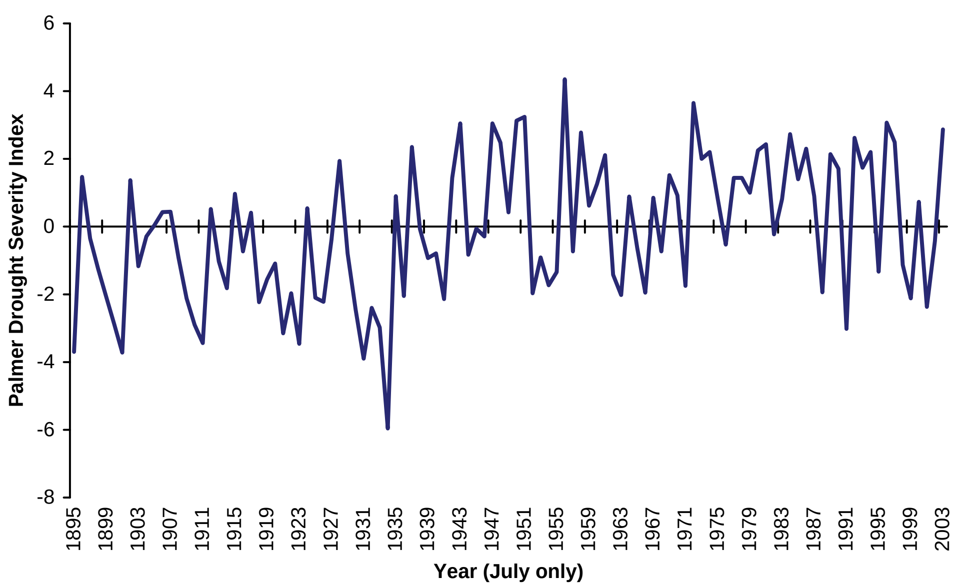

Figure 3.—Palmer Drought Severity Index (July only) for Warren, PA, 1940-2004, data from National Climatic Data Center.

proclamation boundary is nearly 740,500 acres, about 70 percent of which is federal land (513,000 acres). The rugged plateau country in which the ANF lies includes numerous creeks and streams that have created a rolling and sometimes steep topography (elevation up to 1,300 feet).

Climate

Winters are long and cold while summers are comparatively short. The growing season is usually about 148 days. Precipitation is plentiful throughout the year and averages 40 to 45 inches annually; snowfall averages 55 to 85 inches annually. Except for January and February, monthly precipitation usually totals 3 to 4 inches (Fig. 2). Precipitation generally peaks in June with a mean of nearly 5 inches for that month. Infrequent dry periods of varying duration and intensity are most likely during summer and fall. The Palmer Drought Severity Index (PDSI) (July only) from 1895 to 1940 indicates drought events (PDSI less than or equal to -1) 4 of every 5 years (Fig. 3). Between 1941 and 1987, PDSI indicates droughts 1 of every 4 years. There were four significant

Figure 4.—A log and bark landing of the Goodyear Lumber Company around 1912 (photo from Charles Catlin Collection).

drought events on the ANF from 1988 to 2001 following a relatively drought-free period from 1972 to 1987. The droughts in the late 1980s and 1990s coincided with several severe outbreaks of insect defoliators.

History

Conditions on the ANF have changed dramatically since the early 1800s. Today, the Forest is characterized by an abundance of black cherry, sugar and red maple, and other hardwoods. Most of the commercial black cherry timber in the United States is from the Allegheny Plateau (Marquis 1975). The original forest was dominated by eastern hemlock and American beech (Lutz 1930). Stands of eastern white pine originated following numerous catastrophes in well-defined patches (Marquis 1975) that occurred as a distinct forest type. These areas measured in tens rather than hundreds of acres (Hough and Forbes 1943). Current forest conditions have been shaped largely by timber removals at the turn of the 19th century, the decline and subsequent rebound of populations of white-tailed deer (*Odocoileus virginianus*), multiple-use management by the Forest Service over the past 75 years, and disturbances that have occurred during the past 15 years.

Early Timber Removals

The first European settlers reached the area in 1796 and 1797 (Kussart 1938). At first, trees were cut to clear land for agriculture and provide timber for cabins and barns (Marquis 1975). Not long after settlement of the area, forest based industries were developed. In the late 1850s, the tanning industry began using hemlock bark as a source of tannin for curing leather (Marquis 1975). The Civil War created a boom for tanneries because of the demand for harnesses, military equipment, and industrial belting. The vast supply of hemlock on the Allegheny Plateau helped meet this demand. At the end of the 19th century, the tanning industry was using massive quantities of hemlock bark from the Plateau. A chute for sliding hemlock bark down the hillside is shown in Figure 4. Figure 5 shows a trainload of hemlock tanbark.

Between 1850 and 1900 there was increased demand for lumber to build homes, stores, and furniture. The demand for paper and other wood-pulp products increased. When band saws came into use around 1880,

Figure 5.—A trainload of hemlock tanbark of the Central Pennsylvania Lumber Company in McKean County.

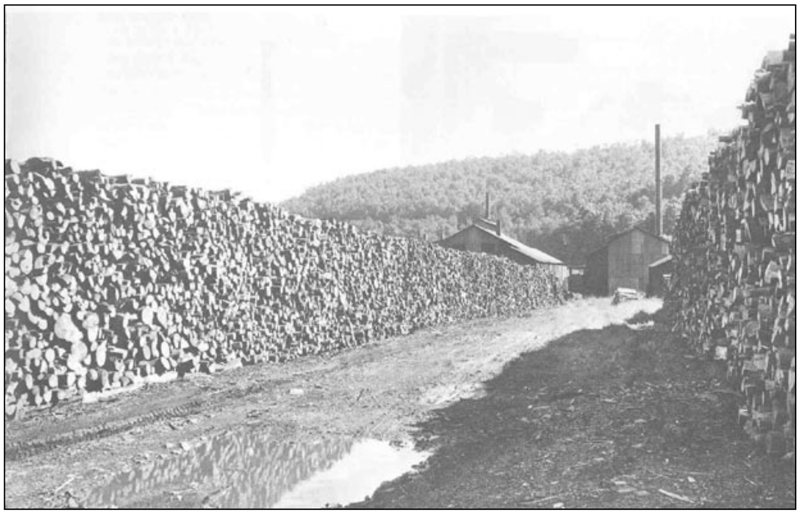

Figure 6.—Bolts of chemical wood at the Otto Chemical Company in Sergeant, McKean County.

Effects of Deer Density

Deer populations have had and continue to have a major impact on the development of vegetation on the Allegheny Plateau. At the turn of the century and following a period of intensive timber harvesting that supported the wood chemical industry, deer populations were low. Unregulated hunting resulted in the near extirpation of deer from some areas. As a result, tree seedlings became established and thrived in most areas where extensive timber harvest had occurred.

some sawmills could cut more than 100,000 board feet per day.

Around 1890, a new forest industry, wood chemicals, began to change forest development. Harvested timber was procured and refined to make acetic acid, charcoal, wood alcohol, and other distillation products (Marquis 1975). Over the next 40 years, this industry provided a market for nearly every size, species, and quality of tree growing in the area. Piles of chemical wood are shown in Figure 6.

Harvesting during this era cleared nearly every tree that was usable. The once large, contiguous forest on the Allegheny Plateau was almost completely removed in what must have been one of the highest records of forest utilization (Horst and Smith 1969; Taber 1974). Following removal of the original forest, regeneration to the same species occurred but in different proportions. Fast-growing, shade-intolerant species such as black cherry and species intermediate in shade tolerance such as red maple increased in proportion while slower growing, shade-tolerant species such as beech and hemlock decreased. Thus, the second-growth forest was essentially even-aged, having arisen from nearly complete forest removals over a relatively short period.

Timber-cutting trends and estimated deer population on the ANF are shown in Figure 7 (Redding 1995). The regeneration in harvested areas serves as forage for deer. In the early 20th century, the deer population rebounded due to the passage of game laws, restocking of deer, and regulation of antlerless harvests. Densities increased rapidly in the presence of a virtually limitless supply of food during the first quarter of the 20th century. As forest vegetation matured and grew above browsing height, the food supply dwindled. Populations crashed twice from 1930 through 1980 following severe winters (early 1940s and late 1970s) but then recovered. Since 1980, deer densities have been more constant largely due to efforts by the Pennsylvania Game Commission to regulate population levels, though

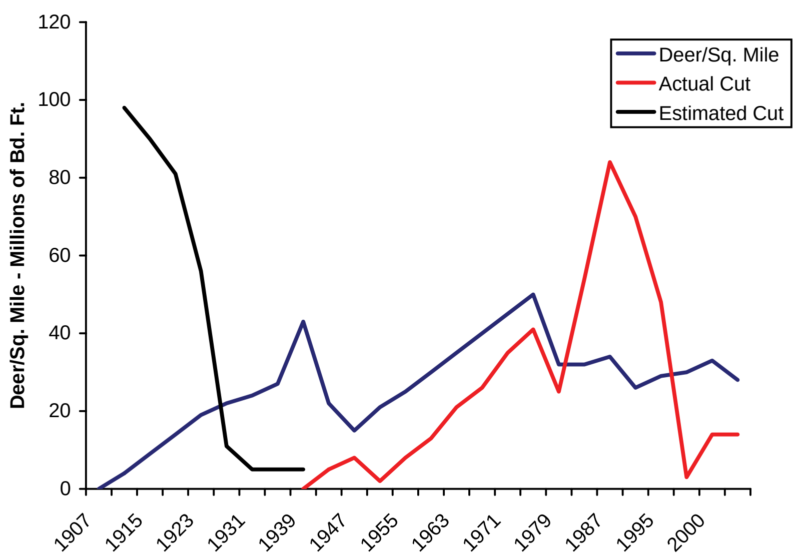

Figure 7.—Deer population and timber cutting trends on the Allegheny National Forest (reproduced from Redding 1995 and updated to 2001 with ANF data).

densities still remain above the level that allow many species to regenerate. This has been the case since 1990 despite a reduction in forest harvesting on the ANF.

The long-term impact from years of high deer densities has been the loss of understory and midstory vegetation over much of the ANF (Marquis and Brenneman 1980; Tilghman 1989; Horsley et al. 2003). Seedlings of many species are not abundant, and most understories are dominated by fern, grass, root suckers of American beech, or striped maple (USDA For. Serv. 1995). On the ANF, the most important factor limiting seedling establishment on the ANF is browsing by white-tailed deer (Marquis and Brenneman 1980; Tilghman 1989; Horsley et al. 2003). The maximum deer density that allows desirable tree seedlings to develop in heavily forested areas of northern Pennsylvania is about 20 per square mile (Tilghman 1989; deCalesta 1994). From the winter of 2000 to 2001, deer populations in the four-county area that includes the ANF averaged 31.5 per square mile, a decrease from estimates for the previous year (R. White, PA Game Comm., 2001, pers. commun.).

The current overstory on the ANF was established when the deer herd was minimal. In 1980, the Pennsylvania Game Commission set a density goal of 20 deer per square mile for the four-county area. To date, this density has not been achieved and the current goal for the ANF is about 20 deer per square mile (USDA For. Serv. 2000). Horsley et al. (2003) found that tree regeneration can be diverse, at this deer density, in heavily forested regions where forest management is practiced.

Multiple-use Forest Management

Since much of the land had been cut over when the ANF was established in 1923, early management focused on developing the second-growth forest and reforesting areas where seedlings failed to develop. The first challenge facing managers was ensuring the survival of the young trees growing amid logging slash. Civilian Conservation Corps enrollees from ANF camps planted trees, built forest roads, and constructed recreation sites. Protecting the forest from wildfires and erosion were other major concerns. Since most stands began developing around the same time, most of the trees on the ANF are roughly 70 to 100 years old. Today, management on the ANF emphasizes forest-ecosystem sustainability and multiple-use.

Currently, the range of Forest Service management and research activities are based on the research and silvicultural guidelines established by the Northeastern Research Station. These activities are designed to benefit vegetation, water, wildlife, and people. For example, achieving adequate natural regeneration of tree species is a major concern on the Allegheny Plateau. Efforts have focused on understanding the growth and development of Allegheny hardwood and oak stands, particularly with respect to requirements for regenerating tree seedlings.

On the ANF, forest health and the effect of the deer herd on the regeneration of species preferred as food have raised concerns (USDA For. Serv. 2000). During the past 15 years, managers have been increasingly challenged by native and exotic disturbance agents. The ANF is responsible for monitoring and describing changes in health and vigor of stand conditions (USDA For. Serv. 2000).

From 1985 to 1995, tree mortality increased in Allegheny hardwood forests (McWilliams et al. 1996; 1999). During this same period nearly 250,000 acres were sprayed with insecticide to reduce defoliation by the gypsy moth, elm spanworm, and forest tent caterpillar. Most of this acreage was sprayed with the biological insecticide *Bacillus thuringiensis* (B.t.). Despite this effort, the ANF has experienced both sudden and gradual tree mortality (Stout et al. 1995).

Adequate natural regeneration of a variety of species on the ANF is another major concern. Adequate numbers of seedlings must be present before a final harvest to assure satisfactory postharvest seedling stocking or growth. Species composition of the advance seedlings largely determines the species composition of the resulting stand (Marquis et al. 1992). Stout et al. (1995) found adequate regeneration on only 8 percent of the 12,000-acre sample, and that understory stocking with ferns exceeded 30 percent on more than 70 percent of the study area. Marquis et al. (1992) found that adequate regeneration was nearly impossible when fern stocking exceeded that percentage. A survey of 6,000 plots on the ANF revealed interference on 70 percent of the study area, and interference by ferns was found on 46 percent of the area (USDA For. Serv. 1995). Striped maple seedlings, beech root suckers, and grasses are other sources of interference (Horsley and Bjorkbom 1983; Horsley and Marquis 1983).

Even-age silviculture often is used to reproduce stands in the cherry-maple type. Grisez and Peace (1973) reported satisfactory natural regeneration on only 35 of 65 clearcuts from the early 1970s. Because of regeneration failure, clearcutting was largely abandoned except in areas with desirable advanced regeneration. Shelterwood cutting is useful in increasing the number of desirable advance seedlings (Marquis 1978). Since 1988, nearly 90 percent of the final harvesting (non-salvage harvests) on the ANF has been shelterwood cuts. When the percentage of ground cover and/or number of interfering stems exceeds thresholds, herbicides often are used to control interfering vegetation such as hay-scented and New York fern, striped maple, grasses, and root suckers of American beech (Horsley 1991). Reforestation activities such as site preparation, fencing, planting, and fertilization and release treatments also play a role in assuring seedling establishment and growth. After adequate regeneration is established, the remaining overstory trees are removed.

Local land managers share similar concerns regarding future species composition and forest sustainability in areas where active reforestation or harvest activity is prohibited. Trees that die may not be replaced through natural processes by an adequate quantity of tree seedlings or appropriate species capable of replacing them (USDA For. Serv. 2001).

Recent Disturbance Events

During the past 15 years, the following native and exotic disturbance agents have been of particular concern on the ANF (Stout et al. 1995):

- Pear thrips (*Taeniothrips inconsequens*)
- Forest tent caterpillar (*Malacosoma distria*)
- Gypsy moth (*Lymantria dispar*)
- Cherry scallopshell moth (*Hydria prunivorata*)
- Fall cankerworm (*Alsophila pometaria*)
- Elm spanworm (*Ennomos subsignarius*)
- Oak leaftier (*Croesia semipurpurana*)
- Linden looper (*Erannis tiliaria*)
- Beech bark disease complex
- Maple decline
- Ash dieback

Many factors are involved in the cause-effect relationship of maple decline, including soil moisture, Armillaria root rot, sugar maple borer, insect defoliators, and air pollution (Horsley et al. 2000, 2002; Marçais and Wargo 2000; Bailey et al. 2004). Ash viruses and canker fungi are factors in ash dieback (Manion 1991).

Since 1985, more than 86 percent of the ANF has been defoliated at least once. Although gypsy moth defoliation peaked in the mid-1980s, damage was observed between 1993 and 1995. Trees also were stressed by severe droughts during the 1988, 1991, 1995, and 1999 growing seasons. Tree mortality was substantial in the oak type in 1988 and in other forest types in the summer of 1994. Some tree decline has continued since then, but certain areas with fewer affected crowns have recovered partially (USDA For. Serv. 2001).

To provide an initial characterization of mortality/decline in the most heavily impacted areas, McWilliams et al. (1999) analyzed stand plot-level data collected between 1994 and 1996 in 869 stands (18,876 acres) with symptoms of decline and mortality. Of the existing basal area in these stands, 12.3 percent was classified as dead and 6.4 percent considered at risk. In some stands, dead and at risk trees constituted a majority; in others, they were a minor component. Black cherry, sugar maple, and red maple accounted for more than 83 percent of the total live basal area prior to decline in the sampled stands. The dieback and mortality of sugar maple, American beech, and red maple were the most significant, with levels of mortality and trees at risk at 43, 20, and 13 percent of the basal area, respectively.

McWilliams et al. (1999) also evaluated understory vegetation. The number of tree seedlings was adequate on only 8 percent of the sampled stands. Vegetation that interferes with tree seedling development and growth was present in sufficient quantities to require treatment in 93 percent of the stands examined. McWilliams et al. (1999) concluded that sparse regeneration and the abundance of interfering vegetation continue to raise questions about the sustainability of forest ecosystems on sites where tree mortality and decline are or may become most severe.

Overview Of Analyses

Description of Data

The analyses in this report are based primarily on three sources of data: 1) Forest Service Forest Inventory and Analysis (FIA) plot data, 2) FHM plot data, and 3) aerial surveys of defoliation. The objective was to describe and quantify vegetation characteristics and insect and disease factors on the ANF, and to determine the effect of insects and diseases on tree and stand damage and overall forest health.

Forest Inventory and Analysis Data

Since 1930, the objective of the FIA program has been to periodically assess the extent and condition of the Nation's forests, and report on trends in this important resource. In the Eastern United States, inventories were conduted on a state-by-state basis, usually every 5 to 15 years. The first FIA inventory of Pennsylvania was conducted in 1958. Plots were remeasured in 1968, 1977-78, and 1989-90 (Alerich 1993). Recently, FIA switched from periodic to annual inventories. For example, in Pennsylvania, 20 percent of the plots are measured each year. This plot network within FIA is known as Phase 2.

Different arrangements of fixed- and variable-radius plots have been used to select sample trees. For each tree, several variables are measured, including diameter at breast height (d.b.h.) for live and dead trees, species, and variables for estimating volume, growth rate, and quality. The last periodic forest inventory of the ANF was conducted in 1988-90 when 168 FIA plots were measured (Alerich 1993). Usually there is one FIA plot for every 6,000 acres (Hansen et al. 1992), though sampling intensity is higher on the ANF (about one plot for every 3,000 acres). For this survey, two plot designs were used: remeasured plots were a 10-point cluster of basal area factor (BAF) 37.5 prism plots while new plots were fixed radius with variable radius points (Appendix I).

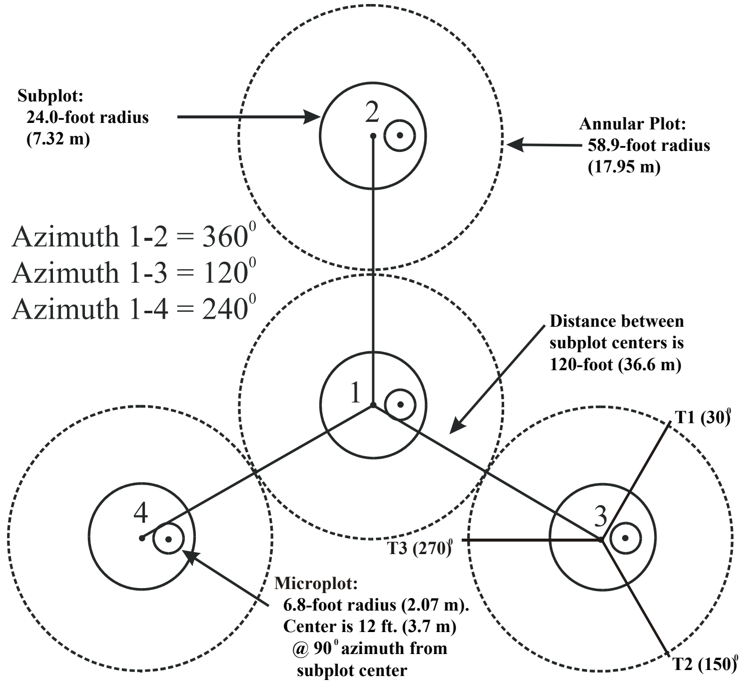

Figure 8.—FHM field plot design.

Eighty-nine percent of the plots visited in 1988-90 were remeasurements from the 1977-78 inventory. The analyses in this report that are based on 1988-90 FIA survey data include all 168 plots unless stated otherwise.

Forest Health Monitoring Data

The national FHM program was implemented in New England in 1990 (Brooks et al. 1992) to monitor, assess, and report on the long-term status, changes, and trends in forest ecosystem health at regional and national scales. FHM was developed due to increasing concerns about the health of the Nation's forests with regard to pollution, insects, diseases, climatic change, and other stressors.

The plot component of FHM (now known as Phase 3 within FIA) is a network of about 4,600 permanent plots covering all 50 States. A systematic sample of the plots is measured each year. Each permanent plot has four 1/24-acre, fixed-area, circular subplots (Fig. 8) (USDA For. Serv. 1998; 2002).[1] All trees 5 inches and larger in d.b.h.

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[1]U.S. Department of Agriculture, Forest Service. 2002. **Forest inventory and analysis national core field guide, volume 2: field data collection procedures for phase 2 plots, version 1.6.** Internal report on file wth U.S. Department of Agriculture, Forest Service. Forest Inventory and Analysis, 201 14th St., Washington, DC.

are measured on these subplots. Seedlings and saplings are measured on 1/300-acre, fixed-area, circular microplots offset 12 feet east of subplot center. Measurements of forest health-related indicators are taken in addition to the basic tree-measurement data collected on Phase 2 FIA plots. A forest health indicator is defined as any environmental component that quantitatively estimates the condition or change in condition of ecological resources, the magnitude of stress, or the exposure of a biological component to stress. Indicators currently being measured on FHM plots are tree mortality, damage, growth, regeneration, crown condition, plant diversity, vegetation structure, ozone bioindicator plants, lichen communities, down woody materials, fuel loading, and soil chemistry.

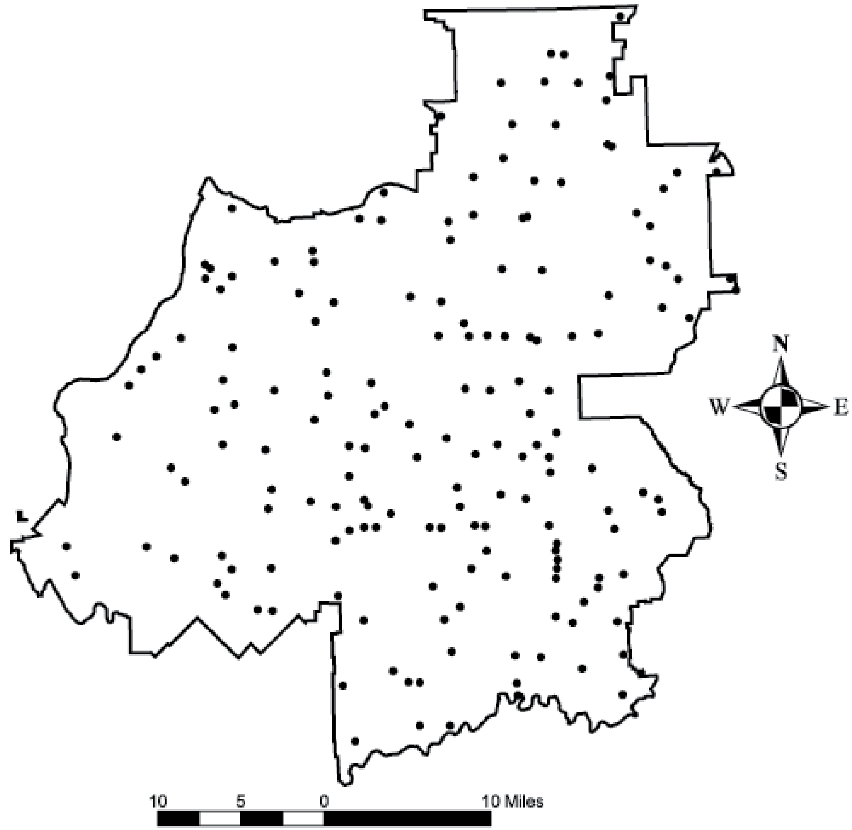


Figure 9.—FIA and FHM plot locations on the ANF (approximate coordinates).

Throughout most of the country, FHM plots are located on a hexagonal grid with one plot per 96,000 acres. An intensified network of 173 FHM plots was established on the ANF in 1998. Each plot was measured at least once in 1998, 1999, 2000, and 2001. For this survey, 168 plots were co-located with the 1988-90 FIA plots and 5 were co-located with newly established FIA plots. The shapes of plots and specific trees sampled differed due to the different plot designs. The approximate locations of the FHM and FIA plots are shown in Figure 9.

Aerial Survey Data

The symptoms of forest stressors often can be detected remotely by aerial photography and/or satellite imagery. The survey component of FHM detection monitoring consists of an aerial survey to detect damage in the form of canopy defoliation and mortality and thus monitor the occurrence and/or spread of insect, disease, blowdown, and other forest disturbances.

Aerial surveys supply a landscape-level overview of forest health conditions at a relatively low cost (McConnell et al. 2000). Forest defoliation usually is documented by a remote sensing technique known as sketch-mapping. A sketch-map is created while flying in an aircraft and observing damage and outlining its location on topographic maps. Sketch-mapping is an acquired and difficult skill that is somewhat subjective because human observers must rely on their judgement in identifying and delineating damaged areas.

The cumulative defoliation frequency (1984-98) for the ANF is shown in Figure 10. All acreage values in this report include the entire area within the proclamation boundary of the ANF (not just public land). The area defoliated by each major insect pest on the ANF is shown in Figure 11. There was little defoliation from 1999 to 2001.

Methods

Kriged Surfaces

We used the ordinary kriging procedure (Deutsch and Journel 1998) to interpolate surfaces of various variables of interest on the ANF from point measurements (FIA and FHM plot data). Kriging is a geostatistical method that provides unbiased estimates at unsampled locations as weighted averages of values from nearby plot locations

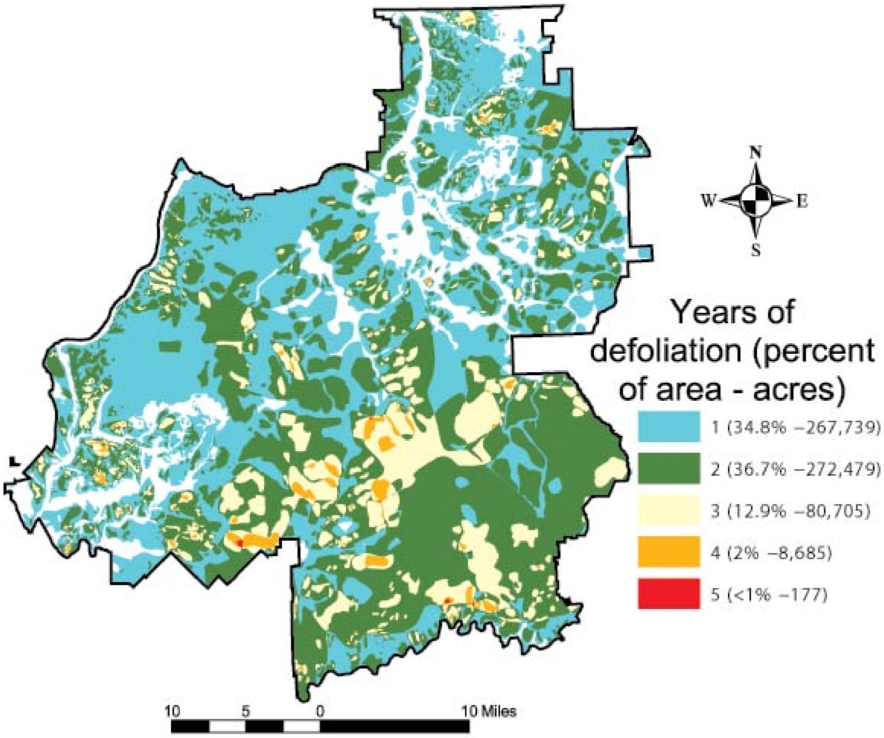


Figure 10.—Years of defoliation (percent of area) by all damaging agents (1984-98); percentage of land area and acreage in each category in parentheses.

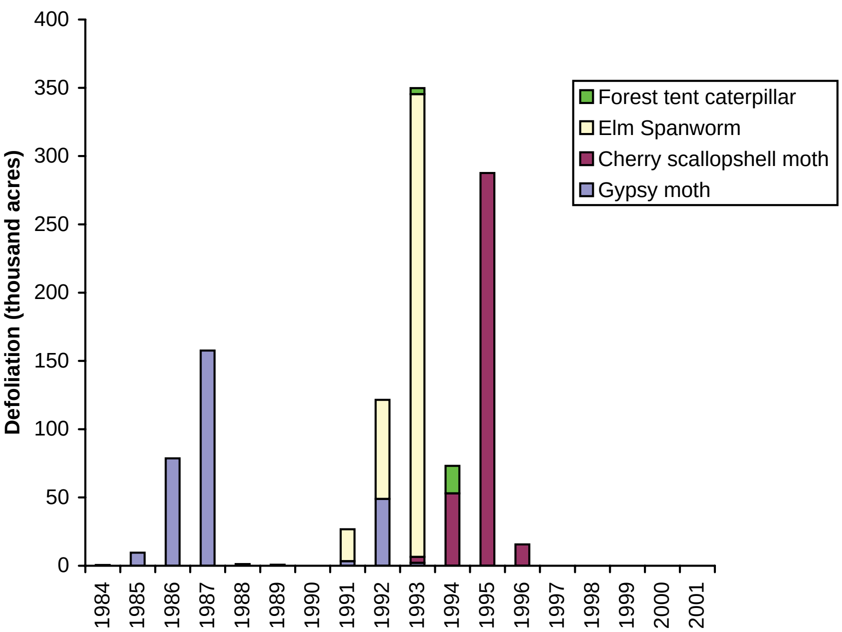


Figure 11.—Area defoliated by major insect pests since 1984.

(Isaaks and Srivistava 1989). Weights are determined on the basis of a semivariogram, a statistical model of the relationship between spatial autocorrelation and distance between pairs of sampled values. For this analysis we generated maps from plot data by calculating kriged estimates on a grid of 1- by 1-km cells. Variography and kriging were performed using the GSLIB software library (Deutsch and Journel 1998).

Species Diversity and Richness

Species diversity is the term used to describe the number of different species present in an area and the distribution of individuals among species. Evenness is the term used to describe how individuals in a community are distributed among various species. If the number of individuals is the same for each species, the community is said to be completely even, though this is rare in nature. When a species has more individuals than the other species, it is said to be dominant. Degree of dominance is another attribute of species diversity. The easiest way to measure species diversity is to count the number of species at a site; this measure is termed species richness. However, species richness does not provide a complete picture of diversity in an ecosystem because abundance is excluded. Diversity indices are calculated numeric values or graphical expressions used to describe species composition of a community in a single number for comparison with values from other communities. The Shannon index is commonly used to describe species diversity of a site. It emphasizes species richness but also takes into account the proportional abundance of the species. It is calculated using the following formula:

$$H' = -\Sigma p_i \ln p_i$$

where H' represents the diversity of a community, p_i represents the proportion of each individual species to the total, and $\ln p_i$ represents the natural logarithm of p_i (Magurran 1988). An index of evenness based on the Shannon index can be calculated using the maximum value of that index if all of the individuals sampled were distributed evenly among the species present. The measure of evenness is derived from the ratio of the observed Shannon diversity to its maximum, calculated as:

$$E = H'/H_{\max} = H'/\ln S$$

where S represents the number of species in the sample. H' is the observed Shannon index and $Hmax$ is the value of H' when the total number of individuals measured (N) is divided equally among the species encountered (S). Values of E are forced between 0 and 1 with 1 representing a situation in which all species are equally abundant (Magurran 1988).

Measures of dominance are based on the abundance of the most common species rather than incorporating species richness. The Berger-Parker index (d) is a simple dominance measure that represents the degree to which a community is dominated by one species and can be useful in describing monocultures. It is calculated as:

$$d = N_{\max}/N$$

where N_{max} represents the number of individuals in the most abundant species, and N is the total number of individuals of all species. An increase in the value of d accompanies a decrease in diversity and an increase in dominance (Magurran 1988).

Effects of Forest Pests

Tree conditions were assessed using tree measurements taken in 1988-90 as part of the FIA program and in 1998, 1999, 2000 and 2001 as part of the FHM program. We used the 1988-90 FIA data to analyze the effects of gypsy moth defoliation from 1985 to 1987. The cherry scallopshell moth and elm spanworm analyses were performed using 1998-2001 FHM data. In the case of remeasured plots, only the most recent measurement was used.

The frequency of defoliation at each plot location was calculated using a geographic information system to determine coincidence of plot locations with yearly sets of defoliation polygons. Defoliation layers were compiled by digitizing sketch-maps of canopy defoliation generated during aerial surveys conducted yearly from 1984 to 1999.

Oneway analysis of variance (ANOVA) was used to test both the effect of tree species composition on defoliation and of defoliation on percent standing dead basal area and percent crown dieback. A P value is a measure of probability that a difference between groups during an experiment happened by chance. For example, a P value of 0.01 means there is a 1 in 100 chance the result occurred by chance. Differences between group means are indicated by the letters *a*, *b*, and *c*. Estimates were calculated as averages of plot values. To analyze the effect defoliation on mortality and crown dieback, we excluded plots with less than 10 percent host-species basal area because we expected an excessively high sampling error of mortality and crown-dieback estimates on hosts. In

Table 1.—Current distribution of Region 9 forest types on the ANF (1998-2001 FHM data)

Forest type	Percent of area
Mixed upland hardwoods	25.5
Allegheny hardwoods	23.6
Red maple	17.2
Northern hardwoods	8.5
Hemlock	4.7
White oak/red oak	4.5
Nonforest	4.0
Oak/hardwood transition	3.9
Red oak	1.7
Sugar maple	1.6
White oak	1.2
Black birch/hickory	1.0
White spruce/Norway spruce	0.6
Chestnut oak	0.6
Pin cherry	0.6
Aspen	0.4
Red pine	0.4

other words, a plot with one tree of a host species that was dead would have 100 percent mortality, inflating the estimates. Crown dieback is defined as recent mortality (3 to 10 years) of branches with fine twigs and reflects the severity of recent stresses on a tree. However, it may be measurable only for several years as most dead fine twigs or branches do not remain on the tree for a long time. Once they fall, there is no visible indicator of how large the tree crown should have been, though it likely would appear smaller than normal for some time depending on the severity of the dieback. The variable is estimated as a percentage of the live crown area that is dead for each tree (USDA For. Serv. 1998).

Current Forest Conditions

Overstory Conditions

In this section we assess current overstory conditions across the ANF using 4 years of FHM data (1998-2001) and past overstory conditions using the 1989 FIA survey. Variables discussed include forest type, tree-species abundance, diameter distribution, stand age and size class by plot, tree crown dieback and damage, abundance and species composition of standing dead trees, and Indiana bat habitat. All tree species that were sampled in the FHM and FIA surveys are listed in Appendix I.

Forest Types

The forest types used by the Eastern Region (9) of the Forest Service are defined in Appendix I. We classified each FHM plot condition into Region 9 forest types by calculating the percentage of the live basal area of each species and combination of species. In some cases there were no overstory trees on a subplot so seedling/sapling data were used to determine forest type. The breakdown of Region 9 forest types on the ANF is shown in Table 1. Nearly 50 percent of the land area is in mixed upland hardwood (25 percent) and Allegheny hardwood (24 percent) forest types. Other than red maple (17 percent), all other forest types account for less than 10 percent of the land area. Four percent of the land area is classified as nonforest because trees or seedlings were not sampled, probably because part of a plot fell on a road, utility right-of-way, or in an opening. The distribution of plots on the ANF by FHM and FIA forest type groups and forest types is shown in Appendix I.

Tree-Species Abundance

Figure 12 shows tree-species abundance expressed as the average live basal area per acre calculated from the 1989 FIA and 1998-2001 FHM data for the 10 most abundant species on the ANF. The number of trees sampled of each species also is shown in Figure 12. The latter numbers represent only sample size and have no relation to abundance. Black cherry and red maple were the two most abundant species, which is consistent with the forest-type information in Table 1. Black cherry, red maple, American beech, eastern hemlock, and sweet birch increased in abundance while sugar maple, northern red oak, and white ash decreased in abundance. Decreases in sugar maple likely reflect the effects of elm spanworm defoliation, drought, and poor soil nutrition (Bailey et al. 2004) while decreases in northern red oak likely reflect the effects of gypsy moth defoliation and drought (Morin et al. 2004). Decreases in white ash probably reflect an observed decline due to multiple stressors.

Figure 13 shows the percentage of total average basal area per acre for the 10 most abundant tree species and the total of all other species. Black cherry and red maple account for more than half of the total average basal area per acre on the ANF.

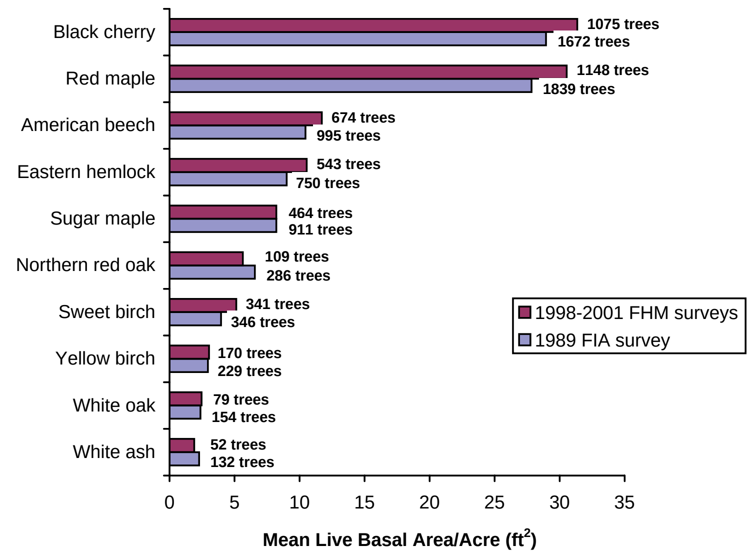


Figure 12.—Average live basal area per acre for major tree species on the ANF.

