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Forest Health Conditions on the Allegheny National Forest (1989-1999): Analysis of Forest Health Monitoring Surveys

R.S. Morin, A.M. Liebhold, K.W. Gottschalk, D.B. Twardus, R.E. Acciavatti, R.L. White, S.B. Horsley, W.D. Smith, and E.R. Luzader

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The Authors

RANDALL S. MORIN