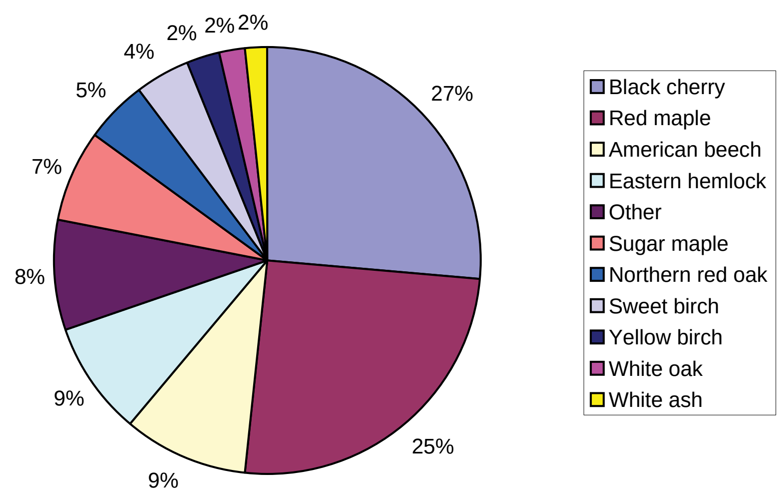


Figure 13.—Percentage of total live basal area for major tree species on the ANF (1998-2001 FHM data).

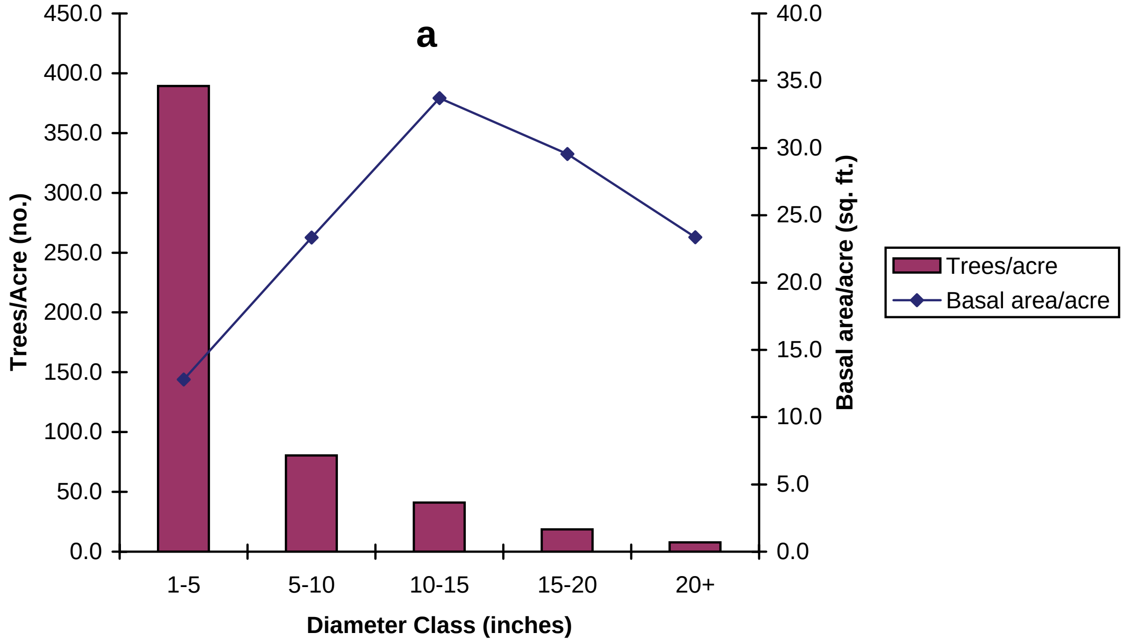
Diameter Distribution

The distribution of basal area and number of trees by diameter across the ANF (80- to 110-year-old high forest and younger stands regenerated over the past 40 years) calculated from 1998-2001 FHM data are shown in Figure 14. Figure 14a shows the number of trees per acre and basal area per acre of all species by 5-inch diameter classes. The number of trees per acre of all species forms an inverse J-shape curve that is typical of uneven-aged stands (Oliver and Larson 1996; Marquis 1992). However, stands on the ANF are even-aged, having regenerated between 1890 and 1930. The inverse-J diameter distribution occurs because of the difference in growth rates of the mix of species that developed following forest removals at the turn of the 19th century. Young seedlings of American beech, sugar maple, eastern hemlock (slow growing), red maple, and black cherry (fast growing) grew together before overstory removal. Following the overstory removal cut, fast-growing species rapidly outgrew slower growing ones, resulting in a diameter distribution stratified by species growth rate (inverse J). In younger stands that originated during the past 40 years, deer have had a substantial impact on the species of regeneration present before overstory removal. Species that are low in food preference to deer (black cherry) or that are resilient to repeated browsing (American beech) make up a large proportion of the regeneration in these younger stands.

Basal area was highest in the 10- to 15-inch diameter class. Figure 14b shows the diameter distribution of basal area for the five most common species and oak spp. Black cherry basal area increased with diameter while eastern hemlock, sugar maple, and American beech decreased with diameter. The highest percentage of red maple basal area was in the 10- to 15-inch diameter class; the highest percentage of oak basal area was in the 15- to 20-inch diameter class.

Spatial Distribution of Selected Tree Species

A kriged surface of percent basal area was created for each of the 10 most abundant species on the ANF. We generated maps (Figs. 15-16) from FHM plot data by calculating kriged estimates on a 1-km grid. The kriging parameters for each surface are listed in Appendix I.



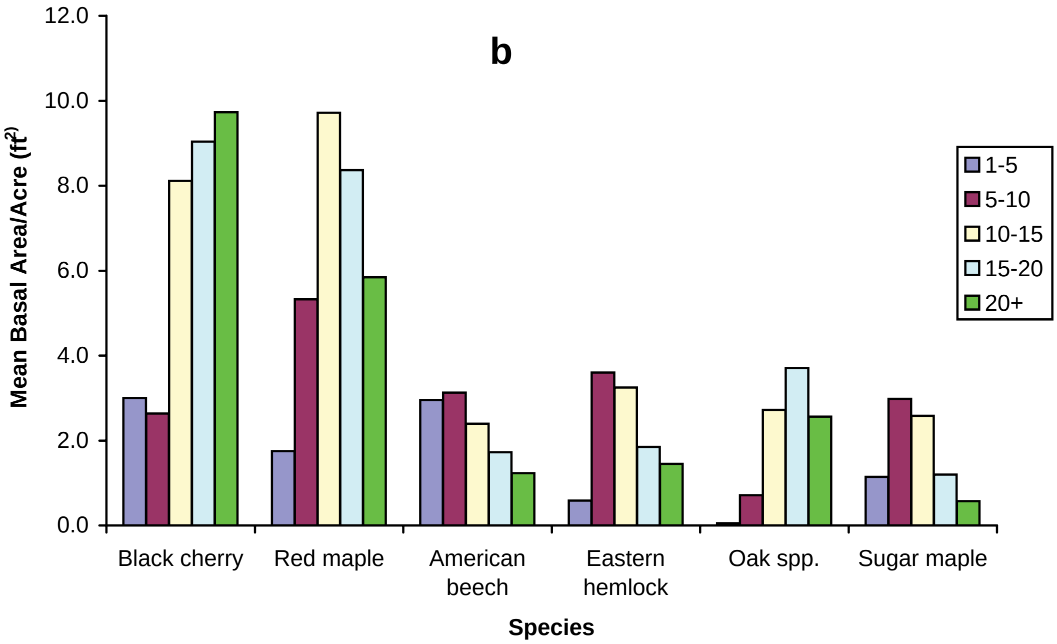


Figure 14.—Diameter distributions by a) number of trees and b) basal area per acre on the ANF.

Figure 15 shows kriged surfaces of percent basal area for black cherry, red maple, American beech, eastern hemlock, and sugar maple. The southeastern two-thirds of the ANF had the largest component of black cherry. The lowest estimated value for percent basal area of black cherry was zero and the highest was 65. Red maple had a more uniform distribution, though the southern third of the ANF has the highest red maple component followed by the northern third. The red maple component is lowest in the central portion but no cell was estimated at less than 6 percent basal area for red maple. The highest estimated value was 53 percent for basal area of red maple. American beech is a small component on most of the ANF; it is most prevalent in a band from the west-central border to the northeastern corner. The highest estimate was 42 percent for basal area of beech. Percent

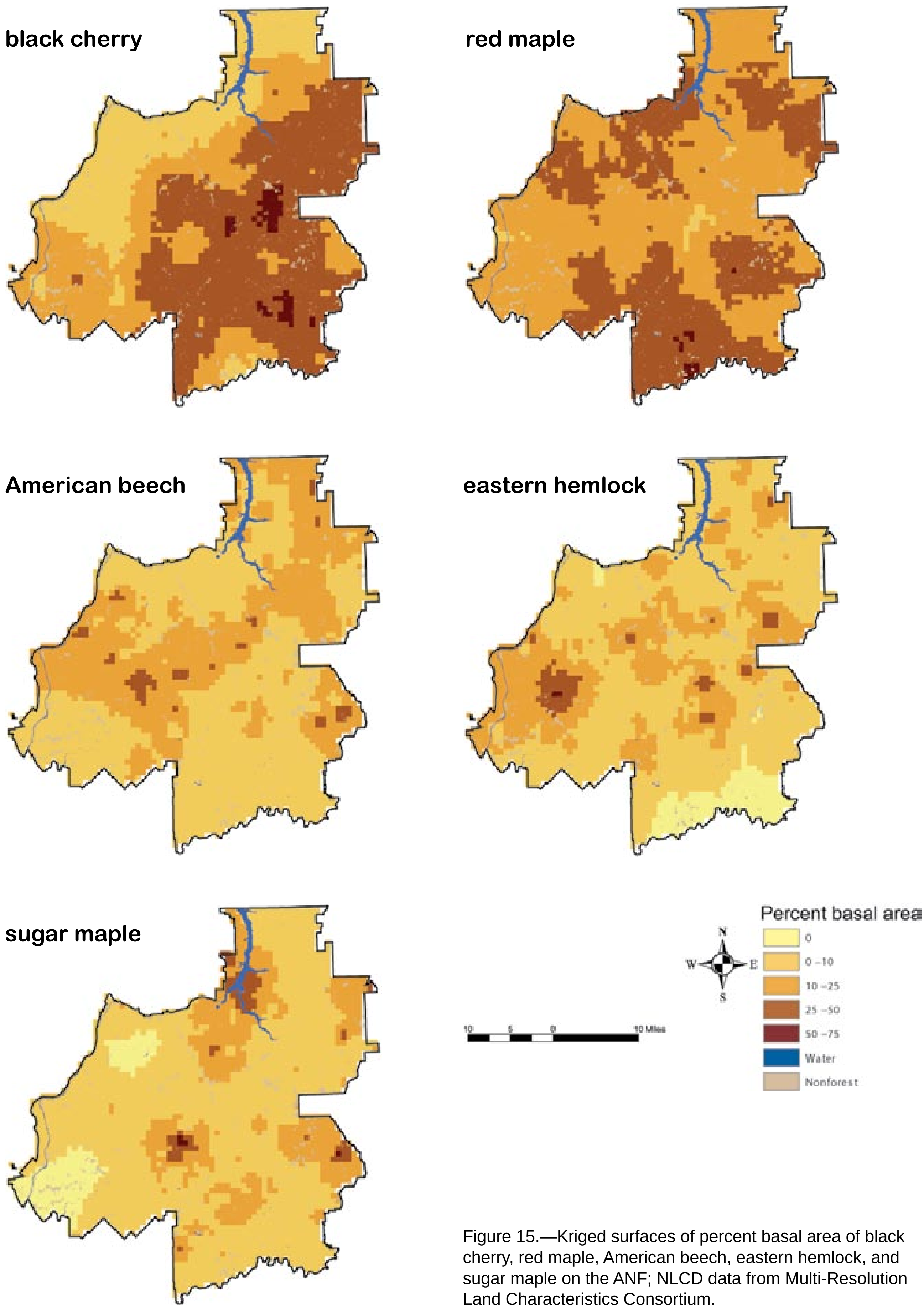


Figure 15.—Kriged surfaces of percent basal area of black cherry, red maple, American beech, eastern hemlock, and sugar maple on the ANF; NLCD data from Multi-Resolution Land Characteristics Consortium.

basal area of eastern hemlock was less than 10 on most of the ANF. Small areas of greater hemlock density probably represent concentrations of this species on lower slopes or bottomlands. The component of sugar maple is higher in the eastern two-thirds of the ANF. Percent basal area of less than 10 sugar maple was on most of the ANF; the highest estimate was 70 percent.

Figure 16 shows kriged surfaces of percent basal area of northern red oak, sweet birch, yellow birch, white oak, and white ash. The northern red oak component is greatest along the northern, western, and southern boundaries of the ANF in areas bordering the Allegheny and Clarion Rivers. Estimates of percent of basal area of red oak ranged from zero to 32. Percent basal area of sweet birch was estimated at less than 10 on most of the ANF. Several areas on the western half of the ANF have a higher component of sweet birch; the highest estimate for basal area was 19 percent. Percent basal area of yellow birch was estimated at less than 10 across the ANF. The white oak component is highest along the northern, western, and southern borders of the Forest. Estimates of percent basal area of white oak ranged from zero to 36. White ash was estimated at less than 10 percent across most of the ANF.

Plot Age Class, Stand-Development Class, and Relative Density

Data describing each plot as a unit (rather than examining individual trees) was used to characterize tree age classes, size classes, and relative density across the ANF.

Age-Class Distribution

The land area in each age class stratified by Eastern Region forest type is shown in Figure 17. Nearly 70 percent of the land area is characterized by 60- to 100-year-old forests due to widespread clearcutting at the turn of the century. Most of this mature forest is in mixed upland hardwoods, Allegheny hardwoods, and red maple forest types. The Allegheny hardwood type constitutes a small portion of the 100+ year age class. Forest types dominated by longer lived species dominate this oldest class.

Distribution by Stand-Development Class

Based on stand-development categories described by Oliver and Larson (1996), we assigned each subplot a stand development class. The classes were stand initiation (0 to 14 years), stem exclusion (15 to 49 years), and understory reinitiation (50+ years). The distribution of subplots on the ANF for each stand-development class is shown in Figure 18. More than half of the subplots were in the understory reinitiation phase (as expected due to a large percentage of trees on the ANF that are 60 to 100 years old; Fig. 16), and contained 80 to 200 ft^2 of basal area per acre.

Relative Density

Relative plot density was calculated using the method of Stout and Nyland (1986) (Fig. 19). Plots were classified as poorly, moderately, or well stocked according to ANF protocol.[2] Fifty-eight percent of the forest in the understory reinitiation class was classified as moderately stocked, and about 18 percent was classified as well stocked. The stand initiation category could not be included because the method described above was inappropriate.

Live-Tree Distribution by Size Class for Indiana Bat Habitat

Live trees provide important habitat for mammals, birds, and insects. The Indiana bat, listed as endangered by the USDI Fish and Wildlife Service, has been a concern on the ANF. The ANF Forest Plan as amended (USDA For. Serv. 2000) lists specific factors that can be used to evaluate the Indiana bat's roosting habitat:

Indiana bat requirements (no. of live trees)			ANF conditions (no. of live trees/acre)
D.b.h. class	Suitable	Optimal	(Mean ± SE)
> 9	8/acre	16/acre	79.08 ± 3.19
> 20	1/acre	3/acre	7.84 ± 0.66

These include criteria for numbers and sizes of live trees per acre according to the bat's habitat suitability index model (Romme et al. 1995). For habitat to be considered

[2]U.S. Department of Agriculture, Forest Service. 2000. **Final environmental impact statement for the eastwide project.** Warren, PA: U.S. Department of Agriculture, Forest Service, Allegheny National Forest. 102 p.

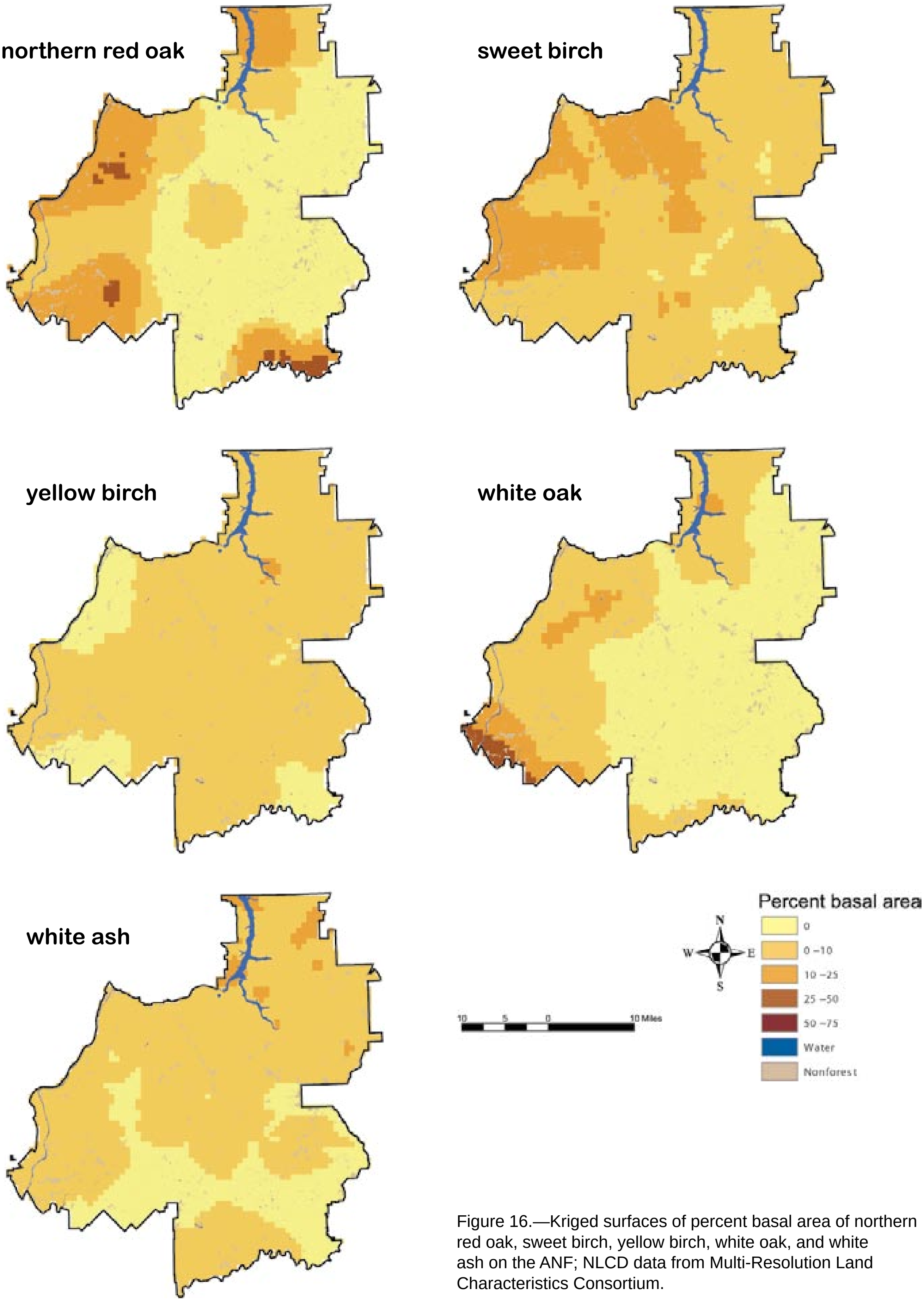


Figure 16.—Kriged surfaces of percent basal area of northern red oak, sweet birch, yellow birch, white oak, and white ash on the ANF; NLCD data from Multi-Resolution Land Characteristics Consortium.

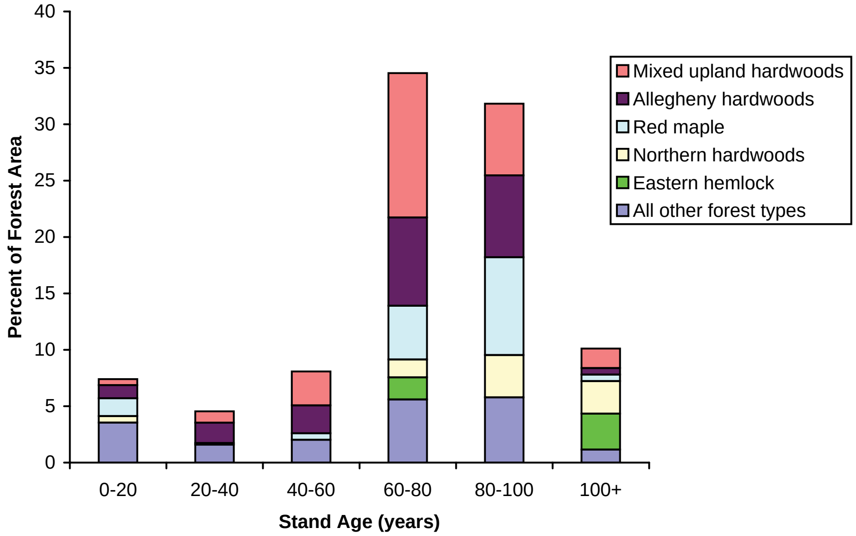


Figure 17.—Distribution of stand age by forest type.

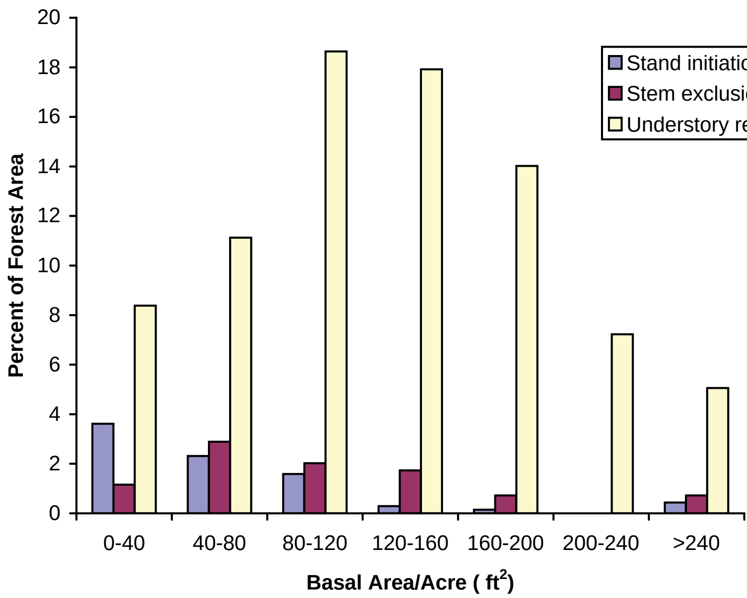


Figure 18.—Distribution of basal area by stand-development class.

suitable, 5 percent of the landscape under consideration must be forested and meet the criteria in the "suitable" column. For habitat to be classified as optimal, 30 percent of the landscape must be forested and meet the criteria in the "optimal" column. The ANF is 94 percent forested (USDA For. Serv. 2000). The live-tree density estimates imply that the average condition across the ANF easily meets both suitable and optimal live-tree habitat requirements. Nearly 60 percent of the plots meet both suitable and optimal conditions for both diameter classes.

Summary of Crown Condition, Tree Damage, and Standing Dead

Crown Dieback

The percentage of basal area of major species in crown-dieback categories measured during the 1998-2001 FHM surveys is shown in Table 2. Trees with less than

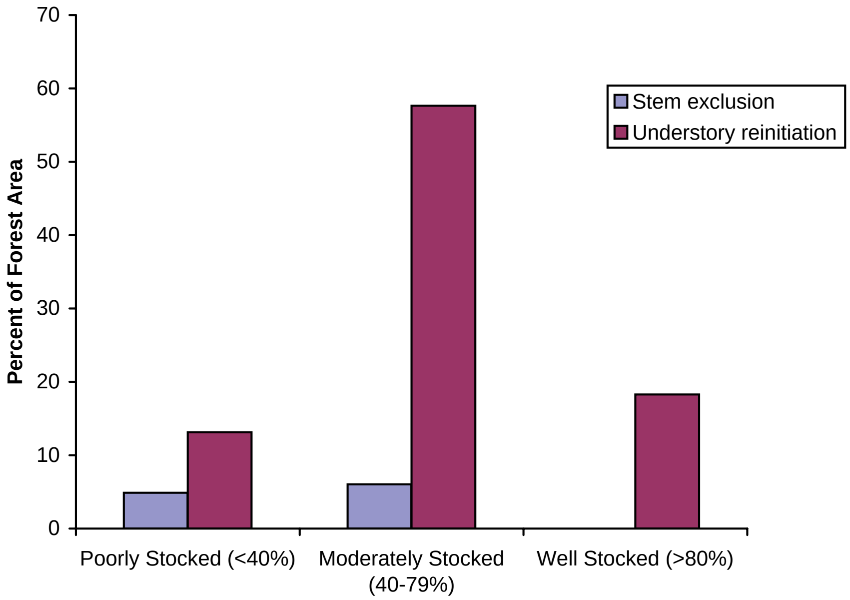


Figure 19.—Distribution of stocking levels by stand-development class.

25 percent dieback generally are healthy and usually recover, those with 25 to 49 percent dieback are in fair health and might recover, and trees with 50 percent or more crown dieback are in poor health and probably will not recover (Gottschalk and MacFarlane 1993). Standing dead trees (100-percent dieback) are included in Table 2.

Crown dieback generally was low for most species, ranging from 50 to 100 percent for 10 to 15 percent of the basal area of American beech, sugar maple, sweet birch, yellow birch, white oak, and white ash. Ash decline is prevalent in the Northeastern United States (Sinclair et al. 1988). Ash yellows, a disease caused by phytoplasma-like organisms, has been associated with dying trees in certain areas where ash is declining (Sinclair et al. 1996). However, not all dying trees are infected with these organisms (Matteoni and Sinclair 1985). Currently, ash decline is thought to have multiple causes (Schlesinger 1990). Northern red oak apparently has recovered well from gypsy moth defoliation and stress from drought in the late 1980s.

A kriged surface of percent crown dieback for all species estimated from the 1998-2001 FHM surveys is shown in Figure 20. Note that Table 2 provides the percent of basal area in crown-dieback categories. By contrast, these maps are estimated values of percent crown dieback

Table 2.—Percent basal area of major tree species on the ANF, by crown-dieback class (1998-2001 FHM data)

	Crown dieback (%)			
Species	0-24.9	25-49.9	50-95	100 (Dead)
Black cherry	88.9	2.4	1.0	7.6
Red maple	91.4	2.5	0.3	5.8
American beech	86.0	3.1	1.5	9.4
Eastern hemlock	91.5	1.9	1.4	5.2
Sugar maple	81.2	2.6	1.3	14.8
Northern red oak	95.2	0.0	0.0	4.8
Sweet birch	88.3	0.0	0.2	11.5
Yellow birch	84.8	1.8	0.0	13.4
White oak	88.4	0.0	0.0	11.6
White ash	85.8	0.0	6.7	7.5

averaged for each plot. Estimated dieback values were highest on the southeastern two-thirds of the ANF. This is consistent with the areas that had the most numerous defoliations (Fig. 10).

Kriged surfaces of crown dieback also were generated for selected species on the ANF estimated from the 1998-2001 FHM surveys (Fig. 21). Dieback of black cherry was greatest in the southeastern two-thirds of the ANF, while red maple dieback was low in all areas except the far western corner. Crown dieback of American beech, eastern hemlock, and sugar maple was low over most of the ANF; white ash dieback was high in the central portion.

Crown Density

Crown density, an estimate of crown condition in relation to a typical tree for the site where it is found, is defined as the amount of crown branches, foliage, and reproductive structures that block light visibility through the crown. Crown density can serve as an indicator of expected growth in the near future.[3]

Percent basal area of major species in crown-density categories measured during the 1998-2001 FHM surveys is shown in Table 3. Trees with higher densities should be considered healthier and more vigorous.

American beech had the highest percentage of basal area (27) in the less than 25 percent crown-density category followed by sweet birch (25 percent). Black cherry, eastern hemlock, and northern red oak have 30 to 40 percent of their basal area per acre in the 25 to 50 percent crown-density category, though black cherry usually has a lower foliage density. Northern red oak and white oak both had less than 1 percent of basal area in the lowest category.

Steinman (2000) reported that trees with crown densities of less than 30 percent are the most likely to die. Crown density as an indicator of tree health is useful for long-term monitoring as trends are evaluated against a baseline measurement. The crown densities established in this report will serve as that baseline.

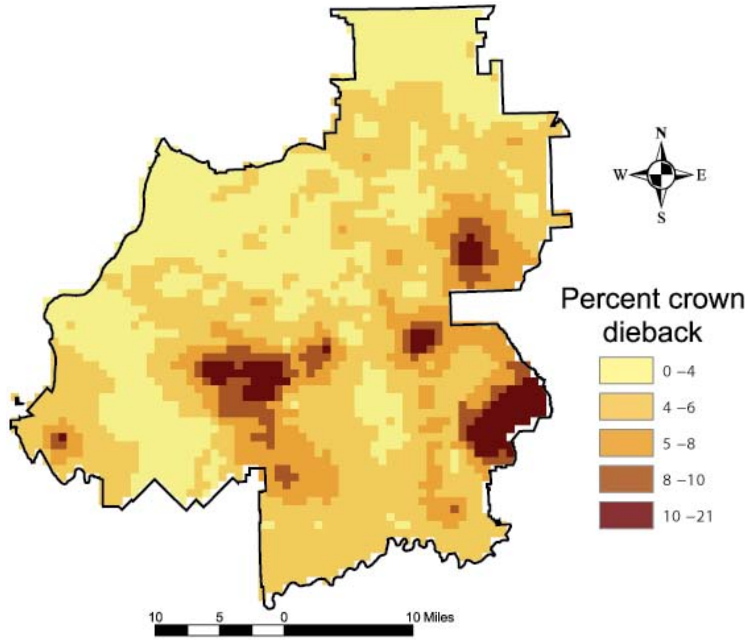


Figure 20.—Kriged surface of percent crown dieback of all species; NLCD data from Multi-Resolution Land Characteristics Consortium.

Table 3.—Percent basal area of major tree species on the ANF, by crown-density class (1998-2001 FHM data)

	Crown density (%)			
Species	0-24.9	25-49.9	50-74.9	75-100
Black cherry	10.4	40.2	47.4	2.0
Red maple	7.0	20.6	63.1	9.2
American beech	27.1	20.5	46.9	5.5
Eastern hemlock	9.0	32.8	49.8	8.3
Sugar maple	16.1	23.5	49.2	11.3
Northern red oak	0.9	29.6	55.6	13.9
Sweet birch	24.8	11.8	50.4	13.0
Yellow birch	9.8	22.0	57.0	11.3
White oak	0.4	18.4	56.5	24.7
White ash	7.9	26.1	55.9	10.1

Crown Ratio

Live crown ratio is a percentage determined by dividing live crown height by total tree height. Live crown height is the distance from the live crown top to the "obvious live crown" base.[3]

Percent basal area of major species in crown-ratio categories measured during the 1998-2001 FHM surveys is shown in Table 4. Trees in the less than 25 percent crown-ratio category probably are unhealthy. Where trees grow close together and self-prune, one would not expect a high proportion in the 75+ percent crown-ratio category except for highly shade tolerant species such as beech, sugar maple, and hemlock.

[3]U.S. Department of Agriculture, Forest Service. 2002. **Forest inventory and analysis national core field guide, volume 2: field data collection procedures for phase 3 plots, version 1.6.** Internal report on file with U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis, 201 14th St., Washington, DC.

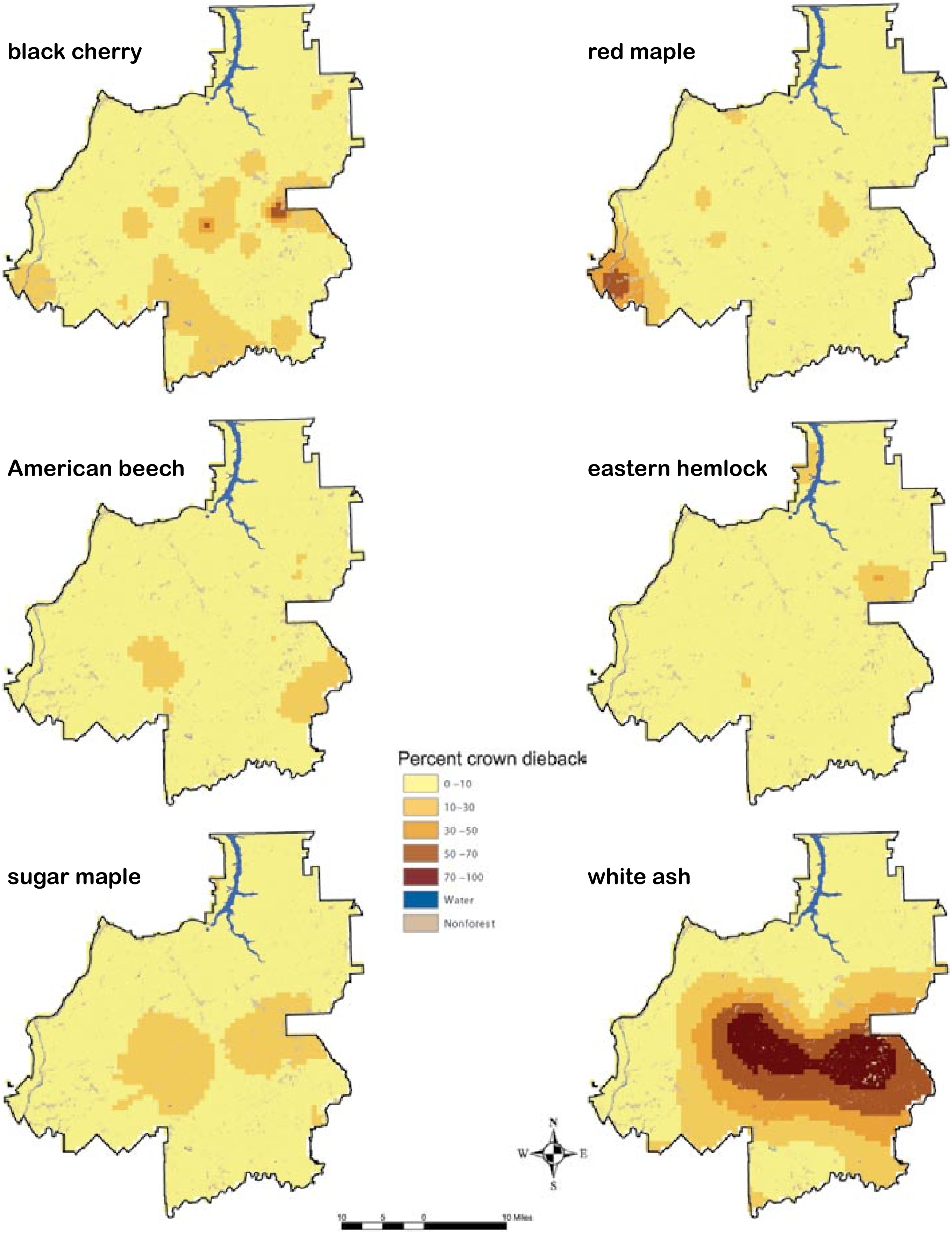


Figure 21.—Kriged surface of percent crown dieback of selected species (1998-2001 FHM data; NLCD data from Multi-Resolution Land Characteristics Consortium).

Foliage Transparency

Foliage transparency is the amount of skylight visible through the live, usually foliated portion of the crown. The normal range of foliage transparency varies by species. For example, black cherry and white ash generally have higher transparency than many other species. However, changes in foliage transparency can occur due to defoliation or reduced foliage resulting from stresses in preceding years.[3]

Percent basal area of major species in foliage-transparency categories measured during the 1998-2001 FHM surveys is shown in Table 5. The transparency for American beech was higher than would be expected for this shade tolerant species. Foliage transparency as an indicator of tree health is useful for long-term monitoring as trends are evaluated against a baseline measurement. The transparencies established in this report will serve as that baseline.

Table 4.—Percent basal area of major tree species on the ANF, by crown-ratio class (1998-2001 FHM data)

	Live crown ratio (%)			
Species	0-24.9	25-49.9	50-74.9	75-100
Black cherry	7.0	74.6	17.5	0.9
Red maple	1.4	34.5	57.3	6.9
American beech	1.2	17.0	39.9	41.9
Eastern hemlock	1.7	5.5	26.6	66.2
Sugar maple	3.9	27.9	55.1	13.1
Northern red oak	0.1	54.7	41.2	3.9
Sweet birch	0.7	42.5	49.7	7.1
Yellow birch	1.6	31.7	52.8	13.9
White oak	0.0	40.9	54.8	4.4
White ash	8.1	66.2	24.7	0.9

Table 5.—Percent basal area of major tree species on the ANF, by foliage-transparency class (1998-2001 FHM data)

	Foliage transparency (%)			
Species	0-24.9	25-49.9	50-74.9	75-100
Black cherry	58.1	40.4	1.0	0.6
Red maple	80.6	18.9	0.3	0.2
American beech	76.5	22.5	0.7	0.3
Eastern hemlock	93.6	4.8	0.2	1.5
Sugar maple	83.4	15.5	0.2	0.8
Northern red oak	72.8	27.2	0.0	0.0
Sweet birch	86.6	13.4	0.0	0.0
Yellow birch	76.3	23.7	0.0	0.0
White oak	96.2	3.8	0.0	0.0
White ash	66.4	28.0	1.1	4.5

Tree Damage

During FHM surveys, damage was assessed for each tree beginning at the roots. As many as three damages can be recorded per tree in the following order: roots, roots and lower bole, lower bole, lower and upper bole, upper bole, crownstem, and branches.[1] In some instances, not all of the damage on a tree is recorded, resulting in an underestimation of damages on the upper part of the tree. However, this bias is small as three damages were only recorded on 2 percent of the sampled trees. Percent basal area of major tree species on the ANF that incured damage is shown in Table 6. The percentage of basal area without signs or symptoms ranged from 41 for American beech to 89 for white oak. Conks and advanced signs of decay were the most frequently observed damage, ranging from 8 percent for white oak to 40 percent for yellow birch. Conks are the fruiting bodies of fungi that cause decay.

Discoloration and decay are the major causes of defect and loss in wood quality of yellow birch. *Nectria galligena* is the most common and damaging stem disease of this species (Erdmann 1990). Therefore, much of the decay on yellow and sweet birch may be due to infection by the *Nectria* fungus. The extensive conks and advanced decay reported in northern red oak requires further evaluation. Decay on American beech is attributed at least partly to the effects of beech bark disease. Affected trees may live for several years (Houston 1994).

The observed decay on trees by tree-size class using the 1998-2001 FHM data is shown in Table 7. Except for northern red oak and white ash, the percentage of

Table 6.—Percent basal area of major tree species on ANF, by damage signs and symptoms (1998-2001 FHM data)

Species	No Damage	Canker	Decay	Open Wound	Resinosis	Cracks	Broken Bole or Roots	Broken/ Dead Roots	Vines	Dead Terminal	Broken/Dead Branches	Damaged Buds or Foliage	Discoloration	Other
Black cherry	59.3	4.7	26.9	3.1	0.3	4.9	0.0	0.1	0.5	1.6	8.4	0.0	0.0	0.0
Red maple	55.0	4.1	35.1	2.5	0.0	8.4	0.0	0.0	0.2	1.6	2.0	0.0	0.2	0.0
Eastern hemlock	67.5	5.3	15.5	4.8	0.0	4.2	0.0	0.2	0.0	9.5	1.8	0.7	0.0	0.0
American beech	41.4	4.8	38.3	7.5	0.0	5.6	1.2	0.0	0.2	5.5	1.4	0.3	0.1	16.3
Sugar maple	53.6	11.0	30.8	7.7	0.0	5.8	0.1	0.3	0.1	7.8	1.6	0.0	0.0	0.2
Northern red oak	56.9	0.0	34.5	0.0	0.0	5.5	0.0	0.0	0.6	0.2	2.8	0.0	0.0	0.0
Sweet birch	61.4	17.4	25.0	6.1	0.0	2.8	0.0	0.0	0.5	0.5	1.8	0.0	0.0	0.0
Yellow birch	50.6	12.3	39.8	3.4	0.0	1.7	0.0	0.0	0.0	1.8	1.4	0.0	0.0	0.0
White oak	89.1	0.0	8.5	0.0	0.0	1.9	0.0	0.0	0.0	0.5	1.4	0.0	0.0	0.0
White ash	82.4	0.0	12.5	0.0	0.0	0.0	1.6	0.0	0.0	2.6	7.7	0.0	0.0	0.0

Table 7.—Percent basal area of major tree species with observed decay on the ANF, by diameter class (1998-2001 FHM data)

	Diameter class (inches)				
Species	0-4.9	5-9.9	10-14.9	15-19.9	>20
Eastern hemlock	0.0	2.5	11.3	21.9	45.1
Red maple	16.2	26.4	29.8	35.6	52.8
Sugar maple	15.7	31.3	34.2	15.0	49.3
Yellow birch	0.9	37.2	38.6	46.5	54.5
Sweet birch	2.3	17.3	24.1	52.5	NA
American beech	13.9	30.3	26.6	66.6	47.4
White ash	0.0	10.4	18.3	7.0	15.8
Black cherry	1.5	14.6	19.0	29.7	36.6
Northern red oak	0.0	23.2	8.7	6.2	0.0
White oak	0.0	6.7	6.1	30.3	53.6

basal area with observed decay increased with diameter class. This trend can be expected as part of normal tree senescence. Decay observed in northern red oak was atypical as it was highest in the 5- to 10-inch diameter class.

Standing Dead Trees

Standing dead trees (at normal background levels), a natural component of healthy forest ecosystems, play an important role in nutrient cycling and provide wildlife habitat. Tree mortality is increasingly affected by factors such as disease and insect damage as a forest ages (Greif and Archibold 2000). Standing dead is not a true measure of mortality because a dead tree can be removed, fall over, or remain standing for a number of years. However, number of standing dead trees can provide an indirect measure of past mortality.

Live and dead basal area per acre and percentage of basal area that is standing dead for major tree species on the ANF are shown in Table 8. Among the five most dominant species, mortality appeared to be proportionally greatest in sugar maple. This increase in percent dead sugar maple likely is due to a general decline in that species on the unglaciated portion of the northern Allegheny Plateau (Horsley et al. 2000). Beech bark disease and elm spanworm defoliation contributed to the

Table 8.—Live and dead basal area per acre (ft^2) and percent basal area that is standing dead for major tree species on the ANF

	Basal area/acre 1998-2001[a]			Basal area/acre 1989[b]		
Species	Live	Dead	Percent dead	Live	Dead	Percent dead
Black cherry	32.5	2.7	7.6	29.0	2.4	7.5
Red maple	31	1.9	5.8	27.8	2.1	7.0
American beech	11.4	1.2	9.4	10.5	0.2	1.7
Eastern hemlock	10.7	0.6	5.2	9.0	0.3	3.4
Sugar maple	8.5	1.5	14.8	10.1	1.1	9.4
Northern red oak	5.7	0.3	4.8	6.6	0.6	8.3
Sweet birch	5.2	0.7	11.5	3.9	1.6	28.9
Yellow birch	2.9	0.5	13.4	2.9	1.0	25.1
White oak	2.5	0.3	11.6	2.4	0.3	11.2
White ash	2	0.2	7.5	2.3	0.3	12.3

[a]FHM data.
[b]FIA data.

increase in the percentage of dead American beech. The high mortality of white oak likely is due to defoliation by gypsy moth. The effects of these disturbances are discussed in detail in subsequent sections. Most birch trees become infected with the *Nectria* fungus and few exceed 60 years of age. Once dead, they tend to decay and fall fairly soon, probably accounting for the decrease in the basal area of standing dead birch from the 1988-90 survey to the 1998-2001 surveys.

The percent of total standing basal area that is dead by diameter class for major species on the ANF is shown in Table 9. Several points can be made from Table 9:

- Nearly one-third of the black cherry basal area in the 5- to 10-inch d.b.h. class was dead. Standing dead accounted for less than 11 percent in the other diameter classes. The high percentage of standing dead in the smallest class likely was due to self-thinning of this shade-intolerant species.
- Percent standing dead red maple was highest (nearly 10 percent) in the 5- to 10-inch d.b.h. class, probably due to self-thinning. The proportion of standing dead was less than 8 percent in the other classes.
- The proportion of standing dead American beech was highest in the largest d.b.h. class. Twenty-seven percent of the basal area in that class was dead, probably due to beech bark disease. Defoliation by gypsy moth and elm spanworm also contributed to beech mortality. The basal area of standing dead beech was 15 percent or less in the other diameter classes.
- A large proportion of sugar maple basal area was in standing dead in the 5- to 20-inch d.b.h. classes. More than 22 percent of the basal area in the smallest diameter class was dead.

Table 9.—Percent of total standing basal area that is dead for major species on the ANF, by diameter class (1998-2001 FHM data)

	Diameter class (inches)			
Species	5-9.9	10-14.9	15-19.9	20+
Northern red oak	33.9	2.2	4.4	3.4
Black cherry	29.1	10.2	6.0	0.9
Sugar maple	22.3	14.8	12.7	0.0
White ash	19.5	21.0	0.0	0.0
Sweet birch	14.6	17.9	6.5	NA
Yellow birch	14.1	21.7	0.0	0.0
White oak	10.5	10.3	9.8	22.3
Red maple	9.5	7.4	4.4	3.1
American beech	7.4	15.0	3.1	27.0
Eastern hemlock	2.7	3.0	7.1	14.7

Sugar maple decline is discussed in detail in a subsequent section.

- Nearly 15 percent of the basal area of eastern hemlock in the largest diameter class was dead. The proportion of standing dead was less than 8 percent in the other classes. The reasons for this mortality are not completely understood.
- Standing dead northern red oak was highest (nearly 34 percent) in the 5- to 10-inch class, most likely from self-thinning. Standing dead basal area was less than 5 percent in the other classes. Since most oak mortality on the ANF occurred more than 12 years ago, a combination of blowdown and salvage operations since the gypsy moth outbreaks of 1985-88 might account for lower proportions of standing dead northern red oak.
- Birch mortality ranged from 14 to 22 percent in the 5- to 15-inch d.b.h. classes. There was no yellow birch mortality in the largest classes, probably because there are few trees of this species in those classes on the ANF.
- Standing dead basal area of white oak was highest (22 percent) in the largest class versus about 10 percent in the other classes. As with eastern hemlock, the reasons for this mortality are not completely understood.
- Nearly 20 percent of the standing basal area of white ash in the 5- to 15-inch d.b.h. classes was dead, likely due to ash decline that has been observed locally for several decades.

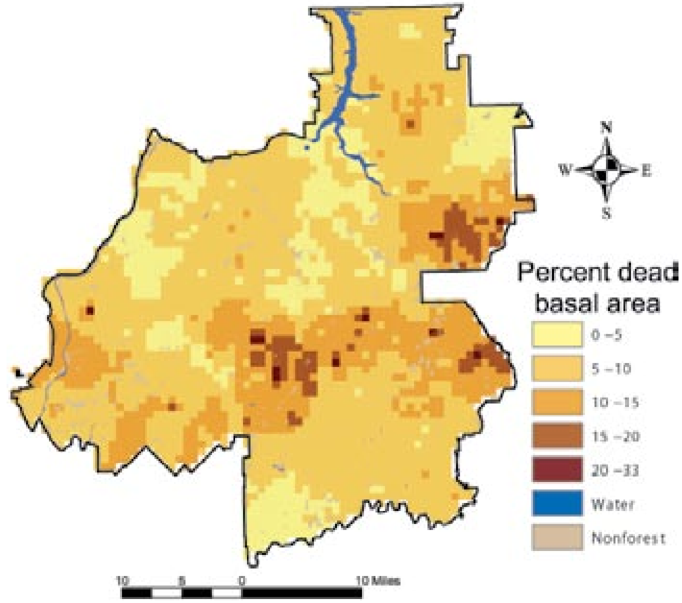


Figure 22.—Kriged surface of percent standing dead basal area (1998-2001 FHM data; NLCD data from Multi-Resolution Land Characteristics Consortium).

Table 10.—Number of standing dead trees per acre in the ANF, by species and diameter class (1998-2001 FHM data); Pennsylvania state averages from McWilliams et. al. (2004)

	Diameter class (inches)				Pennsylvania
Species	>9	>12	>20	Total	state average
Black cherry	2.0	0.9	0.0	2.9	1.2
Red maple	1.5	0.8	0.1	2.4	1.7
American beech	0.9	0.4	0.1	1.4	0.7
Eastern hemlock	0.3	0.2	0.1	0.7	0.6
Sugar maple	1.2	0.2	0.0	1.4	0.9
Northern red oak	0.1	0.1	0.0	0.3	1.0
Sweet birch	0.6	0.2	0.0	0.8	0.7
Yellow birch	0.4	0.1	0.0	0.5	0.3
White oaks	0.2	0.2	0.0	0.5	0.8
White ash	0.2	0.1	0.0	0.2	0.4
Aspen	0.6	0.1	0.0	0.7	0.2
Total	8.0	3.4	0.4	11.8	8.5

Spatial Distribution of Dead-Tree Basal Area

A kriged surface of percent standing dead basal area (all species) estimated from the 1998-2001 FHM data is shown in Figure 22. The greatest proportion of standing dead was in the central two-thirds of the ANF. This also is the area that has been defoliated the most often (Fig. 10).

Number and Distribution of Standing Dead Trees Per Acre

Standing dead trees provide structure, nesting, or roosting sites for numerous species of wildlife, and are important foraging sites for species that rely on insects for food. Table 10 shows the number of standing dead trees per acre by species and d.b.h. class on the ANF as well as

Table 11.—Comparison of size and percentage of trees that were standing and dead in 1989 with their status (standing or fallen) during the 1998-2001 reinventory

Species	Fallen trees		D.b.h.		Mean d.b.h. of fallen trees
	Number	Percent	Range	Mean	
			-----*Inches*-----		*Inches*
Eastern hemlock	3	0	5 to 14	8.1	NA
Red maple	12	0	5.1 to 19.1	8	NA
Sugar maple	23	17.4	5.5 to 23.2	8.3	6.2
Yellow birch	2	0	8.9 to 11.7	10.3	NA
Sweet birch	2	0	6.8 to 9.5	8.2	NA
American hornbeam	1	0	5.6	5.6	NA
American beech	2	0	5.3 to 8.9	7.1	NA
White ash	2	0	7.4 to 9.4	8.4	NA
Bigtooth aspen	3	33.3	5.7 to 17.1	11.3	5.7
Black cherry	32	3.1	5 to 20.8	9.5	9.7
White oak	1	0	12.8	12.8	NA
Northern red oak	2	0	18.3 to 18.8	18.6	NA

state averages as reported by McWilliams et. al. (2004). For most species (exceptions are northern red oak, white oak, and white ash), the number of standing dead trees per acre is greater on the ANF than the average for the rest of Pennsylvania. For black cherry, American beech, and aspen the number of standing dead trees is at least twice the statewide average.

Dead Tree or Snag Longevity

Because dead trees provide habitat for wildlife, the length of time they remain standing is important. Tree species vary in the time they remain standing after death. Black cherry and the oaks generally remain standing longer than maples and American beech. Sample sizes are sufficient for red maple, sugar maple, and black cherry to draw some general conclusions. In Table 11, the first column shows the percentage of standing dead trees that fell since the 1988-90 survey (by 2001). Of the 12 red maples that were dead in 1989, all remain standing. Seventeen percent of the sugar maples had fallen versus only 3 percent of the black cherrys. Although sample sizes were small for the remaining dead tree species except bigtooth aspen, virtually all of these trees are standing after 10 years. Aspen would be expected to fall more quickly because its wood is soft.

Indiana bats prefer larger trees (9+ inches d.b.h.) with flaky bark that they crawl under for shelter (Menzel et al. 2001). As shown in Table 11, larger dead trees tend to remain standing longer than smaller trees. Since virtually all Indiana bat maternity colonies are found under exfoliating bark, the characteristics of individual snags may be more important than the species itself (Romme et al. 1995).

Distribution of Dead Trees by Size Class for Indiana Bat Habitat

In evaluating habitat for the Indiana bat on the ANF, it is highly likely that at least 5 percent of the area is suitable as conditions on the Forest meet the requirements for optimal-dead tree habitat in the smaller d.b.h. classes:

	Indiana bat requirements (no. of dead trees)		ANF conditions (no. of dead trees/acre)
D.b.h. class	Suitable	Optimal	(Mean ± SE)
> 9	3/acre	5/acre	8.34 ± 0.79
> 12	0.1/acre		3.49 ± 0.48
> 20		0.5/acre	0.39 ± 0.11

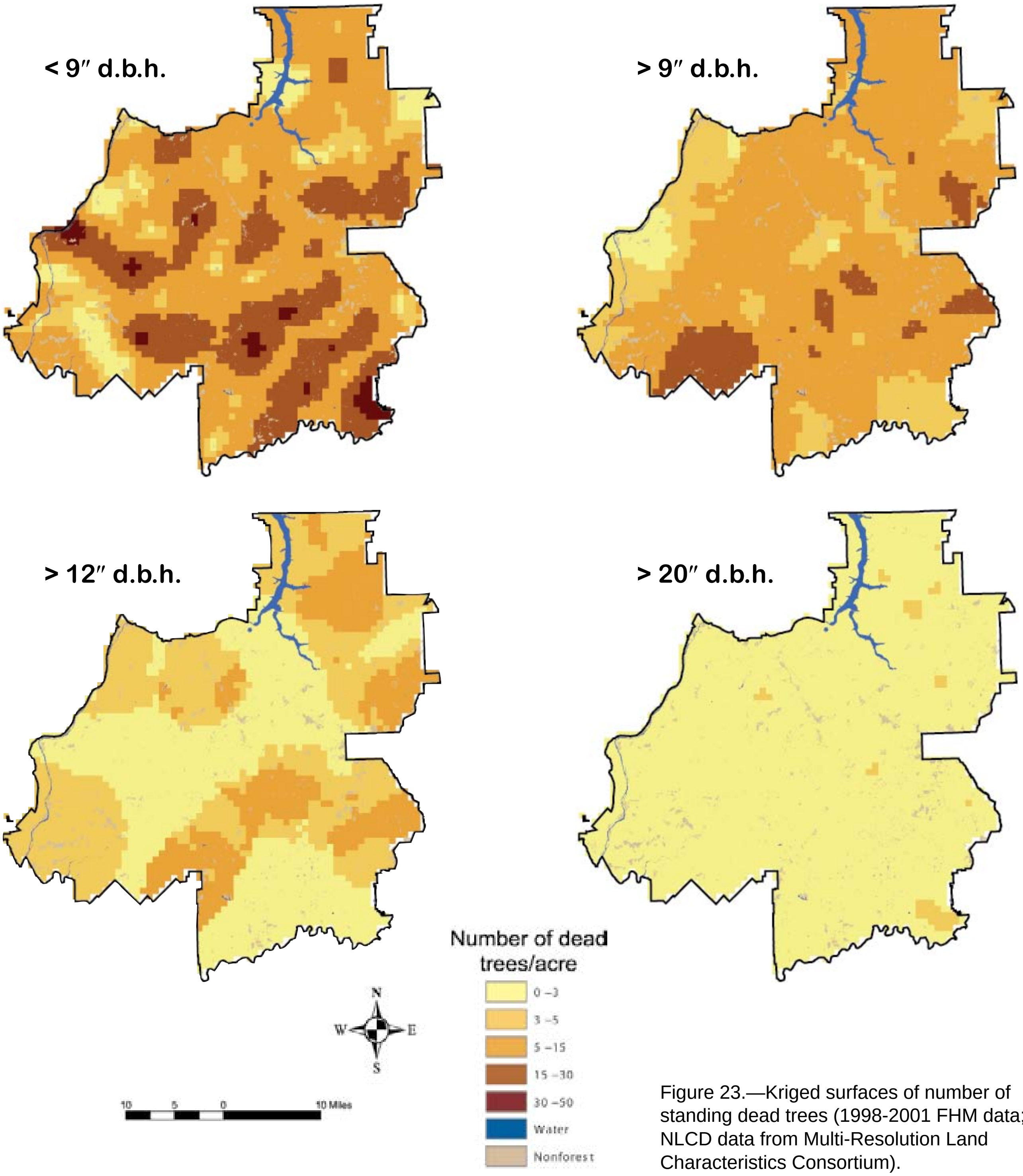


Figure 23.—Kriged surfaces of number of standing dead trees (1998-2001 FHM data; NLCD data from Multi-Resolution Land Characteristics Consortium).

Because the estimated average number of dead trees in the largest size class is slightly below the threshold for optimal habitat (0.39 per acre versus 0.5 per acre), it is less certain that conditions on the ANF meet that criterion, though it is possible that optimal conditions would be met as 94 percent of the ANF is forested (USDA For. Serv. 2000). Thirty-five percent of the plots met requirements for suitable habitat versus 7 percent for optimal conditions.

Figure 23 shows kriged surface representations of the spatial arrangement of the estimated number of dead trees per acre by d.b.h. class from 1998-2001 FHM data.

Table 12.—Overstory richness and diversity indices for trees at least 5.0 inches d.b.h., by Region 9 forest type (1998-2001 FHM data)

Forest type	Species richness	Shannon index	Shannon evenness	Berger-parker index	No. of plot conditions
Mixed upland hardwoods	5.59	1.44	0.46	0.40	50
Allegheny hardwoods	3.74	0.98	0.35	0.57	42
Red maple	3.93	0.99	0.34	0.60	30
Northern hardwoods	5.82	1.44	0.52	0.41	17
Hemlock	4.91	1.14	0.39	0.57	11
White oak/red oak	6.25	1.47	0.45	0.45	8
Sugar maple	2.00	0.50	0.32	0.74	8
Oak/hardwood transition	5.86	1.44	0.44	0.46	7

Table 13.—Overstory richness and diversity indices for trees at least 5.0 inches d.b.h., by stand development stage (1998-2001 FHM data) and deer density

Stand-development category	Species richness	Shannon index	Shannon evenness	Berger-parker index	No. of plot conditions	No. of deer per mile^2
Stand initiation (0-14 years)	2.17	0.58	0.47	0.71	17	25-28
Stem exclusion (15-49 years)	3.67	0.77	0.30	0.71	19	21-50
Understory reinitiation (50+ years)	4.95	1.26	0.42	0.48	153	0-21

Overstory Species Richness and Diversity

All indices were calculated by plot condition; categories with fewer than seven plot conditions were excluded due to small sample sizes. The average species richness, Shannon index, Shannon evenness, and Berger-Parker index were calculated for each FHM plot condition by Eastern Region forest type (Table 12) and stand development category (Table 13). Among Eastern Region types, species richness ranged from 2.0 in the sugar maple type to 6.25 in the white oak/red oak type. The Shannon index ranged from 0.5 in the sugar maple type to 1.47 in the white oak/red oak type. Shannon evenness ranged from 0.32 in the sugar maple type to 0.52 in the northern hardwoods type. The Berger-Parker index ranged from 0.4 in the mixed upland hardwoods type to 0.74 in the sugar maple type.

Forest type is a reflection of site conditions favoring one set of vegetation over another, and site differences might account for variation in diversity. In defining forest types, a name is assigned when the defining species represents more than half of the basal area. Forest types defined as mixed have inherently more diversity than those defined as single species or two species. However, it is possible that species comprising the remaining 50 percent of the basal area are more diverse in some forest types than in others.

Differences in species diversity can be related to a variety of ecological factors and land uses. Silvicultural practices in certain stands might have reduced the abundance of some species and favored others. However, few silvicultural practices completely eliminate species. Physiography and soils strongly determine the composition, size, and productivity of vegetation (Barnes et al. 1992). Soil moisture, nutrients, and pH control species composition, size, and productivity. Whitney (1986) observed that hardwoods were common on richer, finer textured soils of moraines and ridges in presettlement pine sites in Michigan. Coarse-textured, excessively drained soils of ridges favored oaks while finer textured soils of uplands supported more nutrient-demanding hardwoods. American beech and sugar maple grew on coarser textured loams, while hemlock grew on finer textured loams and clays. In New York, the composition of overstory species was positively related to soil texture, stoniness, pH, specific conductance, soil moisture, and percent organic matter (Seischab and Bernard 1991; 1996; Bernard and Seischab 1995). Differences in soils were significant among communities at the Waterloo Barrens in Maine where cation exchange capacity (CEC), pH, Ca, Mg, P, percent organic matter, and total N differed significantly among five vegetation community types identified (Copenheaver et al. 2000). These kinds of relationships merit further investigation on the ANF.

Among stand-development categories, species richness ranged from 2.17 in the stand initiation phase to 4.95 in the understory reinitation phase (Table 13). The Shannon index ranged from 0.58 in the stand initiation phase (0 to 14 years old) to 1.26 in the understory reinitiation phase (50+ years old). Shannon evenness ranged from 0.3 in the stem exclusion phase (15 to 49 years old) to 0.47 in the stand initiation phase. The Berger-Parker index ranged from 0.48 in the understory reinitation phase to 0.71 in the stem exclusion and stand initiation phases.

Disturbance plays an important role in the assembly and maintenance of plant communities beneath the canopy of forests. It can be defined as the mechanism(s) that limit plant biomass by causing its partial or total destruction (Grime 2001). A forested community usually has an understory that is stable due to the natural cycling of small-scale disturbances (Odum 1969). Halpern and Spies (1995) suggested that there are two classes of disturbance effects: initial effects that occur as a direct result of the disturbance and long-term effects on species recovery. Initial effects consist primarily of destruction of vegetation and of propagules through modification of habitat such as seedbed disturbance, changes in light, temperature, and moisture (Gilliam and Roberts 2003). Long-term effects result from changes in species composition, rates of stand development, and competitive interactions.

Table 13 shows that overstory species richness is higher in the stem exclusion and understory reinitiation categories than in the stand initiation category. Several factors likely contributed to this result, particularly deer browsing. Species richness of overstory trees is highest where deer densities were lowest at the time the stands originated, likely reflecting the ability of deer to selectively remove species preferred as food. Also, in the stand initiation phase, there may be as many species present as in the other phases (or at least more than are reflected in the species richness value). However, slower growing, more shade-tolerant species such as American beech and sugar maple were too small (at least 5 inches d.b.h.) to be measured. Faster growing, intolerant species such as black and pin cherry tend to dominate first, attaining larger diameters faster. As a result, fewer species were measured in younger stands. Additional research is needed to confirm the importance of these factors.

Species in the understory can reappear following disturbance by one or more of four basic mechanisms summarized by Gilliam and Roberts (2003): 1) Survival in situ--plants may survive in vegetative form due to the patchy nature of disturbance and low severity of some disturbances, 2) Vegetative regeneration--many plants reproduce vegetatively (Bierzychudek 1982), new shoots form when the aboveground portion of vegetation is killed or damaged, 3) Regeneration from the seedbank, and 4) Regeneration by dispersed propagules. Persistence of community composition in forest understories is referred to as stability, resistance, or resilience (Halpern 1989).

Oliver and Larson (1996) described two patterns of stand development after a disturbance: relay floristics and initial floristics. Relay floristics is one species after another invading a site in a "relaylike" manner. By contrast, according to the initial floristics pattern, species that predominate later have been present since the disturbance. The development pattern after a disturbance usually follows the initial floristics concept.

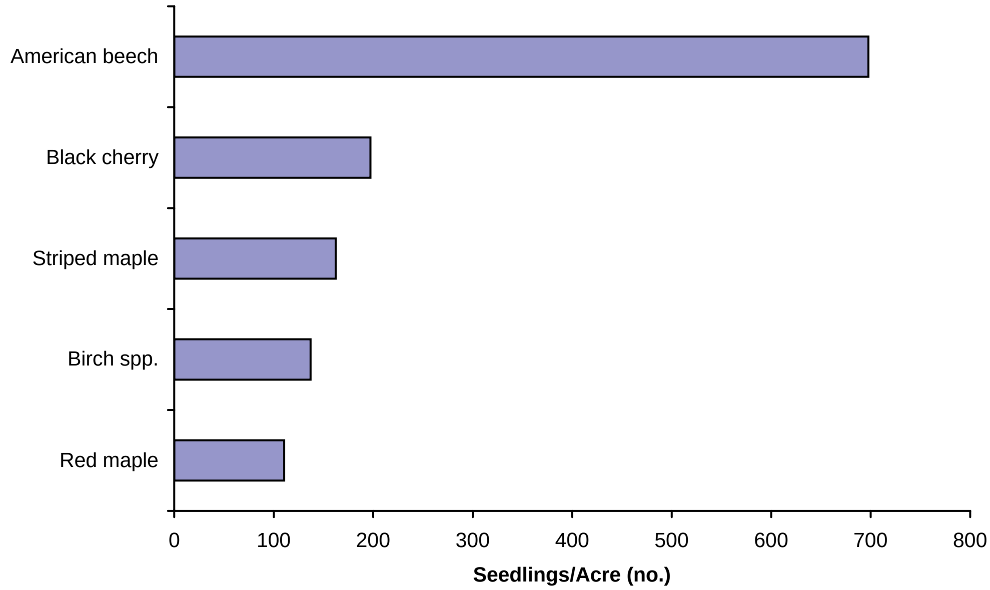


Figure 24.—Number of seedlings per acre on non-oak sawtimber plots (116 plot conditions).

Understory Conditions

Seedling and Sapling Counts

Several studies have reported low stocking of seedlings/saplings in forested stand understories on various portions of the ANF (USDA For. Serv. 1995; McWilliams et al. 1996; 1999; USDA For. Serv. 2000). Browsing associated with high deer populations for more than 70 years has resulted in a lack of understory conditions as deer selectively removed herbaceous plants, shrubs, and tree seedlings. When desired native plants were removed or died, other vegetation (beech, striped maple, ferns, and grass) occupied much of the vacant growing space interfering with the development and growth of tree seedlings.

Where interfering plants are abundant, it is difficult for seedlings (and other native plants) to become established. This has important consequences when catastrophic removal events (e.g., wind damage) occur. It is difficult for vigorous young trees to grow from seed, gain dominance over interfering plants, and replace trees that die.

It is important to quantify densities of seedlings and saplings to predict future stand composition. FHM plots are divided into three stand-size classes based on the average d.b.h. of all live trees that are not overtopped. Stand sizes are defined as sawtimber (11+ inches d.b.h.), poletimber (5 to 10.9 inches d.b.h.), and seedling/sapling (less than 5 inches d.b.h.). For this analysis we calculated the number of seedlings and saplings per acre for each size class. The oak types are the most distinctly different forest types on the ANF, and great concern has been expressed about how to develop the oak seedling component. This separation is important because of the distinct differences between these forest ecosystems and concerns related to the sustainability of the oak forest type group in the eastern United States (Johnson et al. 2002). Therefore, we calculated seedling and sapling density separately for non-oak and oak sawtimber plots. Seedling and sapling data are collected at 6.8-foot, fixed-radius circular microplots. A seedling was defined as a tree at least 1 foot tall but less than 1 inch d.b.h. Saplings were defined as live trees 1 to 4.9 inches d.b.h. It should be noted that seedlings less than 1 foot tall are not counted according to FHM protocol; this affects the estimated species distribution. ANF protocol includes counting all seedlings with a woody stem (i.e., at least 2 years old) and two normal leaves (even if less than 1 foot tall) (Marquis et al. 1992).

Sawtimber Plots

Non-Oak Plots

American beech was the most abundant seedling species on non-oak sawtimber plots followed by black cherry, striped maple, birch spp., and red maple (Fig. 24). Most of the beech stems probably originated from root sprouts. Species with an average of fewer than 100 seedlings per acre included serviceberry, eastern hophornbeam, eastern hemlock, American hornbeam, sassafras, northern red oak, white oak, blackgum, chokecherry, cucumbertree, white ash, Norway spruce, sugar maple, pin cherry, American chestnut, eastern white pine, and American mountain-ash.

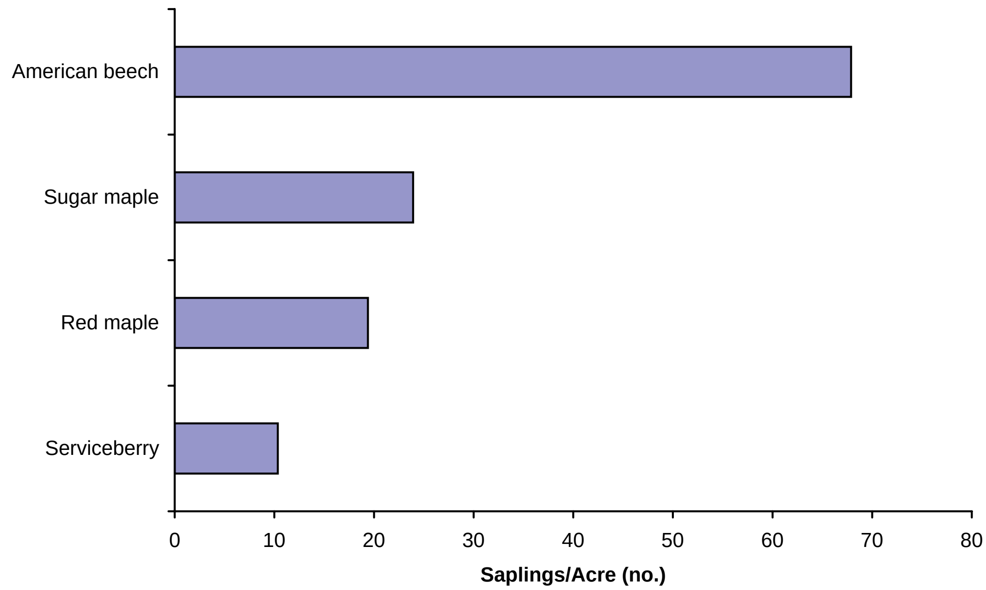


Figure 25.—Number of saplings per acre on non-oak sawtimber plots (116 plot conditions).

American beech was the most abundant sapling on non-oak sawtimber plots followed by sugar maple, red maple, and serviceberry (Fig. 25). Species with fewer than 10 saplings per acre included striped maple, eastern hemlock, American hornbeam, eastern hophornbeam, sweet birch, yellow birch, white ash, and eastern white pine.

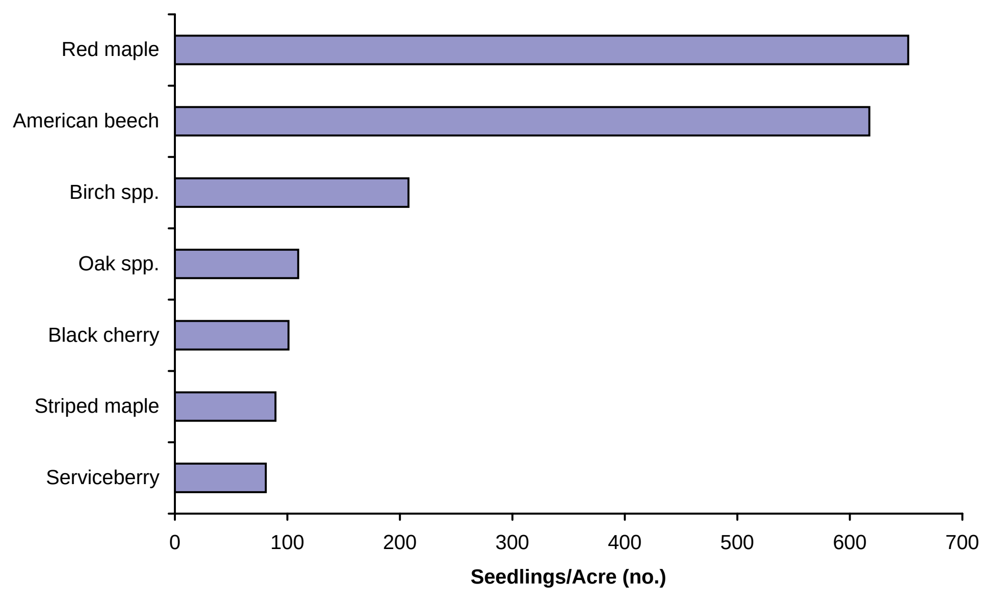


Figure 26.—Number of seedlings per acre on oak sawtimber plots (26 plot conditions).

American beech is more than twice as abundant as any species in both the seedling and sapling classes, with nearly as many stems/acre in each size class as all other species combined. This has raised concerns about long-term forest sustainability, particularly as American beech is susceptible to the beech bark disease complex. Reforestation practices should be implemented to encourage the establishment and development of other tree species.

Oak Plots

Red maple was the most abundant seedling on oak sawtimber plots followed closely by American beech and a much lower abundance of birch spp., oak spp., black cherry, striped maple, and serviceberry (Fig. 26). Of the oak seedlings, 55 percent were northern red oak, 24 percent were white oak, 13 percent were chestnut oak, and 8 percent were scarlet oak. Species with fewer than 50 seedlings per acre included white ash, hawthorn, white oak, sassafras, chestnut oak, scarlet oak, chokecherry, eastern hophornbeam, pignut hickory, blackgum, cucumbertree, American chestnut, sugar maple, and eastern white pine.

American beech was the most abundant sapling on oak sawtimber plots followed by red maple, birch spp., oak spp., and sugar maple (Fig. 27). Of the oak saplings, black and chestnut oak each accounted for 33 percent while white and northern red oak each accounted for 17 percent. Species with fewer than 10 saplings per acre included blackgum, hawthorn, black oak, chestnut oak, serviceberry, northern red oak, white oak, cucumbertree, white ash, hickory spp., and eastern white pine.

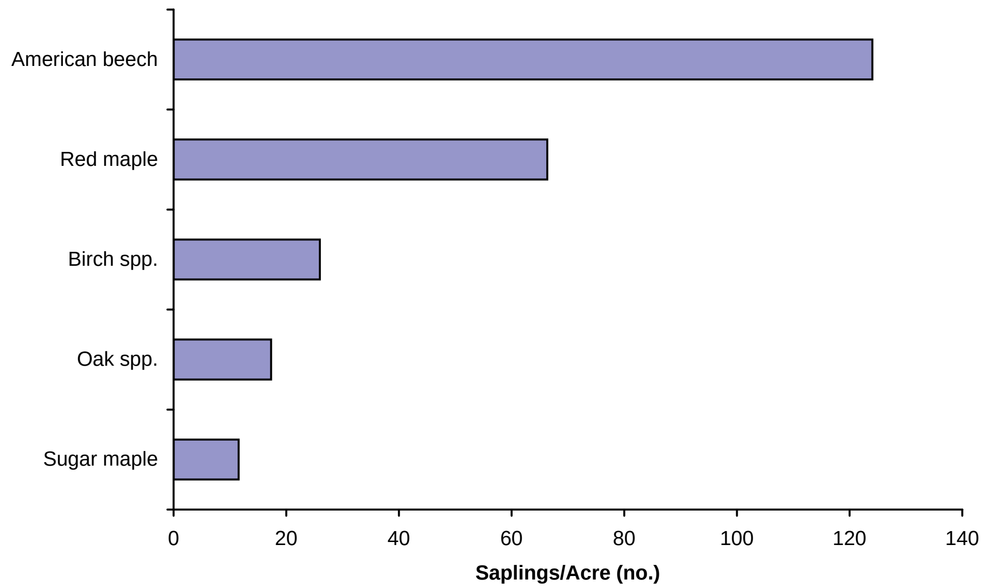


Figure 27.—Number of saplings per acre on oak sawtimber plots (26 plot conditions).

Non-oak seedlings and saplings are 17 and 15 times times more abundant, respectively, than all oak species combined. ANF silvicultural guidelines reflect the importance of adequate numbers of oak seedlings and saplings in determining future species composition (Horsley et al. 1994). Unless this overwhelming abundance of non-oak regeneration changes through natural causes or reforestation, little oak forest will be sustained over the long term, both where timber harvesting occurs and where it is prohibited.

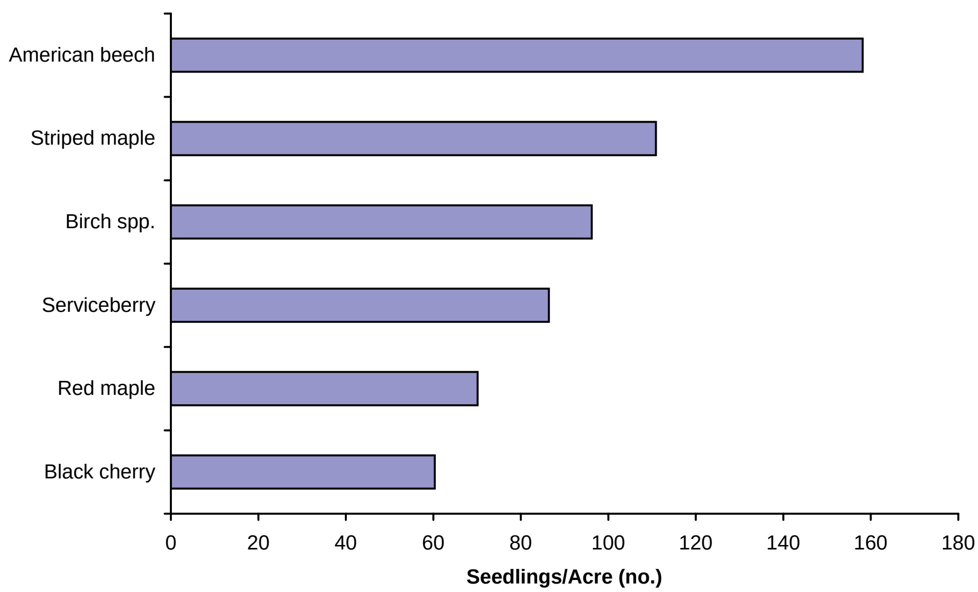


Figure 28.—Number of seedlings per acre on poletimber plots (46 plot conditions).

Poletimber Plots

No distinction was made between non-oak versus oak poletimber plots due to the small sample size for oak poletimber. The distribution of seedlings in poletimber plots was similar to that for non-oak sawtimber plots. American beech was the most abundant species followed by striped maple, birch spp., serviceberry, red maple, and black cherry (Fig. 28). In contrast to the non-oak sawtimber plots (Fig. 24), the number of seedlings per acre is substantially lower on the poletimber plots primarily due to the decrease in American beech and black cherry seedlings. This decrease probably is due to the relatively high density of stems in poletimber versus sawtimber stands, which, in turn, resulted in a lower amount of light reaching the forest floor. Species with fewer than 50 seedlings per acre included sugar maple, sassafras, pin cherry, American hornbeam, northern red oak, American basswood, quaking aspen, eastern hophornbeam, white ash, and eastern hemlock.

Sweet birch was the most abundant sapling on poletimber plots followed by black cherry, American beech, sugar maple, red maple, and yellow birch (Fig. 29). Birch spp. had twice as many saplings per acre as other species. Species excluded (those with fewer than 10 saplings per acre) were serviceberry, striped maple, eastern hemlock, pin cherry, blue spruce, sassafras, quaking aspen, chokecherry, eastern hophornbeam, and white ash.

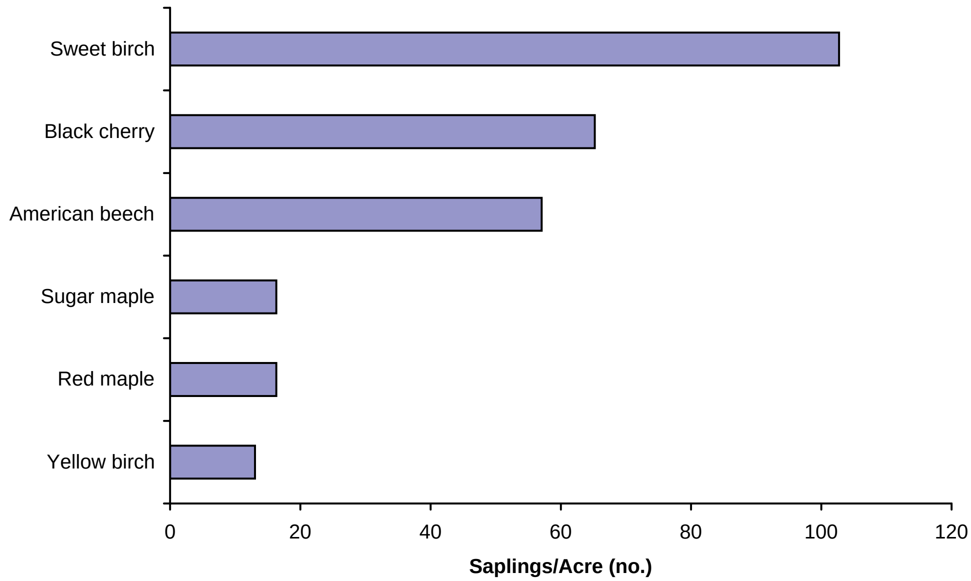


Figure 29.—Number of saplings per acre on poletimber plots (46 plot conditions).

Sweet birch saplings were much more abundant and black cherry saplings were somewhat more abundant on poletimber plots (Fig. 29) than on sawtimber plots (Fig. 25). This probably reflects differences in deer density at the time of stand initiation or the effects of self-thinning of shade-intolerant black cherry. The impact of deer was much lower at the time current sawtimber stands were initiated. Both sweet birch and black cherry are intermediate to low in preference by deer on the Allegheny Plateau (Healy 1971). Sugar and red maple saplings are similar in abundance.

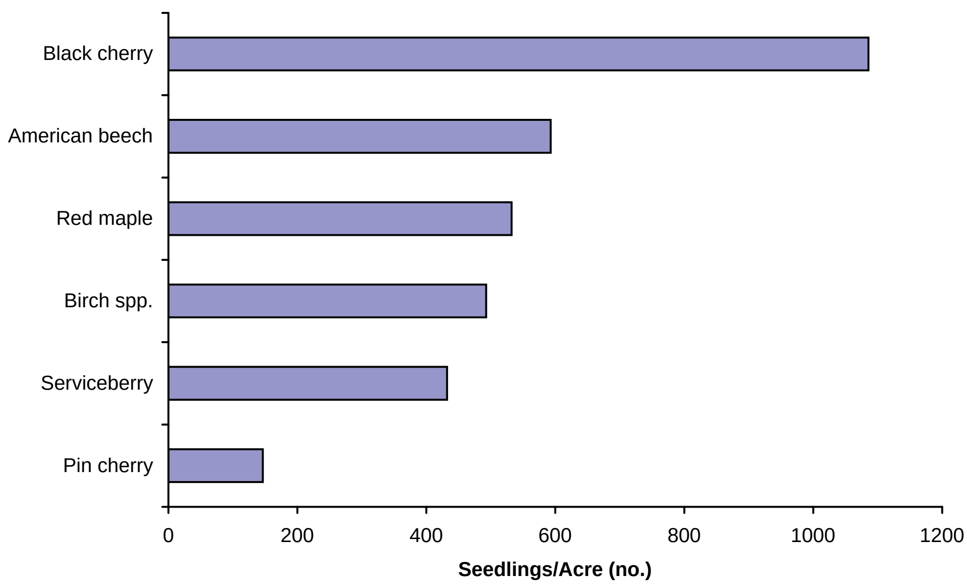


Figure 30.—Number of seedlings per acre on seedling/sapling plots (21 plot conditions).

Seedling/Sapling Plots

Oak and non-oak plots again were combined for analysis due to small numbers of plots in the separate types. Black cherry was the most abundant seedling on seedling/sapling plots followed by American beech, red maple, birch spp., serviceberry, and pin cherry (Fig. 30). Species excluded (those with fewer than 90 seedlings per acre) were striped maple, northern red oak, white oak, eastern hophornbeam, chokecherry, American hornbeam, white ash, and eastern hemlock.

Black cherry, red maple, birch, serviceberry, and pin cherry seedlings were much more abundant on seedling/sapling plots (Fig. 30) than on sawtimber plots (Fig. 24). American beech is similar in seedling abundance on sawtimber and seedling/sapling plots. Again, this reflects differences in deer impact at the time of initiation of current sawtimber and seedling/sapling stands.

Black cherry saplings were the most abundant species on seedling/sapling plots followed by sweet birch, red maple, pin cherry, and American beech (Fig. 31). Once black cherry establishes itself as a seedling in an opening where it is free to grow, growth is rapid and this species dominates the site. Species with fewer than 60 saplings per acre included striped maple, chokecherry, yellow birch, northern red oak, sugar maple, eastern hemlock, white oak, eastern hophornbeam, and serviceberry.

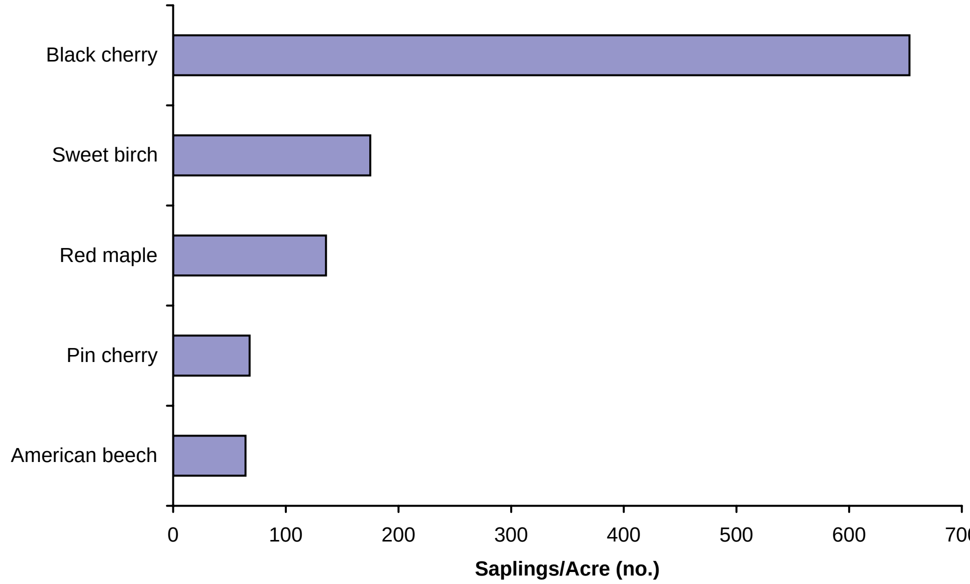


Figure 31.—Number of saplings per acre on seedling/sapling plots (21 plot conditions).

Since black cherry is an abundant sapling in all the stand sizes, this species is likely to increase in dominance on the ANF over the next century. As stated earlier, the most important factor in the dominance of black cherry is that it is not preferred by white-tailed deer. The virtual absence of oak regeneration indicates that oak-dominated stands may transition to stands dominated by other species unless steps are taken to ensure its inclusion. Marquis et al. (1992) outlined standards for achieving desirable regeneration in hardwood forests of the Alleghenies based on surveys using plots. The standards were adjusted to estimate whether each 6.8-foot-radius FHM microplot would be considered stocked with desirable regeneration. When these criteria were used, only 64 of 692 FHM microplots (9.2 percent) met the standards for adequate stocking of tree seedlings.

This low percentage underscores both the adverse effect of deer (Tilgman 1989; Horsley et al. 2003) and the need for reforestation practices that enhance seedling development and diversity, e.g., herbicide/fencing (Horsley et al. 1994) and release treatments (Ristau and Horsley 1999).

Seedling and Sapling Richness and Diversity

Average species richness, Shannon index, Shannon evenness, and Berger-Parker index of seedlings and saplings were calculated for each FHM plot condition by Eastern Region forest type and stand-development category (Tables 14-17).

Since development following a disturbance usually follows the initial floristics concept (Oliver and Larson 1996), sites in the stand initiation phase contain many species. As the canopy closes and the stem exclusion phase occurs, only shade-tolerant species survive in the understory as advance regeneration, e.g., sugar maple and American beech.

Sustainability of Tree Species

Analysis of survey data collected in 1992 from a 6,000-plot sample on 60 percent of the ANF raised concerns about long-term tree species sustainability/diversity (USDA For. Serv. 1995). Specifically, certain species represented in the overstory tree tally are not represented at all or are poorly represented in the tree seedling tally. Analysis of 1998-2001 FHM data raised similar concerns, though the FHM analysis was not designed to address sustainability. Table 18 summarizes the average number of stems per acre tallied for four size classes--seedling (at least 1 foot tall and less than 0.9 inch d.b.h.), sapling (1 to 4.9 inches d.b.h.), trees 5 to 10.9 inches d.b.h., and trees 11 or more inches d.b.h. on FHM plots.

Six tree species with overstory trees tallied had no seedlings or saplings tallied (red pine, shagbark hickory,

Table 14.—Seedling richness and diversity indices, by Eastern Region forest type (1998-2001 FHM data)

Forest type	Species richness	Shannon index	Shannon evenness	Berger-parker index	No. of plot conditions
Mixed upland hardwoods	2.52	0.56	0.28	0.25	50
Allegheny hardwoods	2.62	0.58	0.23	0.22	42
Red maple	2.50	0.56	0.25	0.26	30
Northern hardwoods	1.82	0.46	0.30	0.35	17
Hemlock	2.55	0.50	0.22	0.34	11
White oak/red oak	3.25	0.68	0.42	0.36	8
Sugar maple	5.00	0.71	0.21	0.12	8
Oak/hardwood transition	1.00	0.15	0.12	0.75	7

Table 15.—Seedling richness and diversity indices, by stand development stage (1998-2001 FHM data)

Stand development stage	Species richness	Shannon index	Shannon evenness	Berger-parker index	No. of plot conditions
Stand initiation (0-14 years)	4.53	0.68	0.18	0.11	17
Stem exclusion (14-49 years)	2.89	0.51	0.21	0.33	19
Understory reinitiation (50+ years)	2.37	0.54	0.27	0.30	153

Table 16.—Sapling richness and diversity indices, by Eastern Region forest type (1998-2001 FHM data)

Forest type	Species richness	Shannon index	Shannon Evenness	Berger-parker index	No. of plot conditions
Mixed upland hardwoods	1.50	0.26	0.37	0.86	50
Allegheny hardwoods	1.97	0.46	0.33	0.79	42
Red maple	1.72	0.36	0.33	0.80	30
Northern hardwoods	1.29	0.18	0.30	0.89	17
Hemlock	2.00	0.23	0.16	0.93	11
White oak/red oak	1.43	0.23	0.17	0.88	8
Sugar maple	2.43	0.59	0.27	0.74	8
Oak/hardwood transition	2.00	0.46	0.31	0.79	7

Table 17.—Sapling richness and diversity indices, by stand development stage (1998-2001 FHM data)

Stand development category	Species richness	Shannon index	Shannon evenness	Berger-parker index	No. of plot conditions
Stand initiation (0-14 years)	2.29	0.50	0.18	0.77	17
Stem exclusion (14-49 years)	2.16	0.47	0.28	0.79	19
Understory reinitiation (50+ years)	1.53	0.29	0.35	0.84	153

Table 18.—Number of stems per acre by species and size class (1998-2001 FHM data)

Species	Trees 5-11 inches d.b.h.	Trees 12+ inches d.b.h.	Saplings	Seedlings
Norway spruce	5	1	0	75
white spruce	7	1	0	0
blue spruce	15	0	25	0
slash pine	0	1	0	0
red pine	8	6	0	0
eastern white pine	7	4	12.5	37.5
eastern hemlock	400	127	200	237.5
striped maple	1	0	425	4687.5
red maple	579	473	1200	7387.5
sugar maple	326	92	575	437.5
mountian maple	0	0	0	25
serviceberry	56	3	287.5	4287.5
birch spp.	0	0	125	1712.5
yellow birch	114	33	287.5	487.5
sweet birch	166	58	1462.5	3862.5
American hornbeam	11	0	112.5	312.5
hickory spp.	2	0	12.5	0
pignut hickory	2	0	0	25
shagbark hickory	1	0	0	0
mockernut hickory	4	0	0	0
American chestnut	0	0	0	62.5
hawthorn	0	0	37.5	175
common persimmon	1	0	0	12.5
American beech	376	105	2412.5	19462.5
ash spp.	1	1	0	12.5
white ash	17	33	25	312.5
yellow-poplar	0	14	0	0
cucumbertree	13	23	12.5	87.5
blackgum	11	0	37.5	100
eastern hophornbeam	9	0	100	437.5
sycamore	1	0	0	0
bigtooth aspen	9	11	175	25
quaking aspen	8	4	12.5	37.5
cherry and plum spp.	0	0	0	25
pin cherry	37	1	262.5	650
black cherry	335	471	3362.5	8512.5
chokecherry	0	0	0	112.5
white oak	32	46	12.5	250
scarlet oak	2	5	0	37.5
chestnut oak	9	16	0	62.5
northern red oak	21	85	37.5	637.5
black oak	13	12	0	0
sassafras	12	0	12.5	450
American mountain-ash	0	0	0	12.5
basswood spp.	0	2	0	0
American basswood	8	17	0	37.5

mockernut hickory, yellow-poplar, sycamore, and black oak). Only yellow-poplar had a sufficient number of overstory trees sampled to justify initial inferences from the data. Other tree species with substantially fewer seedlings or saplings tallied than overstory trees include eastern white pine, eastern hemlock, sugar maple, white ash, cucumbertree, black gum, bigtooth aspen, quaking aspen, white oak, scarlet oak, chestnut oak, and American basswood. The lack of seedlings of these species may be due to seed crop issues (infrequent or small crops), poor seedling survival due to overbrowsing by deer, or poor site quality. All of these conditions raise questions about sustainability over the long term. When overstory trees of these species die, are blown down, or are removed, will they be replaced by adequate numbers of young, vigorously growing stems of the same species?

Seedlings of some species are ephemeral, particularly where deer browsing is significant and there is substantial interference from other plants, e.g., fern, grass, striped maple, and American beech root suckers. For example, sugar maple may develop numerous seedlings initially but few become established and grow to a larger size class. In Table 18, the sugar maple shown for the sapling and 5- to 11-inch d.b.h. classes generally are the same age as stems in the greater than 11-inch class; these are stems that were suppressed by faster growing species following forest removals at the turn of the 19th century. Red maple has many small seedlings but often fails to develop well-established, larger seedlings or saplings that can become a codominant component of the next stand. This species is highly preferred by deer and requires several years of low browsing impact to become established in the moderate shade of stands with overabundant numbers of large saplings and small poles.

Additional research is needed to assess the dynamics of tree-seedling development and determine the conditions for successful regeneration. In managed areas, local research and data from ANF post-reforestation treatment surveys suggest that tree species and herbaceous diversity is improved where area fencing (often supplemented by an herbicide treatment) is used, e.g., seedlings of some species preferred by deer begin to develop over time. An assessment of individual species has not been completed.

Disturbance Processes on the Allegheny National Forest

The role of nsects and pathogens in natural disturbance dynamics usually is positive as they cycle nutrients from foliage to soils, kill weak or noncompetitive trees, and decompose dead trees (Haack and Byler 1993). Most insects and diseases rarely reach epidemic levels, but some insect pests cause significant damage at outbreak levels (Mason 1987). Between 1991 and 1996, native insects that reached outbreak levels on the ANF included cherry scallopshell moth, elm spanworm, forest tent caterpillar, and oak leaftier. Collectively, these caterpillars defoliated 611,000 acres.

Exotic organisms are a serious threat to the ecological balance that has evolved through thousands of years of coexistence among native insects, pathogens, and host-tree species (Haack and Byler 1993; Liebhold et al. 1995). Non-native pest species have more frequent outbreaks due to their lack of natural enemies. Damaging exotic organisms on the ANF include gypsy moth, beech bark disease, and pear thrips. The gypsy moth reached outbreak levels on the ANF from 1986 to 1988 and 1991 to 1993. Moreover, the beech scale Nectria complex has been expanding its range southward from New England and New York for many years. It reached the northern portion of the ANF in the early 1980s. Beech mortality associated with this disease first became evident on the ANF in 1986. The disease complex involves the interaction of the European scale insect *Cryptococcus fagisuga* with the exotic canker fungus *Nectria coccinea* var. *faginata* or the native *Nectria galligena*. *Nectria coccinea* var. *faginata* is now thought to be an introduced organism because of its pattern of occurrence in beech scale-infested areas and absence in uninfected forests (Houston 1994).

Natural climatic disturbance (particularly drought) has played a substantial role in shaping the forest ecosystems on the Allegheny Plateau. Four significant drought events between 1988 and 1999 coincided with outbreaks of insect defoliators. Storm activity also has affected the ANF; in 1985, nearly 10,600 acres of forest land were damaged severely by several large tornados.

Figure 32.—Cherry scallopshell moth larva (photo by James B. Hanson, USDA Forest Service, www.forestryimages.org).

Cherry Scallopshell Moth

The native cherry scallopshell moth, *Hydria prunivorata* (Lepidoptera: Geometridae), distributed widely in the Eastern United States and Canada, is not considered a serious pest in most areas. Larvae (Fig. 32) form shelters by fastening together the margins of leaves. Larvae aggregate within these shelters and feed on the upper epidermis of the leaves. As larvae grow, the shelters are enlarged or reformed on new, undefoliated branches (Craighead 1950). This progressive feeding often defoliates entire trees, reducing radial growth the following year. Decline in some stands can occur if repeated defoliations or other stresses occur in successive years (Shultz and Allen 1975; USDA For. Serv. 1979) or in the same year. The cherry scallopshell moth has one generation per year. Pupae overwinter in the leaf litter or in the upper soil layer and adults emerge in late spring to early summer. Females begin laying eggs in late June and continue through midsummer. Pyramid-shape egg masses are laid one to four layers deep on the undersides of leaves (USDA For. Serv. 1979).

The most recent cherry scallopshell moth outbreak on the ANF occurred from 1993 through 1996 (Figs. 33-34). Outbreaks have occurred about every 10 years on the northern Allegheny Plateau. Previous outbreaks occurred from 1972 to 1974 and 1982 to 1984 (Bonstedt 1985). Outbreaks usually last 2 to 3 years and tree decline/mortality can follow after an outbreak. On the ANF, decline has been observed when repeated defoliation or other stresses, e.g., severe drought, occur concurrently or in successive years. Figure 34 shows the area defoliated by the cherry scallopshell moth on the ANF during the last outbreak. The 1995 defoliation affected 290,000 acres (205,000 on federal land), mostly on the southeastern two-thirds of the ANF, despite an important component of black cherry scattered throughout the northern portion.

Because black cherry is the preferred host of cherry scallopshell moth larvae (USDA For. Serv. 1979), and stands dominated by this species were defoliated most often during outbreaks (Table 19); there was a significant

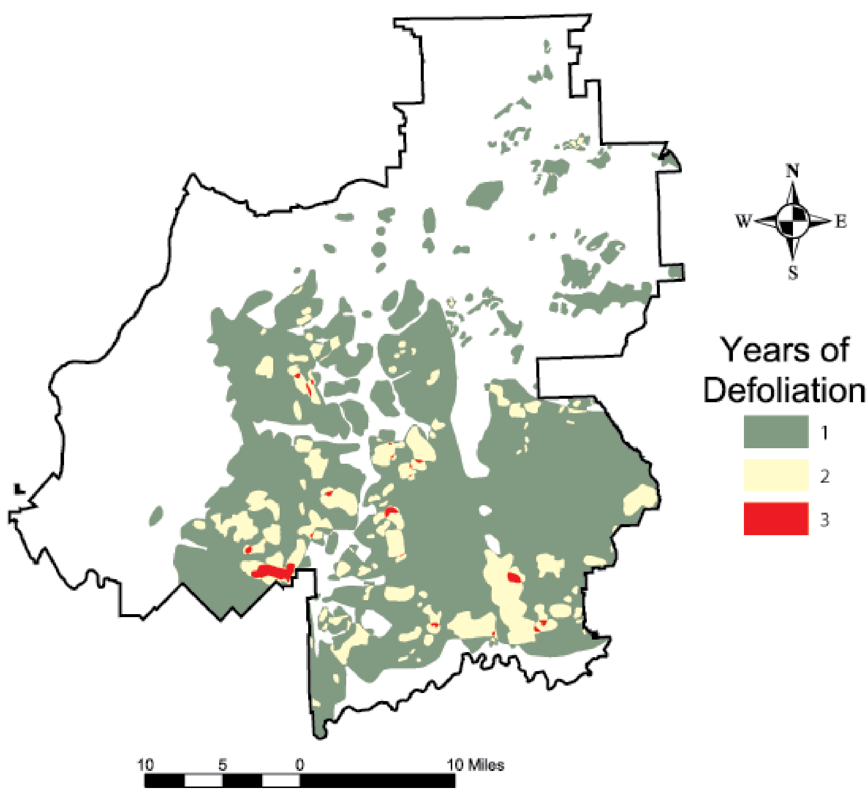


Figure 33.—Frequency of cherry scallopshell moth defoliation from 1993 to 1996 on the ANF.

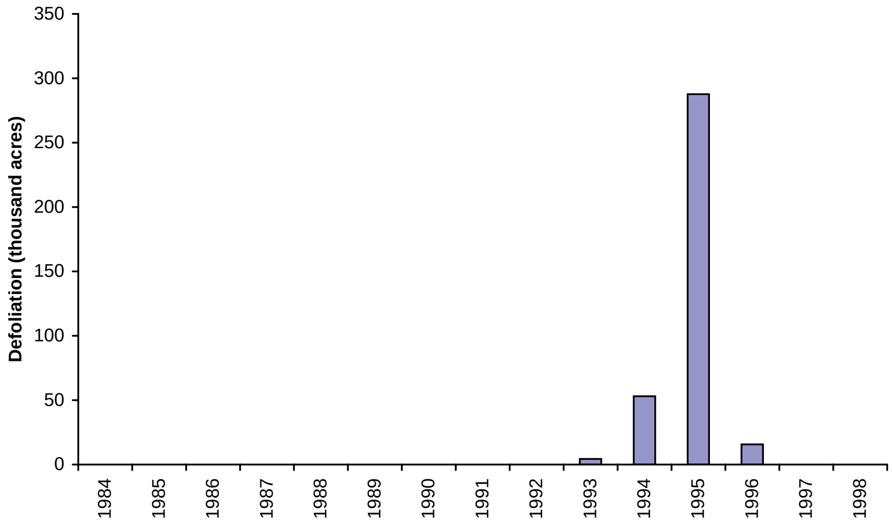


Figure 34.—Acres defoliated by cherry scallopshell moth on the ANF.

Table 19.—Mean stand characteristics averaged over FHM plots grouped by years of defoliation by cherry scallopshell moth (1998-2001 FHM data); number of plots in parentheses (*P* values given for one-way analyses of variance)

Characteristic for	Years of defoliation			
black cherry (%)	0	1	2 or 3	*P* value
Basal area	16.33[a] (81)	30.62[b] (80)	38.87[b] (12)	0.0001*
Mortality	5.45[a] (30)	5.65[a] (58)	17.38[b] (9)	0.0209*
Dieback	7.24 (30)	6.86 (58)	8.87 (9)	0.7530

* Significant at α =0.05 level.

relationship between percent black cherry basal area and years of defoliation (Table 19). The number of years of defoliation was significantly associated with percent standing dead black cherry (Table 19) (Morin et al. 2004). Crown dieback of this species increased with years of cherry scallopshell moth defoliation, though the relationship was not significant (Table 19). With respect to crown condition and mortality, black cherry is affected only by two or more defoliation events, so managers should consider suppression activities following an initial defoliation event.

Elm Spanworm

The elm spanworm, *Ennomos subsignarius* (Lepidoptera: Geometridae), is a native species that is found throughout the Eastern United States and a portion of Canada. Outbreaks are relatively uncommon, though major multiyear outbreaks have occurred in Connecticut and North Carolina. This pest is responsible for periodic severe defoliations of hardwoods such as ash, hickory, walnut, beech, black cherry, elm, basswood, red maple, sugar maple, and yellow birch. Two consecutive summers of defoliation can cause dieback and even mortality when an invasion of secondary pests occurs (USDA For. Serv. 1979).

Elm spanworm has one generation per year. Females lay eggs in small groups on the underside of branches; after overwintering, eggs usually hatch in May or June. Larvae (Fig. 35) feed on the lower surface of leaves but eventually consume everything but the veins (Fig. 36) (USDA For. Serv. 1979). This species is highly polyphagous and nearly all major hardwood species on the ANF are hosts except for yellow-poplar and cucumbertree.

Figure 35.—Elm spanworm larva (photo by Arnold T. Drooz, USDA Forest Service, www.forestryimages.org).

Figure 36.—Elm spanworm defoliation (photo by Arnold T. Drooz, USDA Forest Service, www.forestryimages.org).

The most recent elm spanworm outbreak on the ANF occurred from 1991 through 1993 (Figs. 37-38). The insect population collapsed early in 1994. It is interesting that the western one-third of the ANF had little defoliation even though preferred host tree species were relatively abundant there. In 1993, the area defoliated by the elm spanworm within the proclamation boundary of the ANF covered nearly 340,000 acres (Fig. 38). In 1992, defoliation was substantial following the aerial mapping survey, so the acreage reported in Figure 38 does not reflect total defoliation for that year.

The most highly preferred hosts of elm spanworm on the ANF are black cherry, red maple, sugar maple, and American beech, though the frequency of defoliation was significantly associated only with the proportion of black cherry in stands (Table 20).

As with the cherry scallopshell moth, there was a tendency for greater levels of host crown dieback and tree mortality in stands defoliated by elm spanworm (Table 20). The relationship between sugar maple mortality and years of elm spanworm defoliation was not significant even though mortality was high. This result probably reflects the considerable heterogeneity in site characteristics (e.g., soil nutrition) and low sample size. Also, it may be that crown dieback was low for two or three years of defoliation because many trees already had died. Generally, sugar maple on poor sites die if they suffer more than one defoliation. On good sites sugar maple might survive two or more defoliation events.

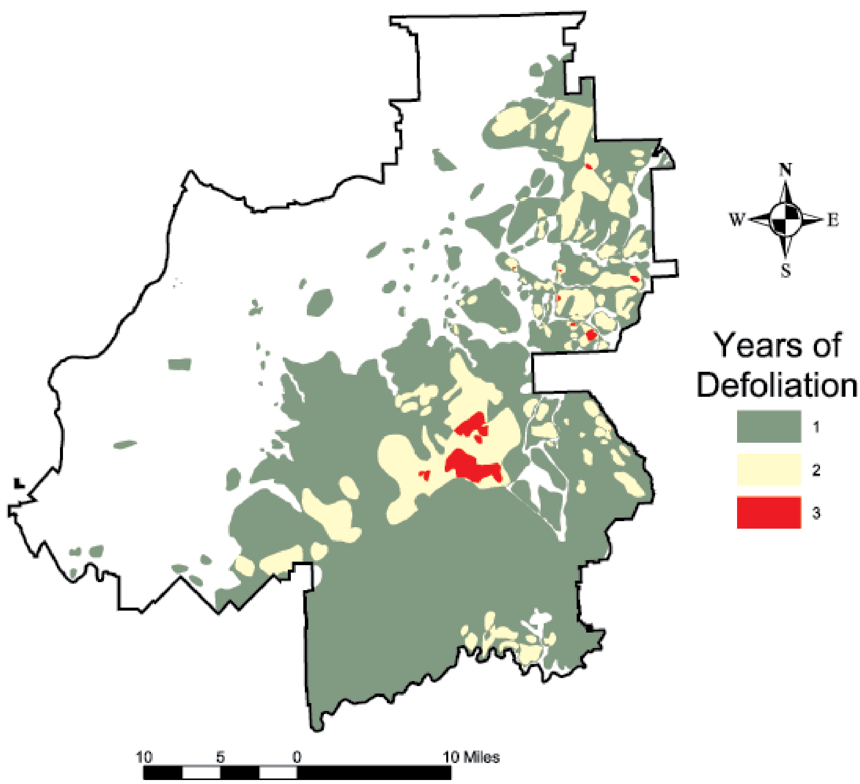


Figure 37.—Frequency of elm spanworm defoliation from 1991 to 1993 on the ANF.

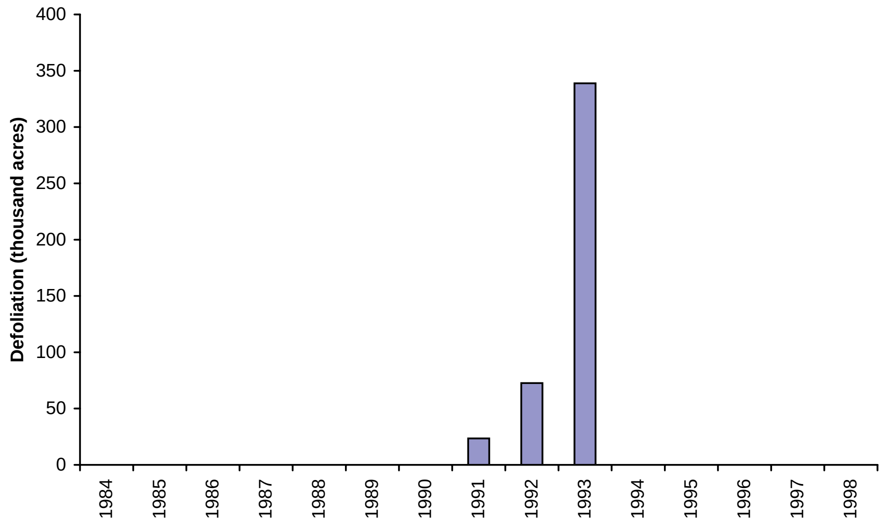


Figure 38.—Acres defoliated by elm spanworm on the ANF.

Table 20.—Mean stand characteristics averaged over FHM plots grouped by years of defoliation by elm spanworm (1998-2001 FHM data); number of plots in parentheses (*P* values given for one-way analyses of variance)

	Years of defoliation			
Stand characteristic (%)	0	1	2 or 3	*P* value
		Black Cherry		
Basal area	15.35[a] (75)	31.46[b] (86)	31.85[b] (12)	0.0001*
Mortality	8.94 (31)	7.54 (59)	15.36 (10)	0.3782
Dieback	5.29 (31)	7.79 (59)	7.7 (10)	0.3185
		Red Maple		
Basal area	22.93 (75)	23.79 (86)	23.57 (12)	0.9641
Mortality	4.71 (58)	4.95 (56)	9.93 (8)	0.2891
Dieback	3.82 (58)	4.41 (56)	4.92 (8)	0.634
		Sugar Maple		
Basal area	6.39 (75)	10.29 (86)	7.12 (12)	0.1978
Mortality	8.22 (15)	15.84 (31)	31.05 (4)	0.1119
Dieback	3.68 (15)	11.11 (31)	1.33 (4)	0.1420
		American Beech		
Basal area	9.65 (75)	10.4 (86)	7.83 (12)	0.7823
Mortality	3.6 (28)	11.5 (27)	9.56 (5)	0.237
Dieback	5.06 (28)	8.76 (27)	6.19 (5)	0.2565

* Significant at α =0.05 level.

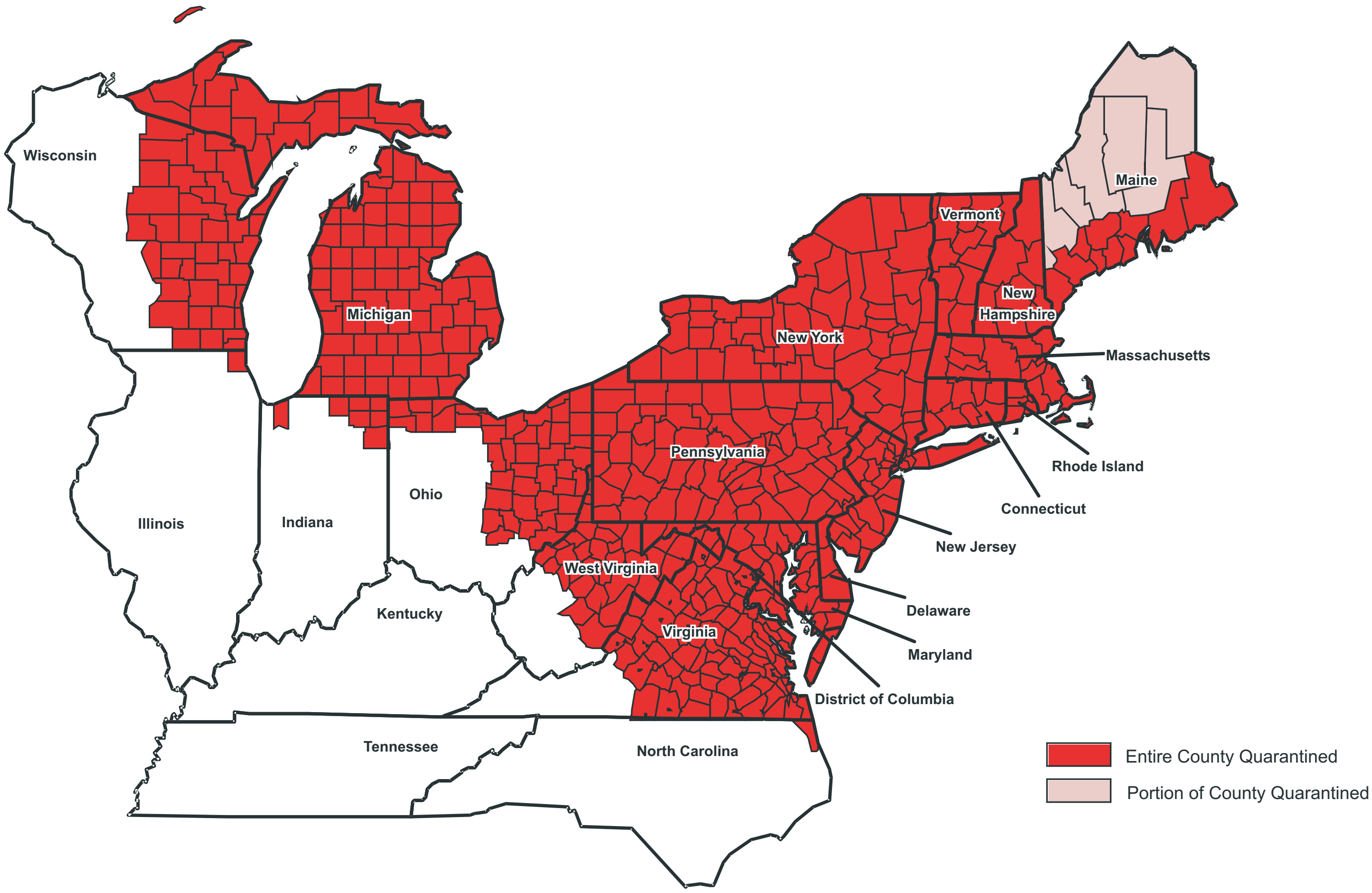


Figure 39.—Gypsy moth quarantine of USDA Animal and Plant Health Inspection Service, 2004.

Gypsy Moth

The gypsy moth, *Lymantria dispar* L. (Lepidoptera: Lymantriidae), was introduced from Europe around 1868 near Boston, Massachusetts. Outbreaks began to occur in that area about 10 years later. Its range has continued to expand and now extends as far west as Wisconsin (Fig. 39). The current estimated rate of spread is about 13 miles per year (Liebhold et al. 1992).

Gypsy moths spend the winter in the egg stage. In April or early May, the eggs hatch and larvae (Fig. 40) feed until June. After feeding is complete, the larvae pupate and emerge as adult moths after about 2 weeks. The adults then mate and the female lays eggs, usually on tree trunks. The gypsy moth has one generation per year (USDA For. Serv. 1979).

Figure 40.—Gypsy moth larva (photo by John H. Gent, USDA Forest Service, www.forestryimages.org).

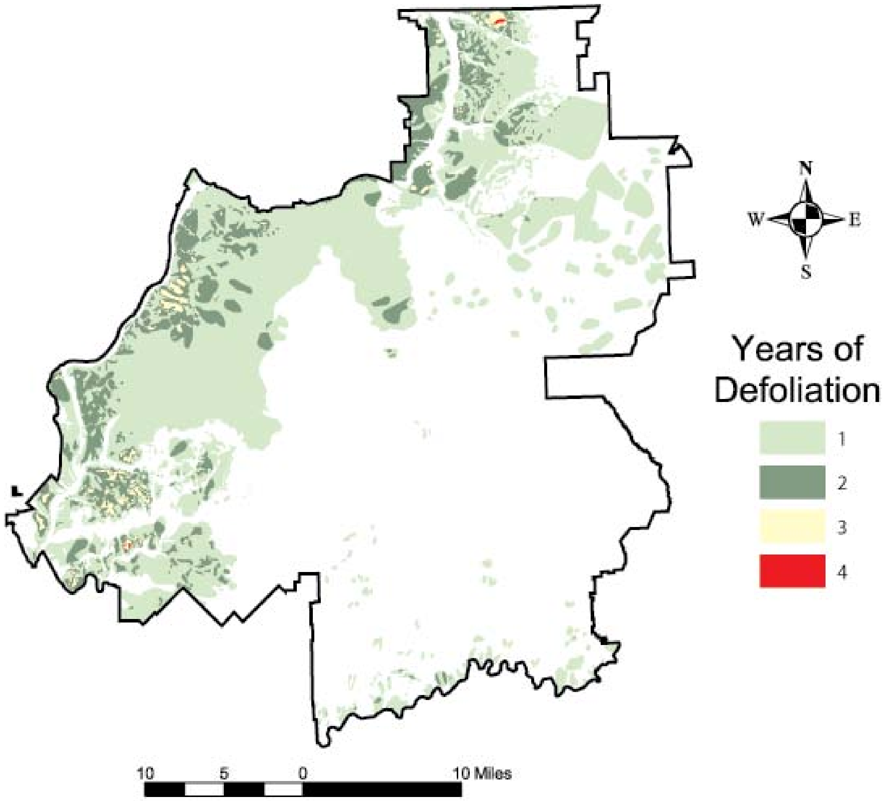


Figure 41.—Frequency of gypsy moth defoliation from 1984 to 1993 on the ANF.

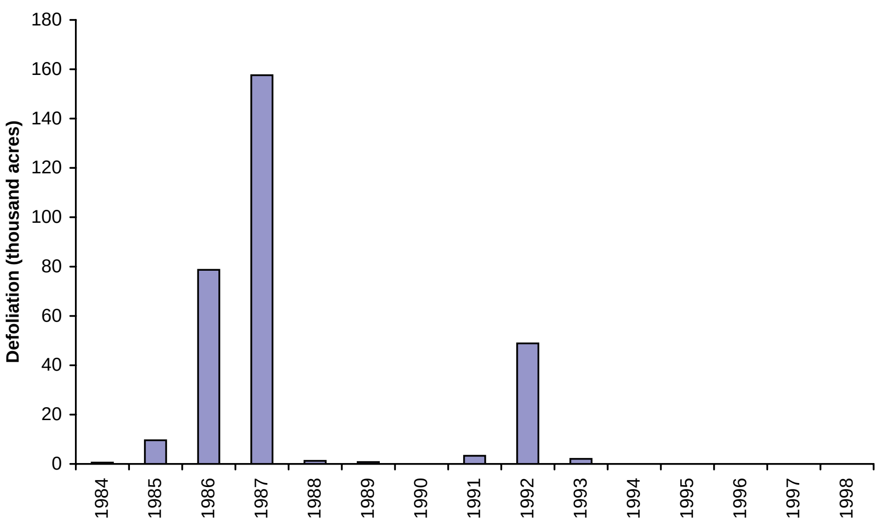


Figure 42.—Acres defoliated by gypsy moth on the ANF.

The most recent major outbreak of gypsy moth on the ANF occurred from 1984 to 1989. A second, less intense outbreak occurred from 1991 to 1993 (Figs. 41-42). Figure 41 shows the area and frequency of defoliation from 1984 to 1993. This frequency distribution is similar to the geographic distributions for northern red, white, and other oaks (Fig. 16). The southern portion of the ANF, just north of the southern boundary, shows little repeated gypsy moth defoliation even though this area has a substantial oak component. Gypsy moth populations peaked in that region later than on the rest of the ANF. Areas in the southern portion that were threatened with repeated severe defoliation were treated more aggressively with aerial applications of the biological insecticide *B.t.* to avoid the higher rates of tree mortality/decline observed elsewhere on the ANF where treatment was less intense. The amount of acreage defoliated by gypsy moth is shown in Figure 42. The worst year during

Table 21.—Mean stand characteristics averaged over FIA plots grouped, by years of defoliation by gypsy moth (1998-2001 FHM data); number of plots in parentheses (P values given for one-way analyses of variance)

Stand characteristic	Years of defoliation		
of all oaks (%)	0	1 or 2	P value
Basal area	2.18[a] (129)	32.83[b] (35)	0.0001*
Mortality	2.85 (6)	9.39 (22)	0.1164

* Significant at α =0.05 level.

the first episode was 1987 when nearly 160,000 acres were defoliated; nearly 50,000 acres were defoliated during the second outbreak in 1992.

The gypsy moth defoliates primarily hardwood trees, especially oak, aspen, and beech, though large larvae feed on other species, particularly during outbreaks (Liebhold et al. 1995). Small larvae feed readily on beech but large larvae avoid this species because its leaves are tough. On the ANF, plots with a higher percentage of oak were defoliated more often by gypsy moth (Table 21). The average amount of basal area of standing dead oak appeared to increase with frequency of defoliation but this relationship was not significant (Table 21).

Beech Bark Disease Complex

Beech bark disease (BBD), an insect-fungus complex that consists of the European scale insect (*Cryptococcus fagisuga*) and the exotic canker fungus *Nectria coccinea* var. *faginata* or the native *Nectria galligena* (Houston 1994), results when a Nectria fungus infects the bark of American beech through the feeding wounds caused by beech scale insects. The beech scale was introduced into Nova Scotia from Europe around the turn of the century. It has since spread southwestward into New England, New York, Pennsylvania, and West Virginia (Manion 1991).

BBD was first detected in Pennsylvania in 1958. Currently, the killing front is moving from the northeast corner toward the southwest corner of the ANF (Fig. 43). The killing front is the area in which trees are infested with both the European scale insect and *Nectria* fungus,

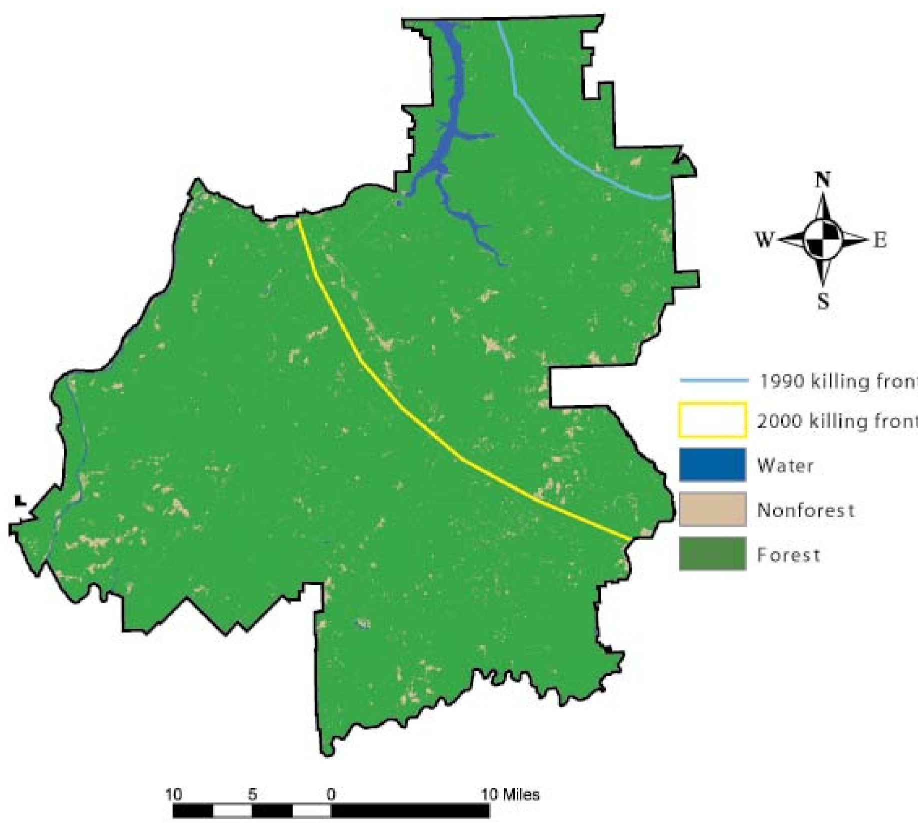


Figure 43.—The 2001 beech bark disease killing front on the ANF from surveys conducted by the USDA Forest Service; NLCD data from Multi-Resolution Land Characteristics Consortium.

Table 22.—Percentage of basal area of standing dead American beech within and outside of killing front of beech bark disease (number of plots in parentheses)

	2001 front		1989 front	
Survey data	Inside	Outside	Inside	Outside
1989 FIA	1.7 (50)	0.8 (73)	2.9 (17)	0.9 (106)
1998-2001 FHM	10.2 (58)	4.1 (64)	9.5 (19)	6.5 (103)

and mortality is occurring. Beech mortality on the ANF was first reported in 1985.

Table 22 shows percent basal area of dead American beech inside and outside of the killing front. Percent standing dead beech was more than twice as great inside than outside the killing front. Beech mortality likely was even higher than reported here since dead beech trees often decay and snap quickly, and thus would not have been measured as standing dead.

An estimated surface of percent standing dead American beech was generated using only FHM plots where this species made up at least 10 percent of the total basal area (Fig. 44). Beech mortality was higher within the killing front though there was significant mortality from other causes (e.g., blowdown) outside of the killing front. Eastern hemlock has shown the greatest increase in relative dominance following the loss of beech to BBD (Runkle 1990; Twery and Patterson 1984; Le Guerrier et al. 2003).

Sugar Maple Decline

Sugar maple dominates the northern hardwood forest, accounting for half or more of the basal area. The largest contiguous area of this forest type extends from northern Ohio and Pennsylvania through southern Ontario and Quebec and eastward through northwestern Massachusetts into western Maine (Nyland 1999).

Numerous reports of sugar maple decline or dieback have been recorded over the last 50 years. Houston (1999) found that crown dieback and death result when at least one predisposing stress event reduces resistance to invasion by opportunistic, secondary organisms that kill tissues. Maple dieback/decline has been associated with insect defoliation, drought, unbalanced nutrition (particularly of Ca, Mg, and K), stand density, and midwinter thaw/freeze events (Long et al. 1997; Houston 1999; Horsley et al. 2000).

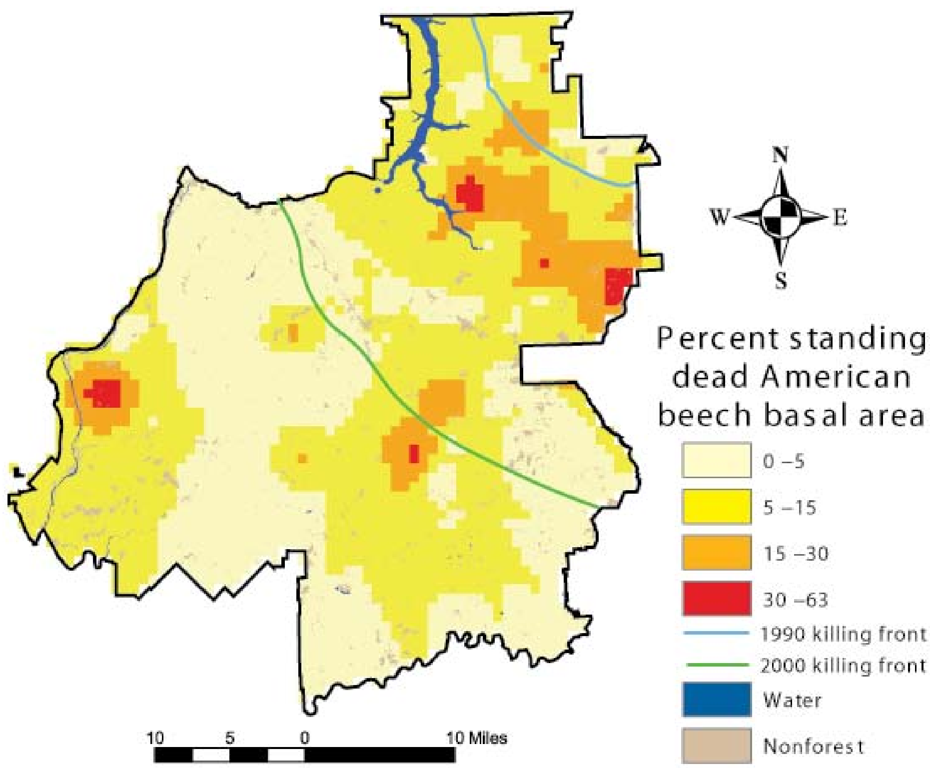


Figure 44.—Kriged surface of percent standing dead American beech basal area (1998-2001 FHM data; NLCD data from Multi-Resolution Land Characteristics Consortium).

Sugar maple can occupy a variety of sites but grows best on moderately fertile and well-drained soils (Godman 1957). It is particularly abundant on lower slopes or coves enriched by leaf litter, colluvium, or nutrient-rich water moving from upslope (Leak 1982; Pregitzer et al. 1983; Smith 1995). In the early to mid-1980s, foresters in northern Pennsylvania observed sugar maple decline in the form of decreased crown vigor, crown dieback, and higher mortality of large trees. Sugar maple growing on the lower slopes of unglaciated sites and in every position on glaciated sites seemed unaffected or only slightly affected. Trees on the upper slopes of unglaciated sites were affected the most. Defoliated stands were more likely to be unhealthy, though not all sites that were defoliated had unhealthy sugar maple. It was concluded that some factor(s) must be involved in making some sites more resistant to decline after defoliation. This resistance was attributed to foliar chemistry (Horsley et al. 2000). Unhealthy sugar maple were found on sites where trees had low foliar Mg and Ca and high Mn (Bailey et al. 2004). Horsley et al. (2000) suggested that sugar maple decline occurs on sites with an imbalance of Mg nutrition and excessive defoliation stress.

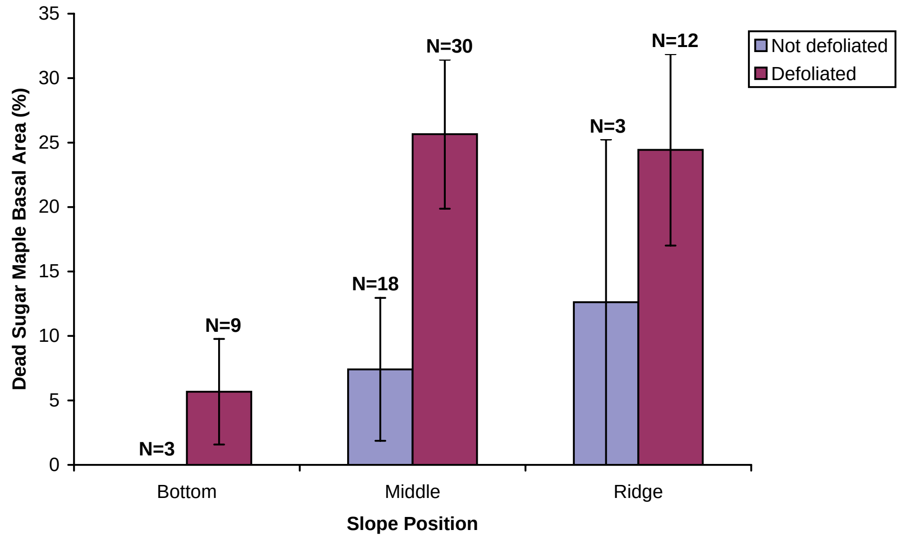


Figure 45.—Mean standing dead sugar maple basal area per acre on FHM plots grouped by slope position (1998, 2000, and 2001 FHM data) and defoliation status.

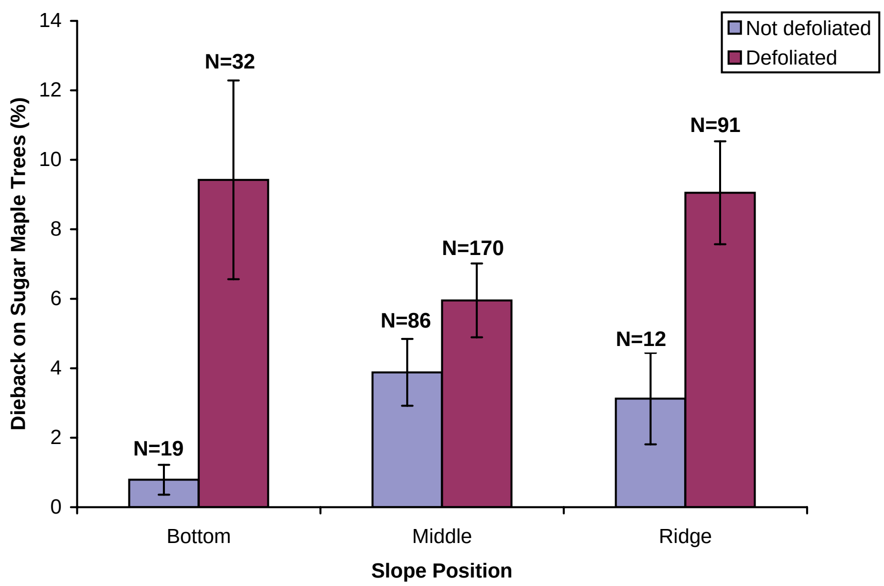


Figure 46.—Mean crown dieback of sugar maple trees grouped by slope position (1998, 2000, and 2001 FHM data) and defoliation status.

The 1998, 2000, and 2001 FHM data were used to compare the basal area of dead sugar maple with the topographical position of the trees and whether they had been defoliated by elm spanworm. The 1999 data were excluded from the analysis because data on topographical position was not collected. In Figure 45, most of the basal area of standing dead sugar maple was on upper and middle slopes whether or not the areas were defoliated. Horsley et al. (2000) reported a similar relationship between sugar maple mortality and slope position, though mortality generally was lower on the lower middle slope. In the data presented here, the middle-slope category was not split between upper and lower. Less nutrient-rich upper slopes are less suitable for sugar maple. Mortality was greater in defoliated than in undefoliated areas regardless of slope position.

Surprisingly, average crown dieback for sugar maple from plots defoliated by elm spanworm was similar for all slope positions (Fig. 46). Crown dieback was higher on all defoliated trees regardless of slope position.

Additional Forest Health Monitoring Indicators

Lichen Communities

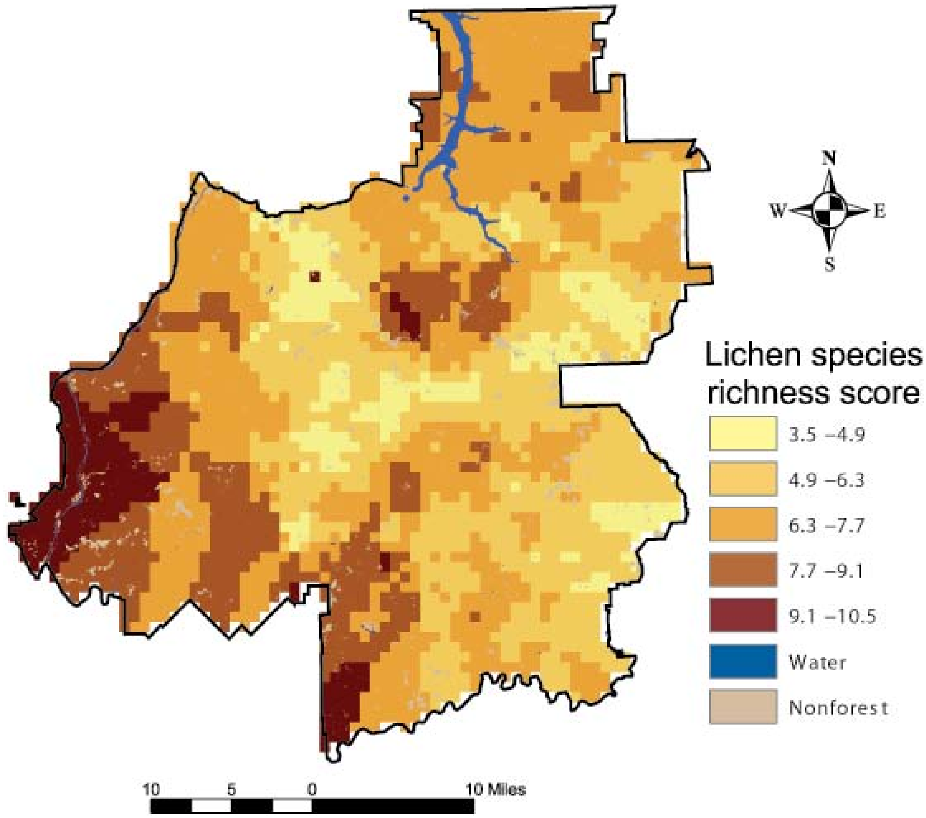


Figure 47.—Kriged surface of lichen species richness on the ANF.

Lichens are composite, symbiotic organisms from as many as three kingdoms. The dominant partner is a fungus. Because fungi cannot catabolize their own nutritional reserves, they usually act as parasites or decomposers. Lichen fungi (kingdom Fungi) cultivate partners that manufacture carbohydrates by photosynthesis. Partners can be algae (kingdom Protista), cyanobacteria (kingdom Monera), formerly called blue-green algae. Some fungi exploit both at the same time (Brodo et al. 2001). Data on lichens were collected from 1999 to 2001 on all 173 ANF FHM plots to determine the presence and abundance of lichen species on woody plants and to obtain samples. Although lichens occur are found on different substrates, e.g., rocks, sampling was restricted to standing trees or branches/twigs that recently fell to the ground. The samples were sent to experts on lichens for species identification.

There is a close relationship between lichen communities and air pollution, especially sulfur dioxide (SO^2) and acidifying or fertilizing nitrogen- and sulfur-based pollutants. Lichens are particularly sensitive to air quality because they must rely on atmospheric sources of nutrition. By contrast, trees may be indicators of chronic air pollution but all other influences on tree growth make it difficult to measure responses to pollutants (McCune 2000). Lichens also are important components of biodiversity in forest ecosystems. Seven lichen genera and 52 lichen species were sampled in the 1999-2001 FHM data (Appendix I). A list of lichen species sampled on the ANF that could be assigned a pollution tolerance also is included in Appendix I. The pollution tolerance scale is a provisional and qualitative ordinal scale developed by Dr. Susan Will-Wolf (FIA Lichen Indicator Advisor) (Showman 1990; 1997; McCune et al. 1997; Showman and Long 1992; McCune 1988; Wetmore 1983; Nash 1975).

A kriged surface of lichen species richness scores is shown in Figure 47. They are called scores because the samples are timed, that is, the scores are not absolute richnesses. Showman and Long (1992) reported that mean lichen species richness was significantly lower in areas of high sulfate deposition (6.3 and 5.4) than in low deposition areas (11.5 and 10.6) in north-central Pennsylvania. The mean species richness score of lichens was calculated by Eastern Region forest type (Table 23) and stand-development stage (Table 24). The oak/hardwood transition forest type had the highest mean species richness score (9.6 species) followed closely by northern hardwoods and white oak/red oak. Mean species richness was much lower on sites in the stand initiation phase, reflecting the lag time for lichen recolonization after harvest or disturbance. Selva (1994) reported that lichen floras become richer over time.

Table 23.—Species richness of lichen species, by Eastern Region forest type (1998-2001 FHM data)

Forest type	Mean species richness	Number of plots
Oak/hardwood transition	9.6	7
Northern hardwoods	8.6	15
White oak/red oak	8.3	8
Mixed upland hardwoods	6.8	45
Red maple	6.4	28
Hemlock	6.0	9
Allegheny hardwoods	5.7	37
Sugar maple	3.0	7

Table 24.—Species richness of lichen species, by stand development stage (1998-2001 FHM data)

Stand development stage	Mean species richness	Number of plots
Stand initiation (0-14 years)	3.7	15
Stem exclusion (15-49 years)	7.1	14
Understory reinitiation (50+ years)	7.0	142

The most common lichen species (present on at least 10 percent of plots) are shown in Figure 48. Their respective pollution tolerances (Appendix I) are in parentheses. Each bar represents 100 percent of the plots and bar segments represent the percentage of plots on which a species was present in each abundance class. The per-plot abundance classes are none, rare (fewer than 3 individuals), uncommon (4 to 10 individuals), common (more than 10 individuals but less than half of the boles and branches contain that species), and abundant (more than half of boles and branches have that species). Species classified as sensitive to pollution were uncommon in the 1999-2001 lichen surveys.

The four most common lichen species on the ANF are shown in Figures 49-52. *Parmelia sulcata* (Fig. 49), extremely widespread in the Northern and Western United States (Brodo et al. 2001), has been described as being resistant to SO_2 (Showman and Long 1992), and, conversely, as a nearly ideal indicator of air pollution (De Wit 1983). The growth and death of this species is measured in The Netherlands, and dying off has been shown to increase at higher

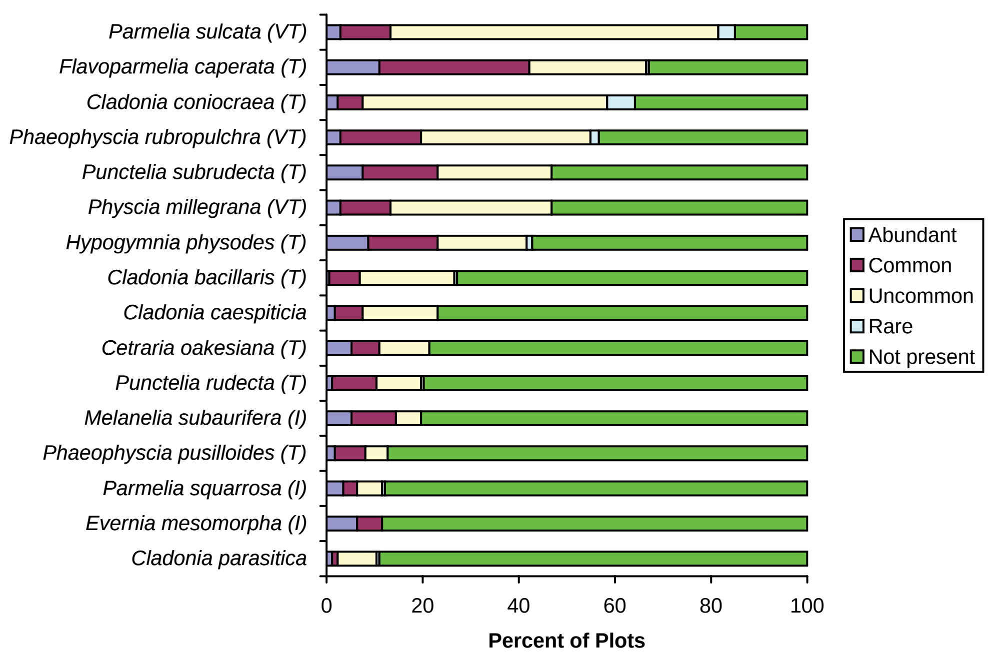


Figure 48.—Lichen distribution by abundance class for the 16 most common species in the ANF (tolerance classes: I = intolerant, T = tolerant, VT = very tolerant).

Figure 49.—*Parmelia sulcata* (photo courtesy of Yale University Press).

Figure 50.—*Flavoparmelia caperata* (photo courtesy of Yale University Press).

Figure 51.—*Cladonia coniocraea* (photo courtesy of Yale University Press).

Figure 52.—*Phaeophyscia rubropulchra* (photo courtesy of Yale University Press).

SO_2 concentrations (De Wit 1983). *Flavoparmelia caperata* (Fig. 50), distributed widely in the Eastern and Southwestern United States, was sensitive to SO_2 near a powerplant in Ohio (Showman 1975). *F. caperata* has been used to monitor the influence of air pollution and city climate on the lichen flora of Long Island (Brodo et al. 2001). *Cladonia coniocraea* (Fig. 51), distributed widely in the East, Northwest, and Pacific Coast, is found most often near tree bases but also grows along the sides of trees when moisture is adequate. *Phaeophyscia rubropulchra* (Figure 52) is distributed widely in the Eastern United States.

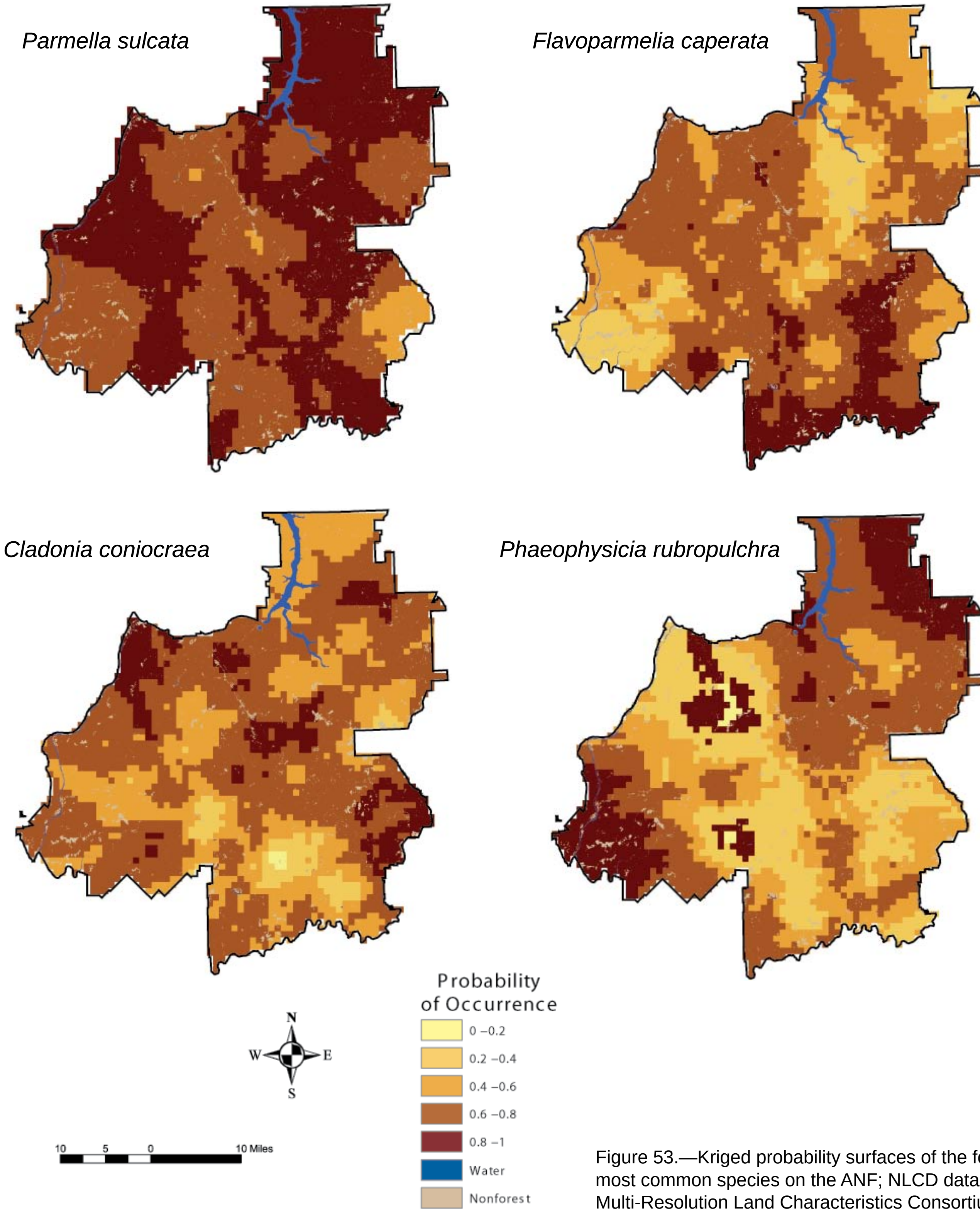


Figure 53.—Kriged probability surfaces of the four most common species on the ANF; NLCD data from Multi-Resolution Land Characteristics Consortium.

Indicator kriged surfaces of the probability of presence were generated for these four lichen species (Fig. 53). That these species differ in spatial distributions across the ANF possibly reflects different ecological and/or habitat preferences.

Sulfate deposition was most severe in Eastern Region compared to other Forest Service regions (Fig. 54) (USDA For. Serv. 2002). To assess the response of lichen species to pollutants across the ANF, a pollution sensitivity index was determined for each FHM plot.

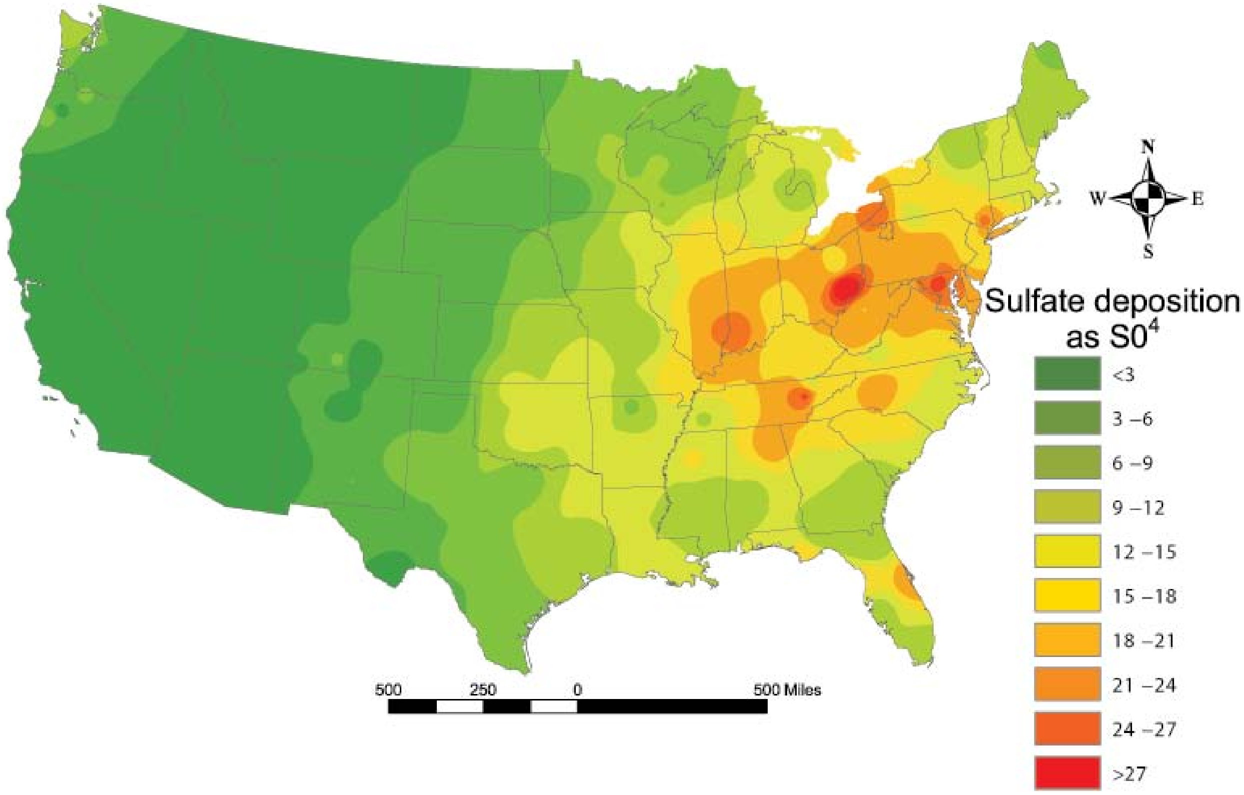


Figure 54.—Sulfate deposition in 1999 and the largest sulfur dioxide point sources; data from National Acid Deposition Program.

The index is calculated as the number of sensitive and intermediate species divided by the total number of rated species using the sensitivity ratings listed in Appendix I. A kriged surface of the pollution sensitivity index was generated (Fig. 55) to display the spatial variation across the ANF landscape. The proportion of sensitive lichen species was highest on the western edge and in two areas in the central part of the ANF. The severity of the pollution response of lichens requires additional study.

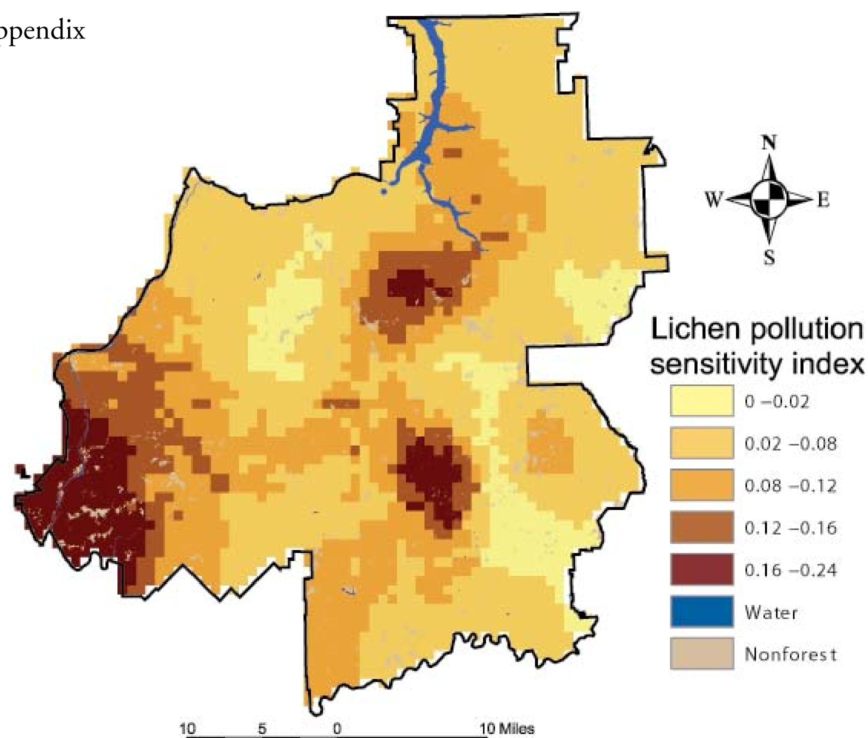


Figure 55.—Kriged surface of the lichen pollution sensitivity index; NLCD data from Multi-Resolution Land Characteristics Consortium.

Down Woody Materials

Down woody materials (DWM), defined as dead matter on the ground in various stages of decay, are important components of forest ecosystems because they affect or otherwise influence the quality and structure of wildlife habitats, structural diversity, fuel loading and fire behavior, carbon sequestration, and storage and cycling of water.[3]

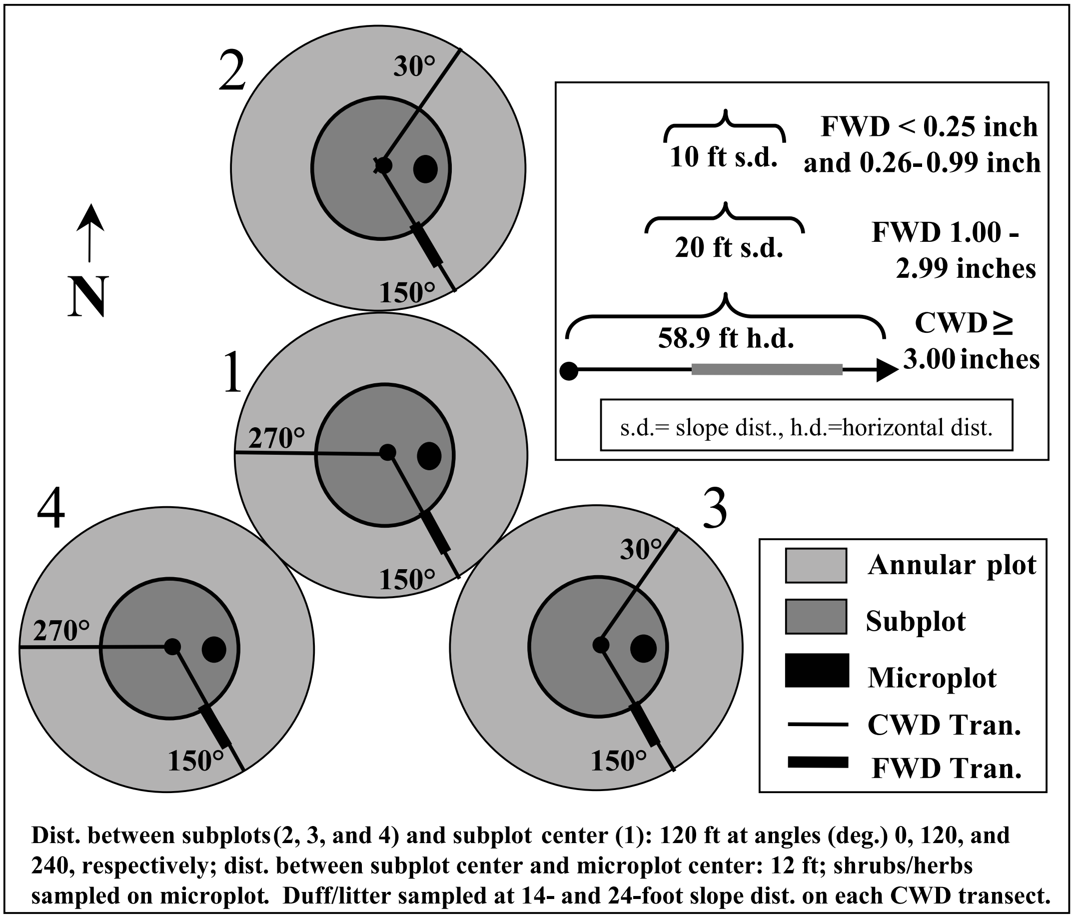


Figure 56.—2001 DWM plot layout for sampling CWD, FWD, and fuels.

Components measured by the DWM indicator include coarse woody debris (CWD), fine woody debris (FWD), duff, litter, herbs/shrubs height, and fuelbed depth. CWD is dead wood 3 inches or larger in diameter (1,000-hr fuels); FWD is dead wood 0.1 to 2.9 inches in diameter (1-,10-, and 100-hr fuels). Litter is the loose plant material on top of the forest floor where little decomposition has occurred. Duff is the layer just below the litter consisting of decomposing leaves and other organic material.

CWD and FWD are sampled using line-intersect sampling methodologies. DWM sample transects begin at each subplot center extending 24 feet to the subplot border. CWD and FWD are sampled along transects occurring in accessible forest land. Three CWD transects are established at azimuths of 30, 150, and 270 degrees. One FWD transect is established at an azimuth of 150 degrees. The depth of the duff and litter layers are important components of fire models used to estimate the behavior, spread, and effects of fire, and smoke production. Litter and duff were measured on microplots in 1999 and 2000 and at the 24-foot location on each transect in 2001.[3] An alternative to reporting mean herb/shrub height and coverage is incorporating them into a single measure of height known as integrated fuel depth (Woodall and Williams 2005).

In 1999 and 2000, the DWM indicator was a pilot sample design tested by the FHM program. The ANF was one of a few selected areas where sampling was conducted in 1999 and 2000. In 2001, the FIA program adopted FHM's pilot sample design and started the DWM indicator. The DWM plot design for 2001 is shown in Figure 56; plot designs from 1999 and 2000 are shown in Appendix I. Designs were sufficiently similar to combine the years for analysis.

Estimates and Summaries of DWM Fuel Loadings

The extensive wildfires that have occurred across the nation in recent years has focused attention on DWM and its potential to sustain large wildfires. Data from the DWM indicator were used to estimate fuel loadings (mass) of CWD, FWD, and total DWM. For the ANF, estimates of DWM vary by fuel class (duff, litter, and 1-, 10-, 100-, and 1,000-hr fuels). These fuel classes area based on the approximate time it takes for the fuel class to experience moisture fluctuations (Deeming et al. 1977). For instance, fine fuels in the 0 to 0.25-inch transect diameter fuel class dry out quickly and thus are called 1-hr fuels. By contrast, a 10-inch log might take more than 1,000 hours to change in moisture content. The majority of the tonnage per acre of DWM on the Allegheny National Forest (64 percent) consisted of duff (Fig. 57).

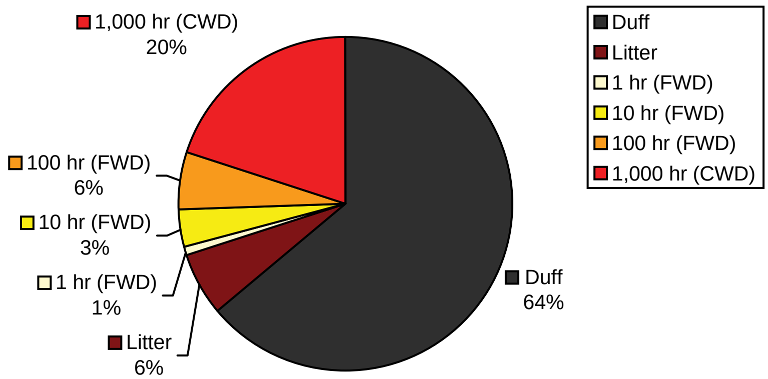


Figure 57.—Total DWM (percent of weight) on the ANF by debris category.

A comparison of DWM between plots within the ANF and the rest of Pennsylvania reveals obvious differences in DWM estimates (Fig. 58). Mean tonnage per acre of duff and 100-hr fuels was higher on plots outside of the ANF. However, the mean tonnage per acre of 1,000-hr fuels was higher on ANF plots. Mean tonnage per acre of litter, 1-hr fuels, and 10-hr fuels was similar on plots inside and outside of the ANF.

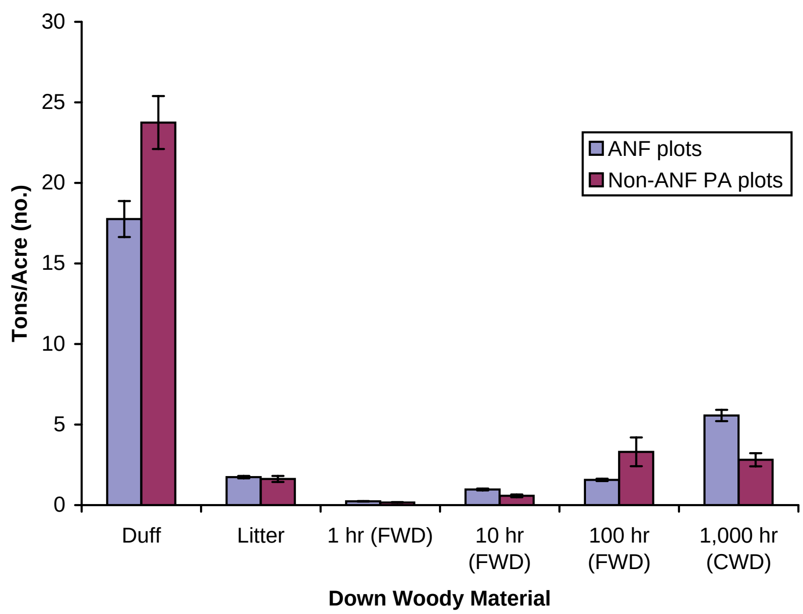


Figure 58.—Mean values of DWM variables on the ANF versus the rest of Pennsylvania.

DWM loadings in tons per acre were broken down by Eastern Region forest type (Table 25). Duff reflected the highest range (13.7 tons per acre) in mean values of all the fuel classes and had the greatest tonnage per acre. Mean tons per acre of duff was highest in the northern hardwoods forest type and lowest in the sugar maple forest type. Levels of litter and fine woody debris were similar among forest types except that the mean value for litter in oak types was substantially

Table 25.—Mean values of DWM variables (tons/acre), by Eastern Region forest type (1999-2001 FHM data)

Forest type	N	Duff	SE	Litter	SE	FWD	SE	CWD	SE
Mixed upland hardwoods	45	15.9	2.2	1.7	0.1	2.6	0.2	5.6	0.7
Allegheny hardwoods	37	17.4	1.5	1.6	0.1	3.0	0.3	5.2	0.7
Red maple	28	20.1	2.9	2.0	0.2	2.7	0.3	5.4	0.8
Northern hardwoods	15	24.6	7.2	1.5	0.2	2.9	0.4	6.2	1.1
All conifers	11	21.6	3.9	1.6	0.2	3.2	0.5	4.7	1.3
Hemlock	9	20.1	4.4	1.5	0.3	3.3	0.6	5.2	1.5
White oak/red oak	8	20.3	3.9	2.6	0.3	2.5	0.2	4.1	0.8
Oak/hardwood transition	7	16.8	5.3	2.4	0.4	2.6	0.4	5.3	2.1
Sugar maple	7	10.9	3.2	1.3	0.2	2.7	0.5	6.5	1.7

higher than that for litter in the other forest types. Levels of coarse woody debris were similar among forest types and lowest in the white oak/red oak forest type.

DWM fuel components vary by tree density (basal area per acre) and stand age (Figs. 59-60) on the ANF. Duff tended to increase with stand age and with basal area to some extent. As stands progress through the latter stages of development and experience higher levels of density/competition, it follows that years of cumulative leaf fall would create deep duff conditions. Also, the denser overstories may shade the duff, thereby reducing decay rates. CWD seems to decrease with increasing stand basal area and stand age (up to age 80), possibly due to CWD recruitment from large stand disturbances (stand replacing event). CWD begins to recover through individual tree mortality as a stand ages. Litter and FWD levels were similar among age and density classes.

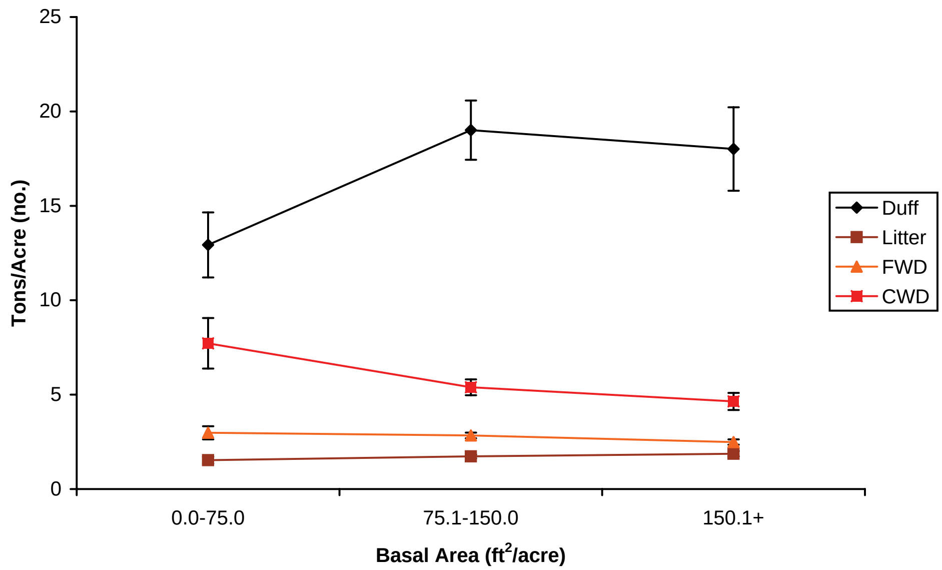


Figure 59.—Mean values of DWM variables on the ANF in basal area/acre classes.

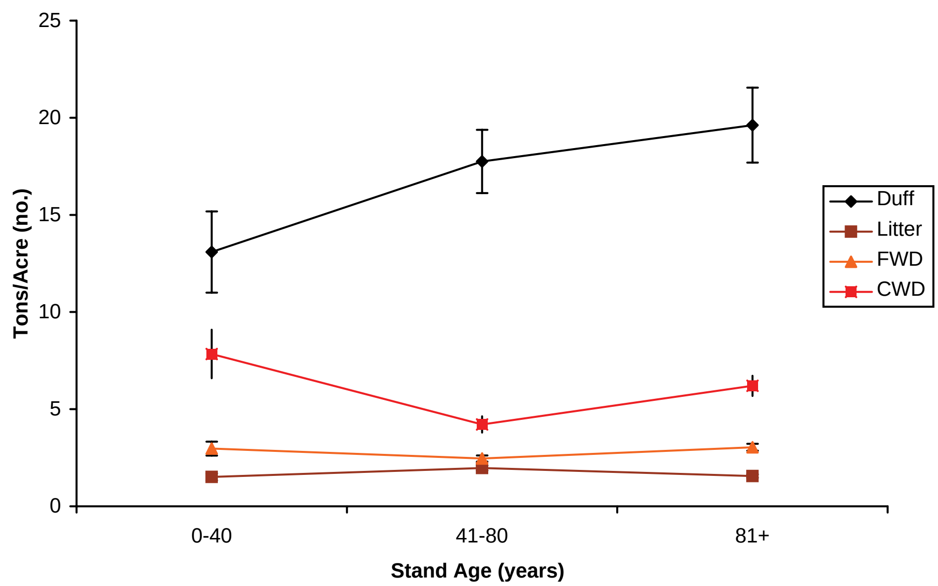


Figure 60.—Mean values of DWM variables on the ANF in stand age classes.

As shown in Figure 61, integrated fuel depth (herb/shrub height and coverage) tended to decrease with basal area per acre and stand age. A more developed herb and shrub layer would be expected in younger, less dense stands due to an increase in available light (less shade). This also might reflect the long-term effects of deer herbivory on understory vegetation in older stands.

Ecology of CWD on the ANF

CWD might be most important ecological attribute of the DWM indicator on the ANF. It represents potential fire hazards and also is an important structural attribute of forest ecosystems (Harmon et al. 1986). CWD creates numerous ecological niches and serves as habitat for plants, animals, protists, bacteria, and fungi (Harmon et al. 1986). The volumes and weights of CWD on the ANF are well within the range of CWD habitat cited in past regional CWD research (Muller and Liu 1991). Although duff accounts for the majority of DWM weight on the ANF (Fig. 57), CWD weight (1,000-hr) is the second heaviest DWM component. The amount of CWD for the average FIA plot on the ANF is nearly twice that for the rest of Pennsylvania (Fig. 58).

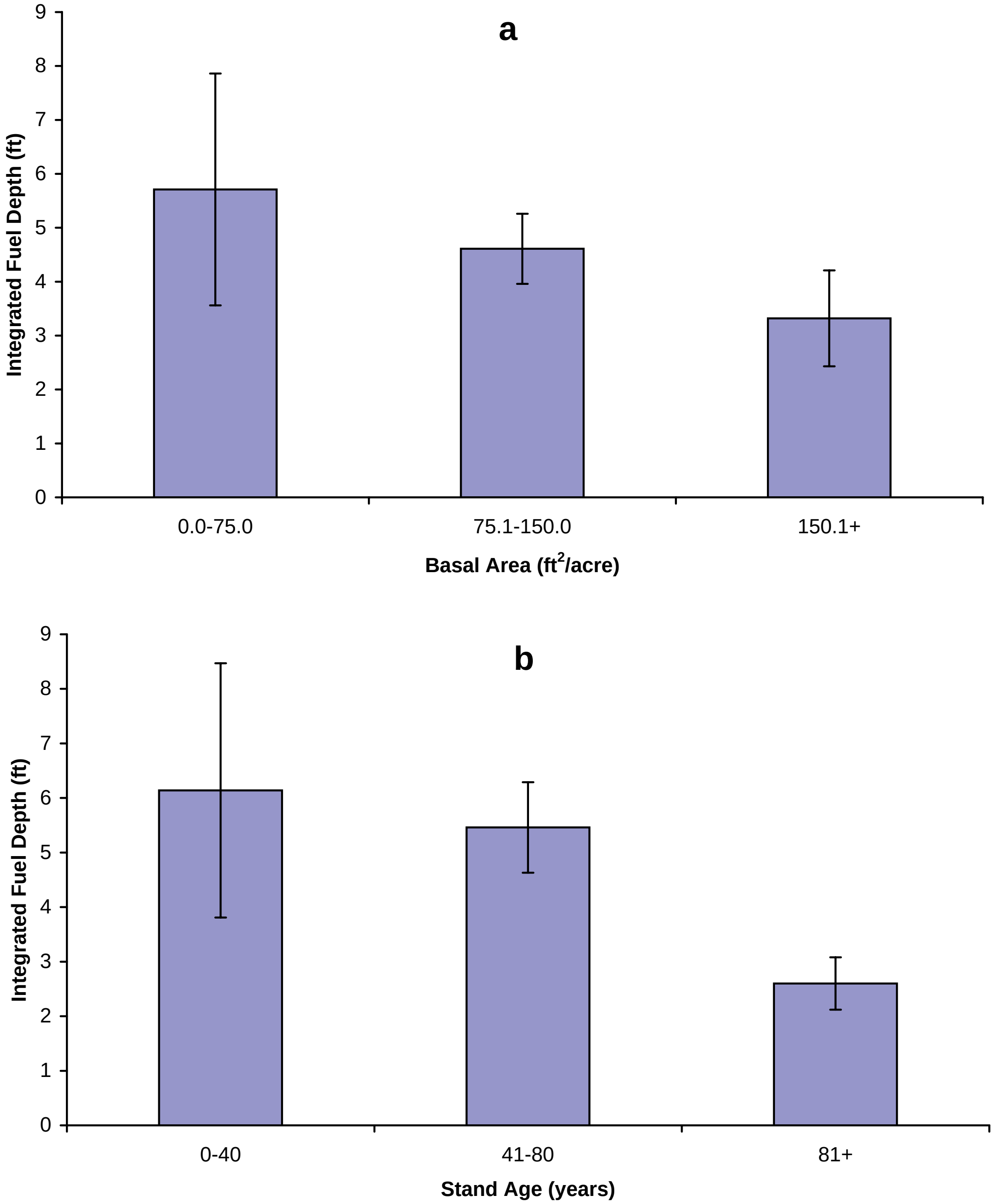


Figure 61.—Mean values of integrated fuel depth on the ANF in (a) basal area/acre classes and (b) stand age classes.

Therefore, data from the DWM inventory indicate that CWD habitat on the ANF may be sufficient. However, as future DWM data are acquired, additional estimates of CWD diameters, decay classes, and species composition might elucidate the attributes of CWD on the ANF.[4]

[4]Woodall, C.W.; Leutscher, B. Extending and intensifying the FIA inventory of down forest fuels: Boundary Water Canoe Area (MN) and the Pictured Rocks National Lakeshore (MI). In preparation.

The relationship between CWD and estimates of stand attributes/disturbance history may allow a reinterpretation of CWD dynamics. The relationship between CWD and standing vegetation often is given little attention, but it could be a driving force in CWD accumulation in eastern forests (Muller and Liu 1991; Rubino and McCarthy 2003). On the ANF, CWD seems to decline with increasing stand basal area (Fig. 59). McCarthy and Bailey (1994) and Muller and Liu (1991) reported similar findings and attributed the

Table 26.—Mean values of CWD volumes (ft^3/acre), by stand development stage (1999-2001 FHM data)

Stand development stage	N	CWD volume	SE
Stand initiation (0-14 years)	14	1294.3	248.92
Stem exclusion (15-49 years)	14	504.2	124.92
Understory reinitiation (50+ years)	140	542.6	39.48

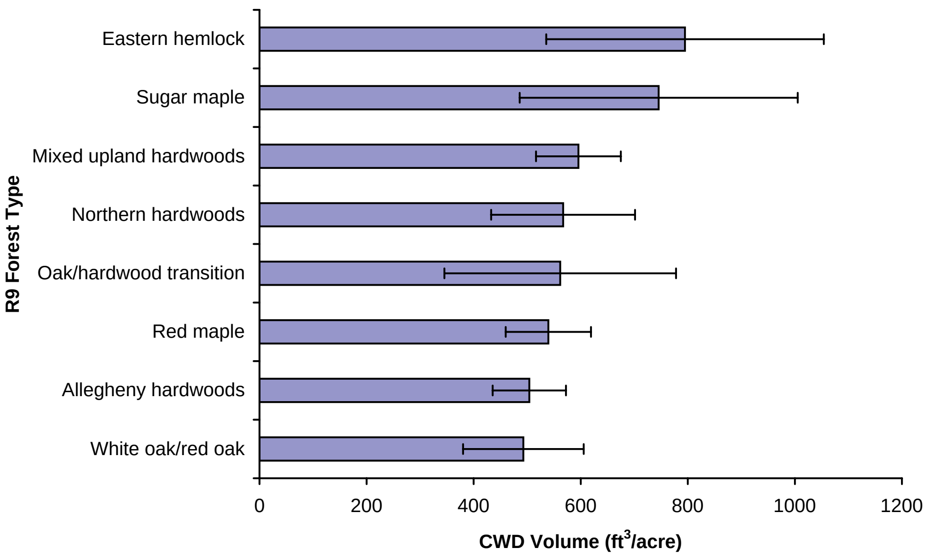


Figure 62.—Mean values of CWD volumes by Eastern Region forest types.

presence of additional CWD in stands with lower basal area relative to logging activity or other disturbance, e.g., insect defoliation. If most of the CWD volumes reside in recently treated stands, this small-diameter logging slash may decompose quickly and may not be as ecologically desirable as larger diameter pieces (McCarthy and Bailey, 1994). This result is affirmed by the relationship between stand age and CWD densities (Fig. 60; Table 26). CWD densities generally follow a U shape over time (Hagan and Grove 1999). The youngest stands have the most CWD on the ANF (Fig. 60; Table 26). Preliminary investigations of CWD levels on the ANF revealed low volumes of CWD in second-growth stands compared to the amount found in the old growth Tionesta Scenic and Research Natural Areas. The volume of CWD in old-growth stands ranged from 866 to 1,659 ft^3/acre (R. White, D. deCalesta and C. Nowak 1998, pers. commun.). By contrast, CWD volumes were much lower in all but the youngest stands on the ANF (Table 26). The relationship between CWD amounts and forest type also might help identify trends. Research has suggested that oak forests contain more CWD than maple forests (McCarthy et al. 2001) possibly because oak logs may decay more slowly than maple logs (MacMillan 1988). Unfortunately, the standard errors of the DWM inventory preclude conclusions except that most CWD masses (Table 25) and volumes (Fig. 62) seem fairly constant across all forest types on the ANF.

Summary of DWM

Initial results from the DWM inventory indicate that fuel loadings do not differ substantially from those of forest ecosystems in the rest of Pennsylvania. CWD weights (1,000 hr) on the ANF may be twice that for the rest of the State, though this does not present a significant fire hazard and may benefit forest diversity and habitat accumulation. The weights of the fine woody fuels (flash fuels) are associated with a considerable proportion of fire behavior. The relationship between CWD and stand attributes suggests that less dense younger stands that

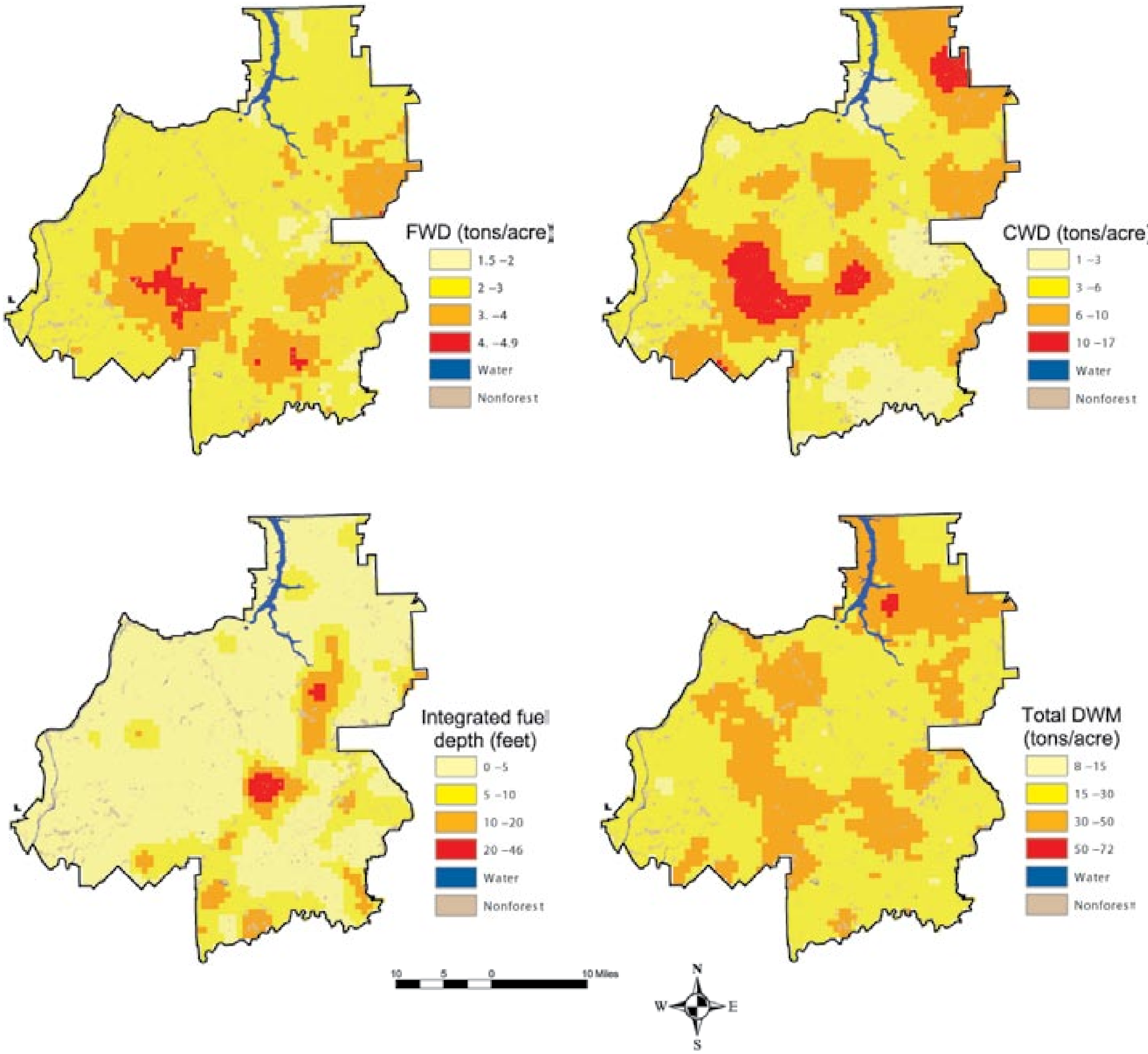


Figure 63.—Kriged surfaces of DWM on the ANF; NLCD data from Multi-Resolution Land Characteristics Consortium.

may have experienced recent disturbances contain the most CWD. CWD recruitment by logging activities over long periods may not establish a sufficient diversity of CWD sizes and decay classes. Data from future DWM inventories should allow more sophisticated hypothesis testing with respect to CWD recruitment and attributes. Kriged surfaces were generated to depict the spatial arrangement of fuels and debris (Fig. 63). The area in the southwestern section of the ANF had both high FWD and CWD loadings and a high percentage of standing dead basal area (Fig. 21).

Soils

The vitality, species composition, and hydrology of forest ecosystems are potentially influenced by any environmental stressor that changes the natural function of the soil.[3] Soil samples are collected from the forest floor (at subplots 2, 3, and 4) and the underlying mineral soil layers (at subplot 2). Once the forest floor has been removed, mineral soils are sampled from 0 to 10 and 10 to 20 cm. The texture of each layer is assigned in the field as organic, loamy, clayey, sandy, or coarse sandy. The physical and chemical properties of the soil layers are determined in a regional laboratory.[3] The protocol for data collection has been changed frequently since the first year that data were obtained on the ANF. Therefore, in instances where all years of data were not available, missing years are listed in tables and/or figures.

The physical properties of soils from FHM plots on the ANF are shown in Table 27. Moisture content was substantially higher in the forest-floor layer than in the mineral-soil layers. Soil-water content is expressed as a percentage of the dry weight of the soil (Thompson and Troeh 1973). Consequently, it is not unusual for the values for soil-moisture content to exceed 100 percent, especially in samples of high organic matter, e.g., the forest floor. Due to the high sorption capacities of soils high in organic matter, the forest-floor layer probably can absorb many times its own weight in water. On the basis of the forest types sampled, the following observations can be made with respect to moisture content (Table 27):

- The white oak type had the lowest average values for all three soil layers. One reason for this may be that it also had the lowest mean forest-floor thickness of the forest types sampled. White oak grows better on somewhat droughty sites than many other species.
- The eastern hemlock, northern hardwoods, and white oak/red oak types had the highest average values for the forest-floor layer.
- The eastern hemlock, northern hardwoods, red maple, and black birch/hickory types had the highest average values for the mineral layers.

Chemical properties from FHM plots on the ANF are shown in Tables 28 and 29. Sugar maple decline tends to be more prevalent on sites with poor nutrition of calcium (Ca) and magnesium (Mg) (Bailey et al. 2004). By contrast, black cherry, red maple, and northern red oak do not seem to have a high requirement for Ca and Mg. Our data appear to confirm this, i.e., Mg and Ca are higher in the northern hardwoods and sugar maple types than in the Allegheny hardwoods, red maple, and oak types) (Table 28). Iron (Fe) levels are nearly twice as high in the mineral layer (0 to 10 cm) for the eastern hemlock type than for other types (Table 29). For the mineral layer (10 to 20 cm), Fe is highest for both the hemlock and sugar maple forest types.

On the basis of the forest types sampled, the following observations can be made concerning pH, extractable phosphorous, total nitrogen, and exchangeable cations (Table 28):

- The pH of the mineral (0 to 10 cm) layer ranges from 3.9 to 4.3.
- The pH of the mineral (10 to 20 cm) layer ranges from 4.1 to 4.4.
- The white oak/red oak type had the highest average values for extractable phosphorous.
- Total mean nitrogen had the highest average values (1.4 percent) in the forest-floor layer.
- Total mean nitrogen generally was higher (0.2 percent) in the 10- to 20-cm layer than the 0- to 10-cm layer (0.1 percent).
- The northern hardwoods type generally had much higher mean values for exchangeable cations than the other types.

Additional research is needed to determine the importance of these observations, how our results compare with those for the rest of Pennsylvania, and whether there are additional relationships among soil characteristics, vegetation, ecological land-type groups, and forest health. Analysis might be limited by the shallow depth of the soil sampling. For the Allegheny Plateau in New York and Pennsylvania, Bailey et al. (2004) demonstrated the value of sampling the upper and lower portions of the B horizon, which extends well below 20 cm. Relationships were better correlated when the entire B horizon was considered.

Table 27.—Mean values for physical soil properties from FHM plots on the ANF, by forest type (1998-2001 FHM data; NA = not applicable)

Forest type	Number of samples	Texture	Moisture content (%) (oven-dry basis)[a]	Coarse fragments (%)[b]	Forest floor thickness
			Forest floor		*---cm---*
Eastern hemlock	24	NA	193.5	NA	6.4
White oak	6	NA	40.1	NA	4.9
Hardwood/oak transition	16	NA	135.7	NA	7.1
White oak/red oak	11	NA	181.1	NA	7.1
Red maple	56	NA	166.2	NA	8.1
Northern hardwoods	18	NA	187.3	NA	6.2
Allegheny hardwoods	64	NA	158.1	NA	6.4
Sugar maple	11	NA	105.6	NA	6.2
Mixed upland hardwoods	77	NA	159.6	NA	7.7
Average for all types	283	NA	147.5	NA	6.7
			Mineral layer (0-10 cm)		
Eastern hemlock	40	organic, loamy, clayey	33.0	12.5	NA
White spruce/Norway spruce	24	loamy, sandy	No data	2.9	NA
White oak	8	loamy	9.7	23.5	NA
Northern red oak	28	loamy, clayey	14.9	17.2	NA
Hardwood/oak transition	32	loamy, sandy	22.2	10.8	NA
White oak/red oak	64	loamy, clayey, sandy	22.9	17.2	NA
Red maple	168	loamy, clayey, sandy	31.8	13.2	NA
Northern hardwoods	72	loamy, clayey	35.8	13.5	NA
Allegheny hardwoods	232	loamy, clayey, sandy	26.7	11.7	NA
Sugar maple	36	loamy, sandy	18.4	16.4	NA
Beech	12	loamy, clayey	No data	2.6	NA
Black birch/hickory	16	loamy, sandy	38.7	21.6	NA
Mixed upland hardwoods	280	loamy, clayey, sandy	29.3	12.3	NA
Average for all types	1012	NA	25.8	NA	NA
			Mineral layer (10-20 cm)		
Eastern hemlock	40	loamy, clayey	28.0	10.8	NA
White spruce/Norway spruce	24	loamy, clayey	No data	4.2	NA
White oak	8	clayey	7.4	6.1	NA
Northern red oak	28	loamy, clayey	11.5	14.9	NA
Hardwood/oak transition	32	loamy, clayey, sandy	22.4	6.4	NA
White oak/red oak	64	loamy, clayey, sandy	20.2	16.0	NA
Red maple	168	loamy, clayey, sandy	33.0	12.1	NA
Northern hardwoods	72	loamy, clayey, sandy	27.9	12.5	NA
Allegheny hardwoods	232	loamy, clayey, sandy	25.5	11.9	NA
Sugar maple	36	loamy	22.8	15.4	NA
Beech	12	loamy, clayey	No data	2.6	NA
Black birch/hickory	16	loamy, coarse sandy	31.4	14.7	NA
Mixed upland hardwoods	280	loamy, clayey, sandy	26.9	10.4	NA
Average for all types	1012	NA	23.4	NA	NA

[a]1999 and 2001 only.

[b]2000 and 2001 only.

Table 28.—Mean values for chemical properties (including exchangeable cations and extractable sulfur) from FHM plots on the ANF, by forest type (1998-2001 FHM data)

Forest type	Number of samples	pH H_2O	pH $CaCl_2$	Organic carbon	Total nitrogen	Extractable phosphorus	Exchangeable cations Na	K	Mg	Ca	Al[b]	ECEC[ab]	Extractable sulfur[b]	Number of samples[b]
				---percent---	---percent---	---mg/kg---	---cmol/kg---						---mg/kg---	
Forest floor														
Eastern hemlock	25	NA	NA	39.4	1.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
White oak	6	NA	NA	42.7	1.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Northern red oak	6	NA	NA	28.1	1.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Oak/hardwood transition	17	NA	NA	30.7	1.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
White oak/red oak	14	NA	NA	30.4	1.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Red maple	69	NA	NA	39.3	1.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
Northern hardwoods	25	NA	NA	35.1	1.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Allegheny hardwoods	76	NA	NA	36.5	1.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sugar maple	12	NA	NA	31.0	1.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
Black birch/hickory	6	NA	NA	23.0	1.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mixed upland hardwoods	91	NA	NA	34.6	1.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average for all types	347	NA	NA	33.7	1.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mineral layer (0-10 cm)														
Eastern hemlock	10	4.1	3.8	4.4	0.2	3.9	4.7	28.3	27.0	137.2	488.0	707.1	27.2	9
Oak/hardwood transition	6	4.3	3.8	2.3	0.1	5.1	7.2	64.0	10.1	26.1	276.7	384.1	28.9	6
White oak/red oak	9	4.1	3.7	2.7	0.1	22.8	6.6	31.8	7.2	34.2	270.3	360.1	25.8	8
Red maple	30	3.9	3.6	3.3	0.2	13.3	7.1	40.3	12.5	31.1	442.4	536.5	31.9	29
Northern hardwoods	12	4.1	3.8	3.7	0.2	3.7	14.6	54.6	82.5	471.6	430.2	1110.1	29.2	11
Allegheny hardwoods	41	4.0	3.7	3.1	0.2	3.3	7.1	37.1	11.6	41.7	491.7	616.4	36.6	32
Sugar maple	6	3.9	3.6	2.7	0.2	2.6	6.5	44.5	13.1	67.5	386.3	517.7	27.0	6
Mixed upland hardwoods	43	4.1	3.8	3.1	0.2	2.6	6.7	36.8	22.0	106.0	422.0	626.7	30.5	36
Average for all types	157	4.1	3.7	3.1	0.2	7.2	7.6	42.2	23.2	114.4	400.9	607.3	29.6	17.1
Mineral layer (10-20 cm)														
Eastern hemlock	10	4.4	4.1	2.2	0.1	1.7	4.9	36.2	20.6	73.8	542.7	693.4	29.0	9
Oak/hardwood transition	6	4.4	4.0	1.1	0.1	8.9	5.5	30.3	6.8	25.1	284.2	351.9	27.8	6
White oak/red oak	9	4.3	3.9	1.5	0.1	17.4	10.3	29.3	7.2	23.4	219.5	299.7	33.9	8
Red maple	30	4.3	4.0	2.0	0.1	7.2	7.0	32.1	8.2	22.6	401.7	474.1	31.1	29
Northern hardwoods	12	4.4	4.0	1.9	0.1	3.8	12.9	45.2	89.2	453.6	281.7	928.8	24.4	11
Allegheny hardwoods	41	4.2	4.0	2.3	0.2	2.4	6.2	29.0	5.8	19.6	420.6	499.7	35.3	32
Sugar maple	6	4.1	3.7	2.5	0.1	2.0	9.1	42.3	10.0	54.5	501.4	617.3	26.1	6
Mixed upland hardwoods	43	4.3	4.0	2.8	0.2	9.4	7.1	31.2	16.0	73.0	370.2	521.5	30.5	36
Average for all types	157	4.3	4.0	2.0	0.1	6.6	7.9	34.5	20.5	93.2	377.7	548.3	29.8	17.1

[a]ECEC=effective cation exchange capacity

[b]2000 and 2001 only

Table 29.—Mean values for extractable micronutrients and trace metals from FHM plots on the ANF, by forest type (2000-2001 FHM data only)

Forest type	Number of samples	Mn	Fe	Ni	Cu	Zn	Cd	Pb
				---mg/kg---				
				Mineral Layer (0-10 cm)				
Eastern hemlock	9	49.6	120.3	0.5	0.1	3.1	0.1	3.1
Oak/hardwood transition	6	103.8	10.2	0.2	0.1	2.5	0.1	2.1
White oak/red oak	8	85.9	15.3	0.3	0.1	2.8	0.1	2.1
Red maple	29	70.1	68.8	0.5	0.1	2.5	0.1	4.1
Northern hardwoods	11	106.5	26.6	1.5	0.2	5.2	0.1	4.3
Allegheny hardwoods	32	120.2	41.1	0.6	0.3	2.9	0.1	3.4
Sugar maple	6	92.1	40.2	0.4	0.1	2.1	0.0	2.2
Mixed upland hardwoods	36	80.1	61.6	1.0	0.1	3.2	0.1	3.4
Average for all types	137	88.5	48.0	0.6	0.1	3.0	0.1	3.1
				Mineral Layer (10-20 cm)				
Eastern hemlock	9	23.2	58.6	0.6	0.1	3.8	0.1	2.2
Oak/hardwood transition	6	20.0	8.4	1.6	0.1	1.8	0.6	1.3
White oak/red oak	7	52.3	4.0	1.1	0.1	2.0	0.0	1.1
Red maple	28	27.9	37.3	1.4	0.1	2.2	0.0	1.8
Northern hardwoods	13	73.3	17.9	3.1	0.1	2.8	0.1	1.4
Allegheny hardwoods	29	52.4	18.9	1.7	0.1	2.1	0.0	2.0
Sugar maple	6	35.9	60.9	1.7	0.1	2.0	0.0	1.5
Mixed upland hardwoods	36	37.1	33.4	1.9	0.1	2.4	0.0	1.6
Average for all types	134	40.3	29.9	1.6	0.1	2.4	0.1	1.6

Vegetation Diversity

The objectives of the FHM vegetation indicator are to assess forest ecosystem health with respect to the diversity, abundance, and rate of change of native and nonnative vascular plant species, as well as the vertical layering of vegetation within a forest[3] (Stapanian et al. 1998). Chronic stressors such as discrete site degradation, climate change, and pollution can change species composition and lead to the decline or local extinction of sensitive species and to an increase in opportunistic species, i.e., invasive and nonnative plants.[3] The abundance and layering of vegetation is a good predictor of wildlife habitat and the severity of damage that might develop when fire occurs. Individual species also are important indicators of a site's potential productivity, economic value, and wildlife forage and shelter.[3]

A vegetation survey requires multiscale sampling because different plant communities have different spatial patterns of species richness, so a single plot size is an arbitrary sample of species diversity. Figure 64 shows the plot design for the FHM vegetation indicator. The following protocols for data collection apply to data collected in 2000 and 2001. Species and cover data for vascular plants are collected on two plot sizes at each subplot point: three 3.28-ft^2 (1-m^2) quadrats, and the 24-foot-radius subplot. On the quadrats, species and cover data are collected for the 0- to 6-foot layer. On each subplot, a time-constrained search of all species in all

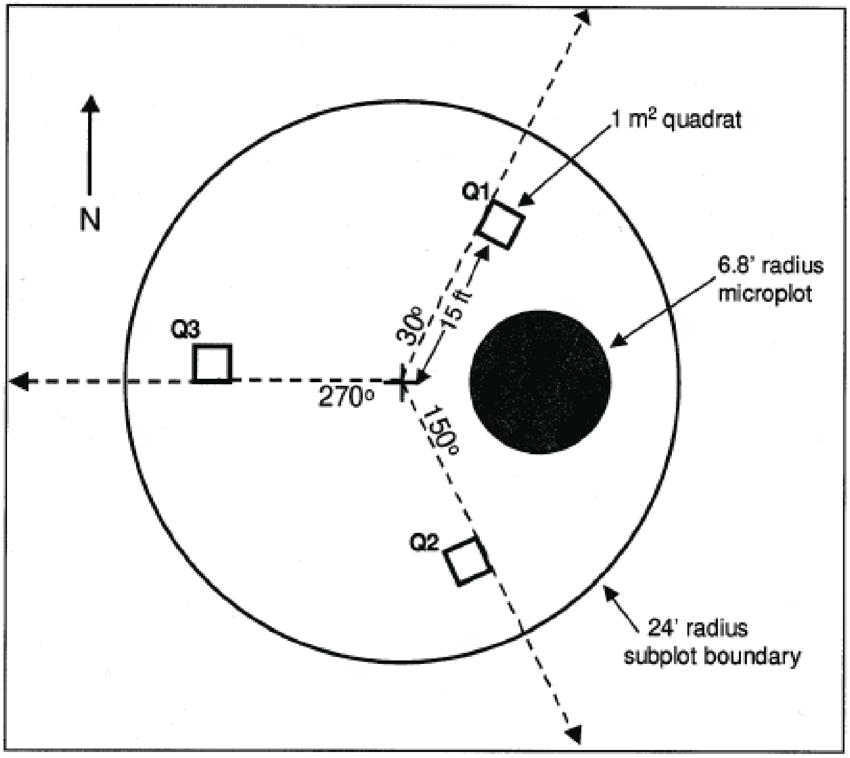


Figure 64.—Layout of FHM subplot showing location of vegetation quadrants.

height strata is conducted and cover is estimated. Total cover of all vegetation in four height layers (0 to 2, 2 to 6, 6 to 16, and 16+ feet) is estimated on each subplot.[2] (USDA For. Serv. 2002). Due to protocol updating, only data on species presence on subplots were collected in all years.

Average percent cover on quadrats of dung, stream, lichens, litter/duff, moss, road, rock, root/bole, soil, trampling, trash/junk, water, and dead wood by Eastern Region forest type and stand-development class are shown in Tables 30-31. The definitions of the quadrat ground cover variables are listed in Appendix I.[3] Litter/duff coverage was the highest overall component (61 percent). Dung was surprisingly high (21 percent), particularly in the pin cherry (84 percent) and white spruce/Norway spruce (53 percent) forest types. Bare soil was low on average on all quadrats. Stream coverage was highest in the red pine forest type, possibly a function of where red pine was planted during the 1930s, i.e., areas that failed to regenerate naturally after the turn of the century harvests.

All of the species of vegetation sampled on the ANF (397 native and 48 nonnative to the ANF) and the percentage of plots on which they were found are listed in Appendix II. An additional 184 specimens remain unidentified or partially identified because they were collected when identification characteristics, e.g., flowers and seeds, were absent. Some of these may be additional species.

Mean species richness of sampled vegetation by forest types (Table 32) ranged from 44 species in the oak/hardwood transition forest type to 81.4 species in the white oak/red oak type. Species richness ranged from 57 to 69 in all other forest types, except for the sugar maple type. Mean species richness of vegetation by stand-development phase (Table 33) ranged from 61.3 species in the stand initiation phase to 75.7 species in the stem exclusion stage.

All nonnative vegetation species sampled on the ANF (48) and the percentage of plots on which they were found also are listed in Appendix II. Five species from the ANF list of invasive plant species of concern were

Table 30.—Percentage of quadrats with ground-cover variables, by Eastern Region forest type

Forest type	No. of quads	Dung	Lichen	Litter/duff	Moss	Road	Rock	Root/bole	Soil	Stream/lake	Trampling	Trash	Water	Wood
Red pine	10	0.0	0.1	81.9	4.7	0.0	0.0	1.8	0.0	10.0	1.0	0.0	0.0	1.5
Hemlock	113	8.5	2.9	70.1	11.9	1.8	1.2	0.6	2.6	1.2	0.6	0.9	4.0	1.2
White spruce/Norway spruce	15	53.3	45.5	2.1	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chestnut oak	12	0.0	0.2	92.1	5.8	0.0	0.5	0.2	0.0	0.0	1.0	0.0	0.0	1.2
White oak	24	0.0	0.6	93.0	3.0	0.0	0.0	0.6	0.3	0.0	1.1	0.0	0.0	2.5
Red oak	36	28.7	4.2	63.2	1.9	0.4	0.0	0.7	0.1	0.0	0.8	0.0	0.0	2.8
Oak/hardwood transition	81	8.3	6.7	73.4	1.8	0.6	2.3	1.1	0.2	0.6	0.3	0.0	6.4	1.0
White oak/red oak	93	26.2	12.1	57.6	2.4	0.7	0.9	0.6	0.8	0.2	0.5	0.0	0.7	0.9
Red maple	298	21.7	5.7	65.5	3.1	1.3	1.3	0.7	0.8	0.4	0.5	0.0	2.6	1.8
Northern hardwoods	181	21.9	10.0	59.2	4.0	1.1	2.5	1.0	1.1	0.1	0.6	0.0	1.1	0.7
Pin cherry	7	84.4	13.6	0.7	1.7	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Allegheny hardwoods	397	20.3	6.9	67.4	3.0	0.7	0.7	1.2	0.5	0.2	0.7	0.1	2.0	1.2
Sugar maple	69	24.7	6.2	63.9	3.4	0.2	0.4	1.0	0.0	0.3	0.5	0.0	3.0	3.5
Beech	19	19.8	45.4	28.7	1.2	5.6	2.2	0.4	0.1	0.6	0.1	0.1	3.3	0.0
Black birch/hickory	36	0.1	0.0	85.8	7.3	0.0	0.9	2.2	0.1	0.0	1.0	0.1	0.0	3.4
Mixed upland hardwoods	501	19.4	3.8	70.0	2.0	1.3	1.3	1.0	0.6	0.3	0.6	0.0	2.9	0.7
Total	1892	21.1	10.2	60.9	3.6	0.9	0.9	0.8	0.5	0.9	0.6	0.1	1.6	1.4

Table 31.—Percentage of quadrats with ground-cover variables present, by stand development stage

Stand development stage	No. of quads	Dung	Lichen	Litter/Duff	Moss	Road	Rock	Root/bole	Soil	Stream	Trampling	Trash	Water	Wood
Stand initiation (0-14 years)	150	4.0	7.1	74.9	0.7	1.4	1.1	1.2	0.4	0.5	0.7	0.0	9.4	4.1
Stem exclusion (15-29 years)	166	24.5	7.4	58.6	3.6	2.0	1.0	1.0	0.4	0.3	0.5	0.1	2.0	2.0
Understory reinitiation (50+ years)	1595	20.4	6.4	66.5	3.6	1.0	1.2	0.9	0.8	0.4	0.6	0.1	1.9	0.9

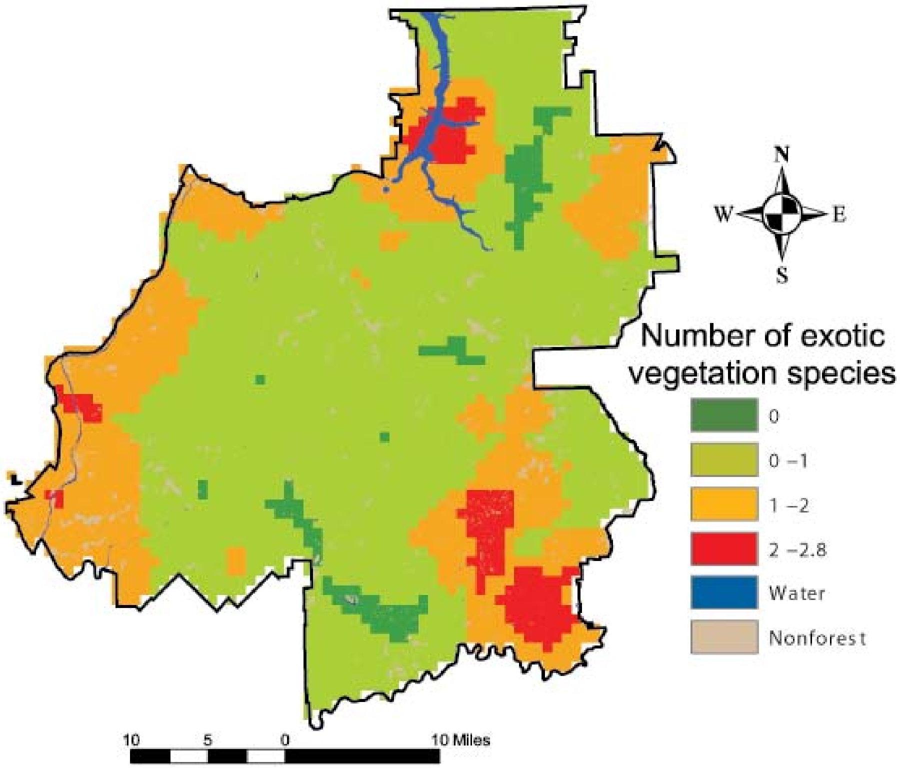


Figure 65.—Kriged surface of exotic vegetation species richness; NLCD data from Multi-Resolution Land Characteristics Consortium.

sampled in the vegetation surveys. Glossy buckthorn (*Frangula alnus*) was sampled on 25 subplots followed by multiflora rose (*Rosa multiflora*) (7), Japanese barberry (*Berberis thunbergii*) (3), canary reed grass (*Phalaris arundinacea*) (2), and crown vetch (*Coronilla varia*) (1). A kriged surface of introduced species richness is shown in Figure 65. It was estimated that the areas near the ANF boundary have more nonnative plant species.

Ozone Bioindicator Plants

Ozone (O_3) is a byproduct of industrial development and is found in the lower atmosphere. It forms when nitrogen oxides and volatile organic compounds react in the presence of sunlight (Krupa et al. 2001). Ground-level O_3 has a detrimental effect on forest ecosystems and certain plant species show visible, easily diagnosed foliar symptoms. O_3 stress in a forest environment can be detected and monitored using these plants as bioindicators. The FHM program uses O_3 bioindicator plants to monitor changes in air quality across a region and to evaluate the relationship between O_3 air quality and the indicators of forest condition.[3] Black cherry

Table 32.—Mean species richness of vegetation on the ANF, by Eastern Region forest type (1998-2001 FHM data)

Forest type	Number of plots	Species richness	SE
White oak/red oak	8	81.4	14.5
Sugar maple	7	75.0	14.2
Northern hardwoods	13	69.5	6.9
Mixed upland hardwoods	45	67.8	6.6
Allegheny hardwoods	35	66.7	5.0
Eastern hemlock	9	66.1	11.1
Red maple	29	57.4	5.6
Oak/hardwood transition	7	44.1	8.3

Table 33.—Mean species richness of vegetation on the ANF, by stand development stage (1998-2001 FHM data)

Stand development stage	Number of plots	Species richness	SE
Stand initiation (0-14 years)	15	61.3	7.9
Stem exclusion (15-49 years)	15	75.7	11.7
Understory reinitation (50+ years)	143	66.2	2.9

Table 34.—Percentage of sampled plants showing ozone injury (1998-2001 FHM data)

	No. of plots evaluated	No. of plants sampled	Percent of leaves with injury					
			No injury	1-6	7-25	26-50	51-75	>75
1998	6	244	55	13	17	7	5	2
1999	10	648	93	1	4	2	1	0
2000	7	417	75	6	7	5	4	3
2001	9	971	92	2	2	3	1	0

Note: Rows may not add to 100 due to rounding.

Table 35.—Number of plants evaluated for ozone injury on the ANF (1998-2001 FHM data; percent injured in parentheses)

Species	1998	1999	2000	2001
Blackberry	118 (59)	106 (41)	118 (54)	196 (19)
Black cherry	90 (61)	283 (2)	167 (16)	257 (10)
Milkweed	31 (6)	90 (0)	29 (0)	131 (6)
Pin cherry	36 (14)	31 (0)	30 (33)	75 (1)
Sassafras	--	--	26 (8)	60 (0)
Spreading dogbane	37 (0)	84 (0)	--	165 (0)
White ash	--	30 (0)	16 (0)	73 (4)
Yellow-poplar	--	24 (0)	11 (0)	--

and blackberry are two abundant species on the ANF that are sensitive to O_3. This report provides results from the expanded O_3 biomonitoring project conducted at the recommendation of the Allegheny Air Quality Assessment (USDA For. Serv. 2002).

O_3 plot data from 1998-2001 are summarized in Table 34. The data showed a high degree of temporal heterogeneity. Nearly half of the sampled plants (44.6 percent) showed some symptoms of O_3 injury in 1998, though most of the injury was on less than 25 percent of their foliage. By contrast, less than 25 percent of the sampled plants showed symptoms in 2000, and less than 8 percent showed injury symptoms in 1999 and 2001. Smith et al. (2003) reported that even when ambient O3 exposures are high, the percentage of injured plants can be reduced sharply in dry years, e.g., 1999 and 2001 on the ANF. Differences in the amount of O_3 injury between years probably are due to precipitation levels rather than ambient O_3 exposure levels.

The number of plants sampled by species with percent injured in parentheses is shown in Table 35. The scientific names of the bioindicator species are listed in Appendix II. Blackberry had the highest occurrences of O_3 damage with 40 to 60 percent of the sampled plants showing symptoms of damage in 1998-2000 versus only 19 percent in 2001. Nearly 60 percent of the black cherry plants sampled showed injury symptoms in 1998, but less than 16 percent showed symptoms between 1999 and 2001. Damage was minimal to other species sampled except in 2000 when one-third of the pin cherry plants sampled showed injury symptoms. Even for species with high occurrences of O_3 injury, the severity was low (Table 35).

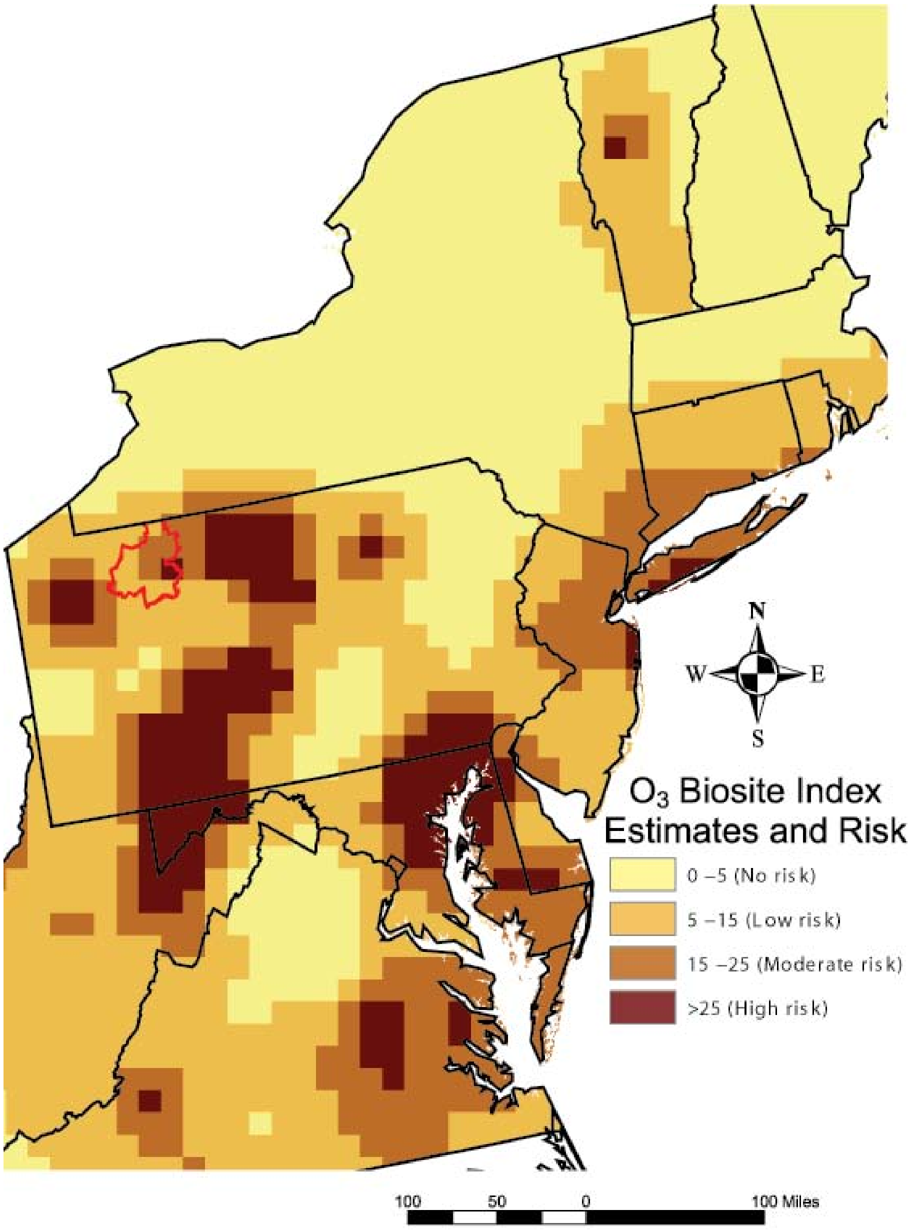


Figure 66.—Estimated surface of ozone biosite index in the Northeastern United States (from Coulston et al. 2003).

Coulston et al. (2003) created an estimated surface of biosite index using block kriging procedures to determine which tree species in the Northeastern United States are sensitive to O_3 (Fig. 66). Biosite index was the average score (amount times severity) for each species averaged across all species on an FHM ozone plot multiplied by 1,000 to allow risk categories to be defined by integers. The central portion of the ANF is in the moderate-risk category.

A typical summer O_3 exposure pattern for Eastern Region is shown in Figure 67 (USDA For. Serv. 2002). The term SUM06 is defined as the sum of all valid hourly O_3 concentrations that equal or exceed 0.06 ppm. Controlled studies have found that high O_3 levels (shown in orange and red) can lead to measurable growth suppression in sensitive tree species (Chappelka and Samuelson 1998).

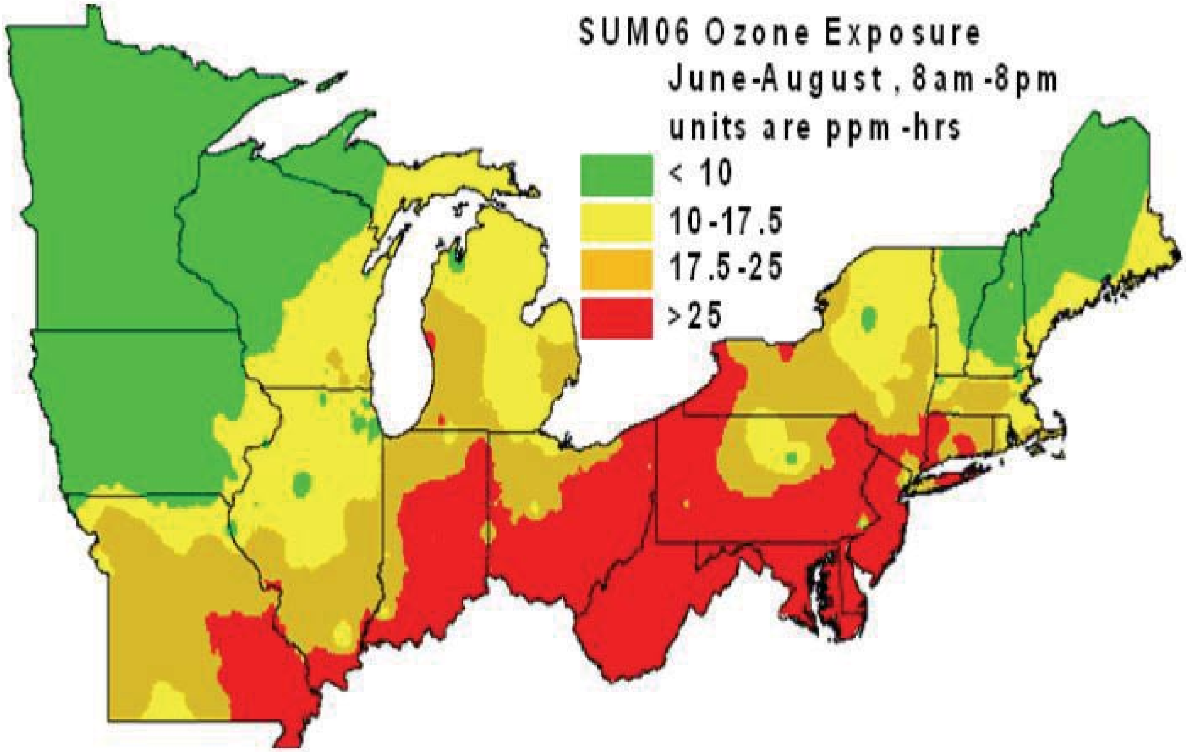


Figure 67.—Typical ozone exposure rates in the Eastern Region; data from Ozone Biomonitoring Project.

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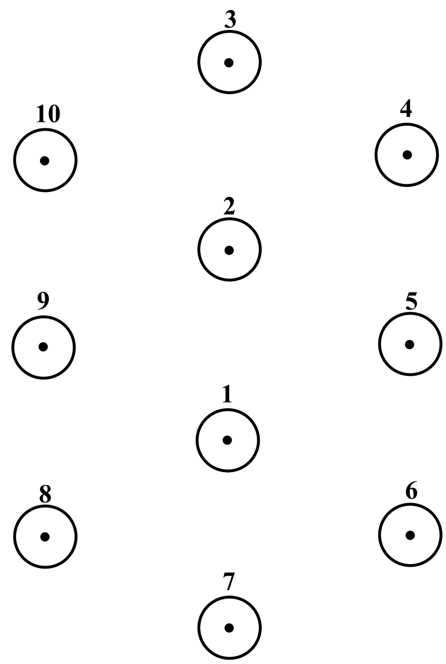
Appendix I

1989 FIA Survey Plot Designs

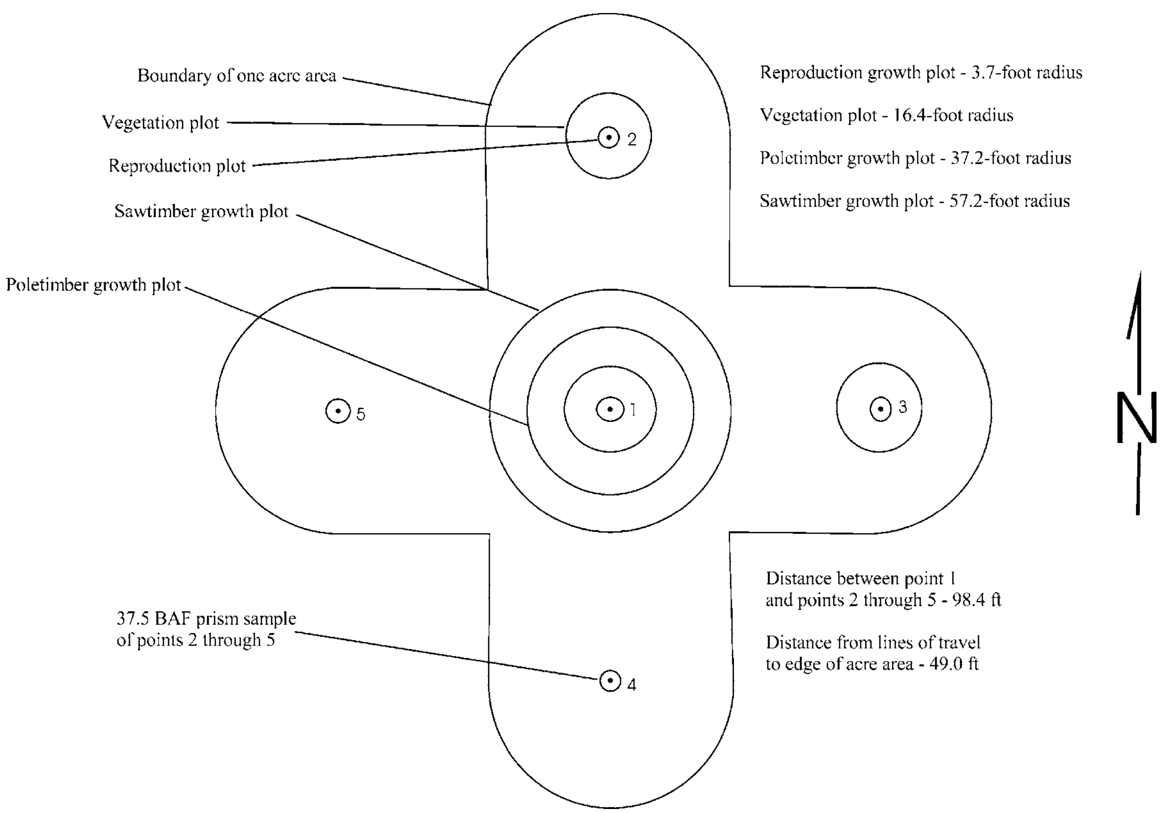
Azimuth between points:

1-2	0°
2-3	0°
3-4	120°
4-5	180°
5-6	180°
6-7	240°
7-8	300°
8-9	0°
9-10	0°

The distance between any point to any adjacent point is 70 ft



Remeasured 10-point cluster (37.5 BAF)



New 5-point fixed- and variable-radius cluster

Common and Scientific Names of Tree Species Found on ANF

American basswood	*Tilia americana*
American beech	*Fagus grandifolia*
American chestnut	*Castanea dentata*
American elm	*Ulmus americana*
American hornbeam	*Carpinus caroliniana*
apple species	*Malus* spp.
ash species	*Fraxinus* spp.
bigtooth aspen	*Populus grandidentata*
birch species	*Betula spp.*
black cherry	*Prunus serotina*
blackgum	*Nyssa sylvatica*
blue spruce	*Picea pungens*
chestnut oak	*Quercus prinus*
chokecherry	*Prunus virginiana*
cucumbertree	*Magnolia acuminata*
eastern hemlock	*Tsuga canadensis*
eastern hophornbeam	*Ostrya virginiana*
eastern redbud	*Cercis canadensis*
eastern white pine	*Pinus strobus*
hawthorn species	*Crataegus* spp.
mountain maple	*Acer spicatum*
northern red oak	*Quercus rubra*
oak species	*Quercus* spp.
pignut hickory	*Carya glabra*
pin cherry	*Prunus pensylvanica*
quaking aspen	*Populus tremuloides*
red maple	*Acer rubrum*
red pine	*Pinus resinosa*
sassafras	*Sassafras albidum*
scarlet oak	*Quercus coccinea*
serviceberry	*Amelanchier* spp.
slippery elm	*Ulmus rubra*
silver maple	*Acer saccharinum*
striped maple	*Acer pensylvanicum*
sugar maple	*Acer saccharum*
sweet birch	*Betula lenta*
white ash	*Fraxinus americana*
white oak	*Quercus alba*
white spruce	*Picea glauca*
yellow birch	*Betula alleghaniensis*
yellow-poplar	*Liriodendron tulipifera*

Region 9 Forest Cover Types

- Red pine: 50 percent or more of the basal area composed of red pine.
- White pine: 50 percent or more of the basal area composed of white pine.
- Hemlock: 50 percent or more of the basal area composed of eastern hemlock.
- White spruce/Norway spruce: 50 percent or more of the basal area composed of white and Norway spruce.
- Chestnut oak: 50 percent or more of the basal area composed of chestnut oak.
- White oak: 50 percent or more of the basal area composed of white oak.
- Red oak: 50 percent or more of the basal area composed of northern red oak.
- Oak/hardwood transition: 50 percent or more of the basal area composed of the combination of oaks, red maple, and black cherry (oaks comprise at least 25 percent of the basal area).
- White oak/red oak: 50 percent or more of the basal area composed of white and northern red oak.
- Red maple: 50 percent or more of the basal area composed of red maple.
- Mixed lowland hardwoods: 50 percent or more of the basal area composed of red maple, ash species, sycamore, silver maple, and oak species.
- Northern hardwoods: 50 percent or more of the basal area composed of sugar maple, beech, yellow birch, or hemlock.
- Allegheny hardwoods: 50 percent or more of the basal area composed of black cherry, yellow-poplar, and white ash.
- Pin cherry: 50 percent or more of the basal area composed of pin cherry.
- Sugar maple: 50 percent or more of the basal area composed of sugar maple.
- American beech: 50 percent or more of the basal area composed of American beech.
- Black birch/hickory: 50 percent or more of the basal area composed of black birch and hickory.
- Mixed upland hardwoods: 50 percent or more of the basal area composed of red maple, black cherry, yellow-poplar, white ash, basswood, cucumbertree, and black birch.
- Aspen: 50 percent or more of the basal area composed of bigtooth and quaking aspen.

Distribution of FHM and FIA Forest Type Groups and Forest Types

The majority of the FHM plots on the ANF were in the maple/beech/birch forest-type group. The forest types within this group include red maple upland hardwoods, black cherry, sugar maple/beech/yellow birch, cherry/ash/yellow-poplar, and hard maple/basswood. The red maple/upland hardwoods and black cherry forest types were the most common on the ANF, covering about 35 and 30 percent, respectively. No other forest type accounted for more than 10 percent of the plots surveyed.

	1998-2001 FHM Data	1989 FIA Data
Forest type/group	Percent of plots	Percent of plots
Maple/beech/birch	72.8	73.2
Red maple/upland hardwoods	34.3	19.6
Black cherry	29.8	38.6
Sugar maple/beech/yellow birch	6.9	15
Cherry/ash/yellow-poplar	1.2	0
Hard maple/basswood	0.6	0
Oak/hickory	15	18.5
Mixed upland hardwoods	8	15.1
White oak/red oak/hickory	4.2	2
White oak	1	0.8
Northern red oak	1.2	0
Red maple/oak	0.6	0
Chestnut oak	0	0.6
White/red/jack pine	8.3	1
Eastern hemlock	7.9	0.9
Red pine	0.4	0
White pine	0	0.1
Nonforest	3.7	0
Nonstocked	0.5	5.1
Exotic Softwoods	0.6	0
Other exotic softwoods	0.6	0
Intermediate	0.6	0
Aspen/birch	0.4	0.4
Aspen	0.4	0.4
Spruce/fir	0	1.1
White spruce	0	1.1
Oak/pine	0	0.7
White pine/red oak	0	0.7

Variogram Parameters for Kriged Maps

Figure 15—black cherry: exponential model, nugget = 300, sil l= 350, range = 4,500; red maple: exponential model, nugget = 350, sill = 120, range = 5,000; American beech: exponential model, nugget = 0, sill = 140, range = 4,000; eastern hemlock: exponential model, nugget = 50, sill = 210, range = 5,000; sugar maple: exponential model, nugget = 0, sill = 220, range = 3,000.

Figure 16—northern red oak: spherical model, nugget = 50, sill = 200, range = 60,000; sweet birch: spherical model, nugget = 90, sill = 40, range = 15,000; yellow birch: spherical model, nugget = 20, sill = 6, range = 20,000; white oak: spherical model, nugget = 20, sill = 65, range = 50,000; white ash: exponential model, nugget = 0, sill = 13, range = 5,000.

Figure 20—exponential model, nugget = 7, sill = 15, range = 5,000.

Figure 21—black cherry: exponential model, nugget = 10, sill = 160, range = 12,000; red maple: spherical model, nugget = 0, sill = 30, range = 13,000; American beech: exponential model, nugget = 30, sill = 20, range = 8,000; eastern hemlock: exponential model, nugget = 0, sill = 37, range = 15,000; sugar maple: pure nugget model, nugget = 175; white ash: pure nugget model, nugget = 175.

Figure 22—exponential model, nugget = 0, sill = 110, range = 1,500.

Figure 23—< 9 inches d.b.h.: spherical model, nugget = 160, sill = 35, range = 10,000; > 9 inches d.b.h.: pure nugget model, nugget = 110; > 12 inches d.b.h.: pure nugget model, nugget = 35; > 20 inches d.b.h.: exponential model, nugget = 0.3, sill = 1.5, range = 6,000.

Figure 44—exponential model, nugget = 0, sill = 290, range = 5,000.

Figure 47—pure nugget model, nugget = 16.

Figure 53—*Parmelia sulcata*: pure nugget model, nugget = 0.15; *Flavoparmelia caperata*: pure nugget model, nugget = 0.23; *Cladonia coniocraea*: exponential model, nugget = 0.19, sill = 0.05, range = 15,000; *Phaeophyscia rubropulchra*: exponential model, nugget = 0.22, sill = 0.04, range = 30,000.

Figure 55—spherical model, nugget = 0.009, sill = 0.005, range = 20,000.

Figure 63—FWD: pure nugget model, nugget = 2.5; CWD: exponential model, nugget = 8, sill = 16, range = 10,000; integrated depth: exponential model, nugget = 25, sill = 40, range = 8000; total DWM: exponential model, nugget = 100, sill = 150, range = 5,000.

Figure 65—exponential model, nugget = 2, sill = 0.75, range = 20,000.

Lichen Species Sampled on the ANF

Genus	Species	Percent of plots sampled
Anaptychia	*palmulata*	0.6
Candelaria	*concolor*	0.6
Canoparmelia	*texana*	2.3
Cetraria	*aurescens*	0.6
Cetraria	*oakesiana*	0.6
Cladonia		8.1
Cladonia	*bacillaris*	21.4
Cladonia	*caespiticia*	0.6
Cladonia	*chlorophaea*	0.6
Cladonia	*coniocraea*	1.7
Cladonia	*cristatella*	27.2
Cladonia	*cylindrica*	23.1
Cladonia	*floerkeana*	3.5
Cladonia	*grayi*	64.2
Cladonia	*macilenta*	4.0
Cladonia	*ochrochlora*	5.8
Cladonia	*parasitica*	1.2
Cladonia	*pyxidata*	0.6
Cladonia	*ramulosa*	1.7
Cladonia	*squamosa*	1.2
Cladonia	*squamosa*	2.9
Cladonia	*peziziformis*	0.6
Cladonia	*furcata*	4.0
Cladonia	*rei*	8.1
Cladonia	*incrassata*	11.0
Cladonia	*decorticata*	0.6
Cladonia	*farinacea*	0.6
Evernia	*mesomorpha*	1.7
Flavoparmelia	*caperata*	1.7
Heterodermia	*speciosa*	1.2

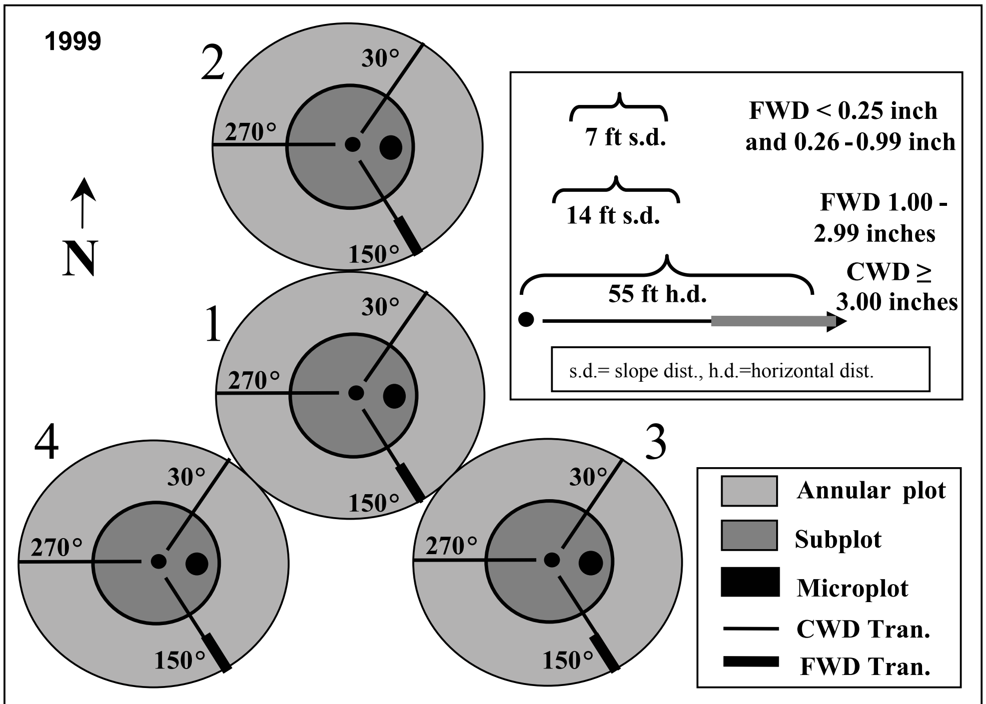
Genus	Species	Percent of plots sampled
Hypogymnia	*physodes*	11.6
Imshaugia	*aleurites*	67.1
Melanelia	*subaurifera*	0.6
Myelochroa	*aurulenta*	0.6
Parmelia		42.8
Parmelia	*squarrosa*	0.6
Parmelia	*sulcata*	0.6
Parmeliopsis		2.9
Parmeliopsis	*hyperopta*	19.7
Parmeliopsis	*capitata*	7.5
Parmotrema		2.9
Parmotrema	*margaritatum*	12.1
Phaeophyscia	*pusilloides*	85.0
Phaeophyscia	*rubropulchra*	0.6
Physcia	*adscendens*	0.6
Physcia	*aipolia*	0.6
Physcia	*millegrana*	1.2
Physcia	*stellaris*	0.6
Physciella	*melanchra*	1.2
Physconia		0.6
Physconia	*detersa*	0.6
Punctelia		12.7
Punctelia	*missouriensis*	56.6
Punctelia	*rudecta*	1.2
Punctelia	*subrudecta*	1.7
Pyxine	*sorediata*	46.8
Usnea		4.0
Usnea	*hirta*	0.6
Usnea	*strigosa*	0.6

Lichen Species Pollution Tolerances

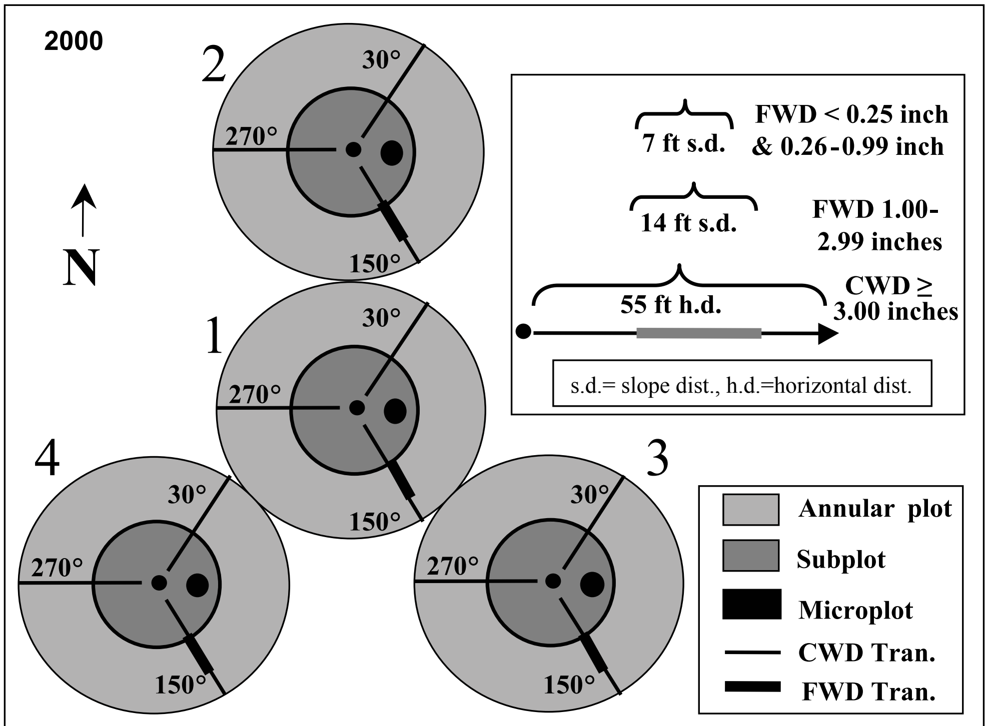
Genus	Species	Pollution tolerance[a]
Anaptychia	*palmulata*	S
Candelaria	*concolor*	T
Canoparmelia	*texana*	S
Cetraria	*oakesiana*	T
Cladonia	*bacillaris*	T
Cladonia	*coniocraea*	T
Cladonia	*pyxidata*	I
Evernia	*mesomorpha*	I
Flavoparmelia	*caperata*	T
Heterodermia	*speciosa*	S
Hypogymnia	*physodes*	T
Imshaugia	*aleurites*	I
Melanelia	*subaurifera*	I
Myelochroa	*aurulenta*	T
Parmelia	*squarrosa*	I
Parmelia	*sulcata*	VT
Parmotrema	*margaritatum*	S
Phaeophyscia	*pusilloides*	T
Phaeophyscia	*rubropulchra*	VT
Physcia	*adscendens*	I
Physcia	*millegrana*	VT
Physcia	*stellaris*	T
Physconia	*detersa*	I
Punctelia	*rudecta*	T
Punctelia	*subrudecta*	T
Pyxine	*sorediata*	I
Usnea	*hirta*	S
Usnea	*spp.*	S

[a] S=sensitive, I=intermediate, T=tolerant, VT=very tolerant.

DWM Plot Designs (1999 and 2000)



Dist. between subplots (2, 3, and 4) and subplot center (1): 120 ft at angles (deg.) 0, 120, and 240, respectively; dist. between subplot center and microplot center: 12 ft; depth/coverage of shrubs/herbs/duff/litter estimated on microplot.



Dist. between subplots (2, 3, and 4) and subplot center (1): 120 ft at angles (deg.) 0, 120, and 240, respectively; dist. between subplot center and microplot center: 12 ft.; depth/coverage of shrubs/herbs/duff/litter estimated on microplot.

Quadrat Ground-Cover Variables

- Dung
- Lichen
- Litter/duff – a continuous layer of accumulated organic matter over forest mineral soil
- Moss
- Road – any constructed portion of a maintained road, and other areas compacted and unvegetated from regular use by motorized vehicles
- Rock – rocks, boulders, or accumulations of gravel or pebbles
- Root/bole – living roots at the base of trees or exposed at the ground surface, and cross-sectional area of live tree boles at the ground line
- Soil – physically weathered soil parent material that may or may not also be chemically or biologically altered
- Stream/lake – body of water contained within banks
- Trampling
- Trash
- Water – ponding or flowing water that is not contained within banks
- Wood – logs and slash, stumps, branches, and limbs

Appendix II

Vegetation Species and Percentage of Subplots Sampled

Scientific name	Common name	Percent of subplots present
Acer		0.72
Acer pensylvanicum	striped maple	33.05
Acer rubrum	red maple	74.43
Acer saccharum	sugar maple	43.97
Acer spicatum	mountain maple	0.14
Achillea millefolium	common yarrow	0.57
Actaea		0.57
Actaea pachypoda	white baneberry	0.43
Adiantum pedatum	northern maidenhair	0.43
Agrimonia rostellata	beaked agrimony	0.14
Agrostis		1.01
Agrostis canina	velvet bentgrass	0.14
Agrostis capillaris	colonial bentgrass	0.14
Agrostis gigantea	redtop	0.72
Agrostis hyemalis	winter bentgrass	0.43
Agrostis perennans	upland bentgrass	9.91
Agrostis scabra	rough bentgrass	3.16
Agrostis stolonifera	creeping bentgrass	0.43
Allium tricoccum	wild leek	1.29
Ambrosia artemisiifolia	annual ragweed	0.14
Amelanchier		37.93
Amelanchier arborea	common serviceberry	9.63
Amelanchier bartramiana	oblongfruit serviceberry	0.29
Amelanchier laevis	Allegheny serviceberry	1.72
Amelanchier X intermedia	intermediate serviceberry	0.14
Amphicarpaea bracteata	American hogpeanut	0.86
Anaphalis		0.43
Anaphalis margaritacea	western pearly everlasting	0.57
Anemone quinquefolia	nightcaps	2.59
Antennaria		0.14
Antennaria neglecta	field pussytoes	0.14
Anthoxanthum odoratum	sweet vernalgrass	2.44
Apocynum		0.29
Apocynum cannabinum	Indianhemp	0.14
Arabis hirsuta	hairy rockcress	0.14
Aralia nudicaulis	wild sarsaparilla	2.87
Aralia spinosa	devil's walkingstick	3.3
Arctium minus	lesser burrdock	0.29

Appendix II continued

Scientific name	Common name	Percent of subplots present
Arisaema triphyllum	Jack in the pulpit	16.67
Arisaema triphyllum ssp. triphyllum	Jack in the pulpit	0.29
Asarum		0.14
Asplenium platyneuron	ebony spleenwort	0.14
Aster		2.01
Athyrium		0.14
Athyrium filix-femina	common ladyfern	1.29
Atriplex cristata	crested saltbush	0.14
Berberis		0.29
Berberis thunbergii	Japanese barberry	0.57
Betula		9.63
Betula alleghaniensis	yellow birch	29.02
Betula lenta		41.67
Bidens		0.29
Bidens connata	purplestem beggarticks	0.29
Bidens frondosa	devil's beggartick	0.72
Bidens tripartita	threelobe beggarticks	0.14
Boehmeria		0.43
Boehmeria cylindrica	smallspike false nettle	0.43
Botrychium		0.43
Botrychium dissectum	cutleaf grapefern	0.14
Botrychium multifidum	leathery grapefern	0.29
Botrychium oneidense	bluntlobe grapefern	0.14
Botrychium virginianum	rattlesnake fern	0.14
Brachyelytrum erectum	bearded shorthusk	61.35
Bromus pubescens	hairy woodland brome	0.14
Bulbostylis capillaris	densetuft hairsedge	0.29
Calamagrostis canadensis	bluejoint	0.29
Calamagrostis coarctata	arctic reedgrass	0.14
Calamovilfa longifolia	prairie sandreed	0.14
Caltha palustris	yellow marsh marigold	0.57
Cardamine		1.01
Cardamine diphylla	crinkleroot	1.44
Cardamine impatiens	narrowleaf bittercress	0.14
Cardamine pensylvanica	Pennsylvania bittercress	1.15
Cardamine rotundifolia	American bittercress	0.14
Carex		47.7
Carex aestivalis	summer sedge	7.47
Carex albicans	whitetinge sedge	0.43
Carex annectens	yellowfruit sedge	0.14

Appendix II continued

Scientific name	Common name	Percent of subplots present
Carex appalachica	Appalachian sedge	1.44
Carex arctata	drooping woodland sedge	2.16
Carex baileyi	Bailey's sedge	2.01
Carex blanda	eastern woodland sedge	2.44
Carex bromoides	bromelike sedge	0.72
Carex brunnescens	brownish sedge	1.44
Carex communis	fibrousroot sedge	13.22
Carex crinita	fringed sedge	1.01
Carex debilis	white edge sedge	51.44
Carex debilis var. pubera	white edge sedge	0.14
Carex debilis var. rudgei	white edge sedge	1.29
Carex deweyana	Dewey sedge	1.87
Carex digitalis	slender woodland sedge	2.44
Carex disperma	softleaf sedge	1.01
Carex folliculata	northern long sedge	0.14
Carex gracillima	graceful sedge	2.01
Carex gynandra	nodding sedge	1.58
Carex hirtifolia	pubescent sedge	0.29
Carex hitchcockiana	Hitchcock's sedge	0.29
Carex hystericina	bottlebrush sedge	0.43
Carex intumescens	greater bladder sedge	11.64
Carex laxiculmis	spreading sedge	6.32
Carex laxiculmis var. laxiculmis	spreading sedge	0.14
Carex laxiflora	broad looseflower sedge	6.61
Carex leptalea	bristlystalked sedge	0.29
Carex lucorum	Blue Ridge sedge	0.43
Carex lurida	shallow sedge	1.15
Carex normalis	greater straw sedge	0.14
Carex novae-angliae	New England sedge	0.86
Carex ormostachya	necklace spike sedge	0.14
Carex pallescens	pale sedge	0.29
Carex pensylvanica	Pennsylvania sedge	8.91
Carex plantaginea	plantainleaf sedge	4.31
Carex prasina	drooping sedge	1.44
Carex projecta	necklace sedge	1.72
Carex radiata	eastern star sedge	1.58
Carex scabrata	eastern rough sedge	2.01
Carex scoparia	broom sedge	2.73
Carex seorsa	weak stellate sedge	0.14
Carex stipata	owlfruit sedge	0.57

Appendix II continued

Scientific name	Common name	Percent of subplots present
Carex striatula	lined sedge	0.43
Carex swanii	Swan's sedge	8.91
Carex tenera	quill sedge	0.14
Carex torta	twisted sedge	0.14
Carex trisperma	threeseeded sedge	1.44
Carex vulpinoidea	fox sedge	0.86
Carpinus caroliniana	American hornbeam	7.04
Carya		0.14
Carya alba	mockernut hickory	0.14
Carya cordiformis	bitternut hickory	1.01
Carya glabra	pignut hickory	0.86
Carya ovalis	red hickory	0.43
Carya ovata	shagbark hickory	1.01
Castanea dentata	American chestnut	0.86
Caulophyllum thalictroides	blue cohosh	1.15
Centaurium pulchellum	branched centaury	0.14
Cerastium fontanum ssp. vulgare	big chickweed	0.14
Chelone glabra	white turtlehead	0.14
Chrysosplenium americanum	American golden saxifrage	1.15
Cinna		1.72
Cinna arundinacea	sweet woodreed	0.86
Cinna latifolia	drooping woodreed	14.51
Circaea		1.29
Circaea alpina	small enchanter's nightshade	5.75
Circaea alpina ssp. alpina	small enchanter's nightshade	0.14
Circaea lutetiana	broadleaf enchanter's nightshade	0.14
Circaea lutetiana ssp. Canadensis	broadleaf enchanter's nightshade	0.14
Cirsium		0.14
Claytonia		0.14
Clematis virginiana	devil's darning needles	0.72
Clinopodium vulgare	wild basil	0.57
Clintonia borealis	bluebead	0.14
Conopholis		0.43
Conopholis americana	American cancer-root	0.14
Coptis trifolia	threeleaf goldthread	8.48
Cornus		0.72
Cornus alternifolia	alternateleaf dogwood	1.44
Cornus florida	flowering dogwood	0.14
Coronilla varia	purple crownvetch	0.14
Corylus		0.14

Appendix II continued

Scientific name	Common name	Percent of subplots present
Corylus americana	American hazelnut	0.57
Corylus cornuta	beaked hazelnut	0.57
Crataegus		5.17
Crataegus intricata	Copenhagen hawthorn	0.14
Crataegus pruinosa	waxyfruit hawthorn	1.15
Crataegus punctata	dotted hawthorn	0.14
Cypripedium		0.29
Cypripedium acaule	moccasin flower	1.72
Cystopteris fragilis	brittle bladderfern	0.29
Dactylis glomerata	orchardgrass	1.15
Dalibarda repens	robin runaway	8.33
Danthonia		7.9
Danthonia compressa	flattened oatgrass	29.89
Danthonia spicata	poverty oatgrass	2.87
Dennstaedtia		0.57
Dennstaedtia punctilobula	eastern hayscented fern	64.94
Deparia acrostichoides	silver false spleenwort	2.01
Deschampsia caespitosa	tufted hairgrass	0.14
Diarrhena obovata		0.14
Dichanthelium acuminatum	tapered rosette grass	1.72
Dichanthelium acuminatum var. fasciculatum	western panicgrass	0.43
Dichanthelium clandestinum	deertongue	12.64
Dichanthelium dichotomum	cypress panicgrass	0.43
Dichanthelium latifolium	broadleaf rosette grass	0.14
Diervilla lonicera	northern bush honeysuckle	1.01
Digitaria ischaemum	smooth crabgrass	0.14
Dioscorea		1.01
Dioscorea villosa	wild yam	0.43
Disporum lanuginosum	yellow fairybells	1.29
Doellingeria		0.14
Doellingeria umbellata	parasol whitetop	7.76
Doellingeria umbellata var. umbellata	parasol whitetop	0.14
Drosera rotundifolia	roundleaf sundew	0.14
Dryopteris		15.23
Dryopteris campyloptera	mountain woodfern	1.72
Dryopteris carthusiana	spinulose woodfern	2.16
Dryopteris intermedia	intermediate woodfern	56.75
Dryopteris marginalis	marginal woodfern	1.44
Dryopteris X triploidea	triploid woodfern	0.29
Echinochloa muricata var. microstachya	rough barnyardgrass	0.14

Appendix II continued

Scientific name	Common name	Percent of subplots present
Elymus hystrix	eastern bottlebrush grass	1.29
Elymus riparius	riverbank wildrye	0.29
Elymus virginicus	Virginia wildrye	0.14
Epifagus virginiana	beechdrops	7.18
Epigaea repens	trailing arbutus	1.01
Epilobium leptophyllum	bog willowherb	0.14
Equisetum		0.57
Equisetum arvense	field horsetail	0.14
Equisetum sylvaticum	woodland horsetail	0.14
Erechtites hieraciifolia	American burnweed	3.16
Eurybia divaricata	white wood aster	16.24
Eurybia macrophylla	bigleaf aster	1.29
Euthamia graminifolia	flat-top goldentop	1.01
Fagus grandifolia	American beech	72.41
Festuca subverticillata	nodding fescue	1.87
Festuca trachyphylla	hard fescue	0.14
Fragaria		0.29
Fragaria virginiana	Virginia strawberry	0.14
Frangula alnus	glossy buckthorn	3.59
Fraxinus		0.29
Fraxinus americana	white ash	18.97
Galeopsis bifida	splitlip hempnettle	0.14
Galium		1.01
Galium aparine	stickywilly	0.57
Galium asprellum	rough bedstraw	0.57
Galium circaezans	licorice bedstraw	0.57
Galium obtusum	bluntleaf bedstraw	0.29
Galium odoratum	sweetscented bedstraw	0.29
Galium palustre	common marsh bedstraw	0.14
Galium tinctorium	stiff marsh bedstraw	0.72
Galium triflorum	fragrant bedstraw	6.61
Gaultheria procumbens	eastern teaberry	10.49
Gaylussacia baccata	black huckleberry	1.87
Geranium		0.14
Geranium maculatum	spotted geranium	0.14
Geum		0.43
Geum canadense	white avens	1.29
Glyceria		0.86
Glyceria melicaria	mannagrass	8.05
Glyceria striata	fowl mannagrass	2.3

Appendix II continued

Scientific name	Common name	Percent of subplots present
Goodyera tesselata	checkered rattlesnake plantain	0.14
Gratiola neglecta	clammy hedgehyssop	0.14
Gymnocarpium		0.72
Hackelia virginiana	beggarslice	0.14
Hamamelis virginiana	American witchhazel	16.67
Hepatica nobilis	hepatica	1.58
Hepatica nobilis var. acuta	sharplobe hepatica	0.86
Hepatica nobilis var. obtusa	roundlobe hepatica	0.29
Hieracium		0.57
Hieracium lachenalii	common hawkweed	0.14
Hieracium paniculatum	Allegheny hawkweed	0.14
Hieracium scabrum	rough hawkweed	0.14
Hieracium venosum	rattlesnakeweed	0.14
Hieracium X marianum	hawkweed	0.14
Holcus lanatus	common velvetgrass	1.44
Houstonia caerulea	azure bluet	0.57
Huperzia		0.57
Huperzia lucidula	shining clubmoss	9.63
Hydrocotyle americana	American marshpennywort	0.86
Hydrophyllum canadense	bluntleaf waterleaf	0.29
Hydrophyllum virginianum	Shawnee salad	0.29
Hypericum		1.44
Hypericum ellipticum	pale St. Johnswort	0.29
Hypericum mutilum	dwarf St. Johnswort	0.43
Hypericum perforatum	common St. Johnswort	0.43
Hypericum punctatum	spotted St. Johnswort	0.29
Ilex montana	mountain holly	23.71
Ilex verticillata	common winterberry	0.29
Impatiens		5.75
Impatiens capensis	jewelweed	1.87
Juncus bufonius	toad rush	0.29
Juncus effusus	common rush	4.89
Juncus effusus var. decipiens	lamp rush	0.14
Juncus tenuis	poverty rush	1.58
Kalmia latifolia	mountain laurel	4.17
Laportea canadensis	Canadian woodnettle	1.15
Leersia		0.14
Leersia oryzoides	rice cutgrass	0.43
Leersia virginica	whitegrass	3.16
Leucanthemum vulgare	oxeye daisy	0.72

Appendix II continued

Scientific name	Common name	Percent of subplots present
Lilium philadelphicum	wood lily	0.14
Linaria vulgaris	butter and eggs	0.14
Lindera benzoin	northern spicebush	1.15
Liriodendron tulipifera	tuliptree	9.77
Lobelia inflata	Indian-tobacco	1.29
Lobelia spicata	palespike lobelia	0.14
Lolium arundinaceum	tall fescue	0.14
Lolium perenne	perennial ryegrass	0.14
Lolium pratense	meadow ryegrass	0.29
Lonicera canadensis	American fly honeysuckle	0.14
Lotus corniculatus	birdfoot deervetch	1.01
Luzula		0.43
Luzula acuminata	hairy woodrush	0.43
Luzula multiflora	common woodrush	0.72
Lycopodiella		0.14
Lycopodium		6.75
Lycopodium annotinum	stiff clubmoss	5.03
Lycopodium clavatum	running clubmoss	8.91
Lycopodium dendroideum	tree groundpine	4.17
Lycopodium digitatum	fan clubmoss	4.02
Lycopodium obscurum	rare clubmoss	23.99
Lycopodium tristachyum	deeproot clubmoss	0.14
Lycopus		2.16
Lycopus uniflorus	northern bugleweed	3.88
Lycopus virginicus	Virginia water horehound	0.72
Lysimachia ciliata	fringed loosestrife	0.14
Lysimachia quadrifolia	whorled yellow loosestrife	4.02
Magnolia acuminata	cucumber-tree	26.01
Maianthemum canadense	Canada mayflower	48.85
Maianthemum racemosum	feathery false lily of the vally	1.44
Malus		0.72
Medeola virginiana	Indian cucumber	40.23
Melampyrum lineare	narrowleaf cowwheat	0.14
Mentha arvensis	wild mint	0.14
Milium effusum	American milletgrass	1.58
Mitchella repens	partridgeberry	50.86
Mitella diphylla	twoleaf miterwort	0.14
Monotropa uniflora	Indianpipe	11.49
Muhlenbergia sylvatica	woodland muhly	0.29
Myosotis arvensis	field forget-me-not	0.14

Appendix II continued

Scientific name	Common name	Percent of subplots present
Myosotis scorpioides	true forget-me-not	0.14
Nyssa sylvatica	blackgum	4.45
Oclemena acuminata	whorled wood aster	5.75
Onoclea sensibilis	sensitive fern	5.46
Oryzopsis		0.14
Oryzopsis asperifolia	roughleaf ricegrass	1.01
Osmorhiza claytonii	Clayton's sweetroot	0.43
Osmunda		4.02
Osmunda cinnamomea	cinnamon fern	12.79
Osmunda claytoniana	interrupted fern	3.74
Ostrya virginiana	hophornbeam	10.06
Oxalis		0.72
Oxalis corniculata	creeping woodsorrel	0.14
Oxalis grandis	great yellow woodsorrel	0.29
Oxalis montana	mountain woodsorrel	36.35
Oxalis stricta	common yellow oxalis	4.31
Packera aurea	golden ragwort	0.29
Panax quinquefolius	American ginseng	0.14
Panicum		0.43
Panicum dichotomiflorum	fall panicgrass	0.14
Parthenocissus quinquefolia	Virginia creeper	0.43
Phalaris arundinacea	reed canarygrass	0.29
Phleum pratense	timothy	0.86
Phytolacca americana	American pokeweed	0.72
Picea abies	Norway spruce	0.57
Picea glauca	white spruce	0.29
Pilea pumila	Canadian clearweed	5.17
Pinus resinosa	red pine	0.43
Pinus strobus	eastern white pine	3.45
Plantago		0.29
Plantago rugelii	blackseed plantain	0.14
Plantago virginica	Virginia plantain	0.14
Platanthera		0.43
Platanthera clavellata	small green wood orchid	0.29
Platanthera hookeri	Hooker's orchid	0.14
Platanthera macrophylla	greater roundleaved orchid	0.14
Platanthera orbiculata	lesser roundleaved orchid	0.86
Platanus occidentalis	American sycamore	0.14
Poa		0.72
Poa alsodes	grove bluegrass	4.45

Appendix II continued

Scientific name	Common name	Percent of subplots present
Poa compressa	Canada bluegrass	0.29
Poa nemoralis	wood bluegrass	1.15
Poa pratensis	Kentucky bluegrass	0.72
Poa saltuensis	oldpasture bluegrass	1.01
Poa sylvestris	woodland bluegrass	0.14
Poa trivialis	rough bluegrass	0.86
Podophyllum peltatum	mayapple	2.59
Polygala paucifolia	gaywings	0.72
Polygonatum		1.44
Polygonatum biflorum	smooth Solomon's seal	0.86
Polygonatum pubescens	hairy Solomon's seal	4.45
Polygonum		0.43
Polygonum amphibium	water knotweed	0.29
Polygonum caespitosum	oriental ladysthumb	0.43
Polygonum cilinode	fringed black bindweed	4.74
Polygonum hydropiperoides	swamp smartweed	0.43
Polygonum persicaria	spotted ladysthumb	0.29
Polygonum punctatum	dotted smartweed	0.43
Polygonum sagittatum	arrowleaf tearthumb	2.87
Polygonum virginianum	jumpseed	0.14
Polypodium		0.14
Polypodium virginianum	rock polypody	0.57
Polystichum acrostichoides	Christmas fern	15.95
Populus		0.29
Populus grandidentata	bigtooth aspen	2.87
Populus tremuloides	quaking aspen	3.88
Potentilla		0.43
Potentilla norvegica	Norwegian cinquefoil	0.14
Potentilla simplex	common cinquefoil	6.61
Prenanthes		3.16
Prenanthes alba	white rattlesnakeroot	0.29
Prenanthes altissima	tall rattlesnakeroot	0.43
Prenanthes trifoliolata	gall of the earth	0.29
Prunella vulgaris	common selfheal	2.16
Prunus		0.29
Prunus americana	American plum	0.14
Prunus pensylvanica	pin cherry	10.34
Prunus serotina	black cherry	68.97
Prunus virginiana	chokecherry	0.57
Pteridium		1.01

Appendix II continued

Scientific name	Common name	Percent of subplots present
Pteridium aquilinum	western brackenfern	8.48
Pycnanthemum		0.14
Pyrola		0.57
Quercus		0.72
Quercus alba	white oak	9.63
Quercus coccinea	scarlet oak	1.44
Quercus prinus	chestnut oak	2.01
Quercus rubra	northern red oak	20.11
Quercus velutina	black oak	5.03
Ranunculus		2.3
Ranunculus hispidus	bristly buttercup	0.29
Ranunculus hispidus var. caricetorum	bristly buttercup	0.14
Ranunculus recurvatus	blisterwort	0.29
Ranunculus repens	creeping buttercup	0.57
Rhododendron		0.57
Rhododendron prinophyllum	early azalea	0.14
Rhus hirta	staghorn sumac	0.14
Ribes		1.15
Ribes cynosbati	eastern prickly gooseberry	0.29
Ribes glandulosum	skunk currant	0.43
Ribes hirtellum	hairystem gooseberry	0.14
Ribes lacustre	prickly currant	0.14
Ribes rotundifolium	Appalachian gooseberry	1.72
Rosa		0.72
Rosa carolina	Carolina rose	0.29
Rosa multiflora	multiflora rose	1.44
Rubus		19.4
Rubus allegheniensis	Allegheny blackberry	35.34
Rubus flagellaris	northern dewberry	2.73
Rubus hispidus	bristly dewberry	11.21
Rubus idaeus	American red raspberry	5.46
Rubus occidentalis	black raspberry	0.86
Rubus pubescens	dwarf red blackberry	0.29
Rumex		0.14
Rumex acetosella	common sheep sorrel	1.15
Rumex crispus	curly dock	0.29
Rumex obtusifolius	bitter dock	0.29
Salix		0.43
Salix sericea	silky willow	0.29
Sambucus		2.3

Appendix II continued

Scientific name	Common name	Percent of subplots present
Sambucus nigra ssp. canadensis	common elderberry	0.72
Sambucus racemosa	red elderberry	0.43
Sassafras albidum	sassafras	5.03
Schizachne purpurascens	false melic	0.29
Schizachyrium scoparium	little bluestem	0.14
Scirpus		0.43
Scirpus atrovirens	green bulrush	1.58
Scirpus cyperinus	woolgrass	1.29
Scirpus georgianus	Georgia bulrush	0.29
Scirpus polyphyllus	leafy bulrush	0.43
Scutellaria		0.14
Scutellaria lateriflora	blue skullcap	1.01
Sisyrinchium		0.14
Sisyrinchium angustifolium	narrowleaf blue-eyed grass	0.14
Smilax		2.73
Smilax glauca	cat greenbrier	1.01
Smilax herbacea	smooth carrionflower	1.01
Smilax rotundifolia	roundleaf greenbrier	3.16
Smilax tamnoides	bristly greenbrier	0.86
Solanum dulcamara	climbing nightshade	0.29
Solidago		1.58
Solidago caesia	wreath goldenrod	0.43
Solidago caesia var. curtisii	mountain decumbent goldenrod	0.14
Solidago canadensis	Canada goldenrod	0.14
Solidago canadensis var. scabra	Canada goldenrod	0.57
Solidago flexicaulis	zigzag goldenrod	0.57
Solidago rugosa	wrinkleleaf goldenrod	16.24
Solidago rugosa ssp. aspera	wrinkleleaf goldenrod	0.43
Solidago rugosa ssp. rugosa var. villosa	wrinkleleaf goldenrod	0.14
Sorbus		0.29
Sorbus aucuparia	European mountain ash	1.01
Spiraea tomentosa	steeplebush	0.86
Stellaria		0.14
Stellaria borealis	boreal starwort	0.29
Stellaria graminea	grasslike starwort	0.14
Stellaria longifolia	longleaf starwort	0.29
Streptopus lanceolatus var. roseus	twistedstalk	2.44
Symphyotrichum lanceolatum	white panicle aster	0.29
Symphyotrichum lateriflorum	calico aster	0.57
Symphyotrichum lateriflorum var. lateriflorum	calico aster	0.14

Appendix II continued

Scientific name	Common name	Percent of subplots present
Symphyotrichum novae-angliae	New England aster	0.14
Symphyotrichum novi-belgii	New York aster	0.14
Symphyotrichum pilosum	hairy white oldfield aster	0.43
Symphyotrichum prenanthoides	crookedstem aster	1.87
Symphyotrichum racemosum	smooth white oldfield aster	0.57
Symplocarpus foetidus	skunk cabbage	0.72
Taraxacum officinale	common dandelion	1.58
Thalictrum dioicum	early meadow-rue	0.14
Thelypteris noveboracensis	New York fern	57.33
Tiarella cordifolia	heartleaf foamflower	10.92
Tilia americana	American basswood	4.17
Toxicodendron radicans	eastern poison ivy	0.43
Trientalis borealis	starflower	26.58
Trifolium		0.29
Trifolium pratense	red clover	0.14
Trifolium repens	white clover	0.14
Trillium		15.23
Trillium erectum	red trillium	1.87
Trillium undulatum	painted trillium	8.48
Tsuga canadensis	eastern hemlock	31.9
Tussilago farfara	coltsfoot	0.14
Typha angustifolia	narrowleaf cattail	0.14
Ulmus americana	American elm	0.14
Ulmus rubra	slippery elm	0.29
Urtica dioica	stinging nettle	0.29
Uvularia perfoliata	perfoliate bellwort	0.29
Uvularia sessilifolia	sessileleaf bellwort	25.72
Vaccinium		0.72
Vaccinium angustifolium	lowbush blueberry	7.76
Vaccinium myrtilloides	velvetleaf huckleberry	0.14
Vaccinium pallidum	Blue Ridge blueberry	4.31
Vaccinium stamineum	deerberry	1.58
Veratrum viride	green false hellebore	0.72
Veronica		0.14
Veronica officinalis	common gypsyweed	3.02
Viburnum		0.72
Viburnum acerifolium	mapleleaf viburnum	5.03
Viburnum dentatum	southern arrowwood	0.57
Viburnum dentatum var. lucidum	southern arrowwood	0.29
Viburnum lantanoides	hobblebush	0.86

Appendix II continued

Scientific name	Common name	Percent of subplots present
Viburnum nudum var. cassinoides	withe-rod	0.57
Vicia		0.14
Vicia sativa	garden vetch	0.14
Viola		54.74
Viola blanda	sweet white violet	8.19
Viola blanda var. palustriformis	sweet white violet	1.72
Viola hastata	halberdleaf yellow violet	0.57
Viola hirsutula	southern woodland violet	0.29
Viola macloskeyi	small white violet	0.43
Viola macloskeyi ssp. pallens	smooth white violet	0.29
Viola pubescens	downy yellow violet	0.72
Viola rostrata	longspur violet	0.29
Viola rotundifolia	roundleaf yellow violet	0.57
Viola sagittata	arrowleaf violet	0.29
Viola sororia	common blue violet	0.72
Viola tricolor	johnny jumpup	0.14
Vitis		3.3
Vitis aestivalis	summer grape	0.14
Waldsteinia fragarioides	Appalachian barren strawberry	0.72

Introduced Vegetation Species and Percent of Subplots Sampled

Scientific name	Common name	Percent of subplots present
Achillea millefolium	common yarrow	0.57
Agrostis capillaris	colonial bentgrass	0.14
Agrostis gigantea	redtop	0.72
Anthoxanthum odoratum	sweet vernalgrass	2.44
Arctium minus	lesser burrdock	0.29
Berberis thunbergii	Japanese barberry	0.57
Cardamine impatiens	narrowleaf bittercress	0.14
Centaurium pulchellum	branched centaury	0.14
Cerastium fontanum ssp. vulgare	big chickweed	0.14
Coronilla varia	purple crownvetch	0.14
Dactylis glomerata	orchardgrass	1.15
Digitaria ischaemum	smooth crabgrass	0.14
Festuca trachyphylla	hard fescue	0.14
Frangula alnus	glossy buckthorn	3.59
Galeopsis bifida	splitlip hempnettle	0.14
Galium odoratum	sweetscented bedstraw	0.29
Hieracium lachenalii	common hawkweed	0.14
Holcus lanatus	common velvetgrass	1.44
Hypericum perforatum	common St. Johnswort	0.43
Leucanthemum vulgare	oxeye daisy	0.72
Linaria vulgaris	butter and eggs	0.14
Lolium arundinaceum	tall fescue	0.14
Lolium perenne	perennial ryegrass	0.14
Lolium pratense	meadow ryegrass	0.29
Lotus corniculatus	birdfoot deervetch	1.01
Myosotis arvensis	field forget-me-not	0.14
Myosotis scorpioides	true forget-me-not	0.14
Phleum pratense	timothy	0.86
Picea abies	Norway spruce	0.57
Poa compressa	Canada bluegrass	0.29
Poa pratensis	Kentucky bluegrass	0.72
Poa trivialis	rough bluegrass	0.86
Polygonum caespitosum	oriental ladysthumb	0.43
Polygonum persicaria	spotted ladysthumb	0.29
Ranunculus repens	creeping buttercup	0.57
Rosa multiflora	multiflora rose	1.44
Rumex acetosella	common sheep sorrel	1.15
Rumex crispus	curly dock	0.29
Rumex obtusifolius	bitter dock	0.29

Introduced Vegetation Species and Percent of Subplots Sampled continued.

Scientific name	Common name	Percent of subplots present
Solanum dulcamara	climbing nightshade	0.29
Sorbus aucuparia	European mountain ash	1.01
Stellaria graminea	grasslike starwort	0.14
Taraxacum officinale	common dandelion	1.58
Trifolium pratense	red clover	0.14
Trifolium repens	white clover	0.14
Tussilago farfara	coltsfoot	0.14
Typha angustifolia	narrowleaf cattail	0.14
Viola tricolor	johnny jumpup	0.14

Morin, Randall S.; Liebhold, Andrew M.; Gottschalk, K.W.; Woodall, Chris, W.; Twardus, Daniel B.; White, Robert L.; Horsley, Stephen B.; Ristau, Todd E. 2006. **Analysis of forest health monitoring surveys on the Allegheny National Forest (1998-2001).** Gen. Tech. Rep. NE-339. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 102 p.

Describes forest vegetation and health conditions on the Allegheny National Forest (ANF). During the past 20 years, the ANF has experienced four severe droughts, several outbreaks of exotic and native insect defoliators, and the effects of other disturbance agents. An increase in tree mortality has raised concerns about forest health. Historical aerial surveys (1984-98), Forest Inventory and Analysis plot data collected in 1989, and FHM plot data collected 1998-2001 were analyzed to compare disturbed and undisturbed areas. Tree mortality and crown dieback levels were compared between undefoliated areas and areas defoliated by cherry scallopshell moth, elm spanworm, and gypsy moth. American beech mortality was compared inside and outside the beech bark disease killing front. This study illustrates the value of an intensified grid of P3 plots and demonstrates the integration of aerial survey and plot data.

Keywords: forest health, crown condition, cherry scallopshell moth, elm spanworm, gypsy moth, beech bark disease

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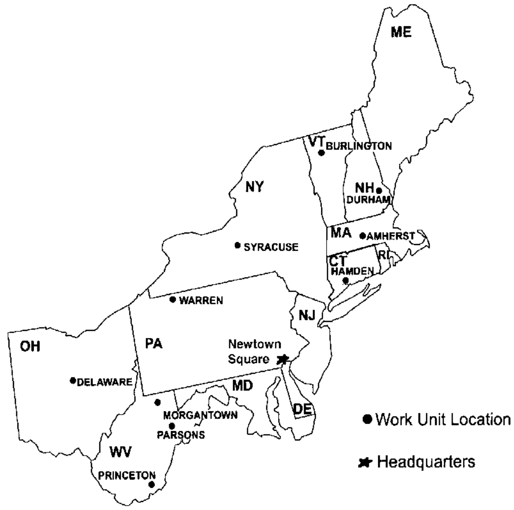

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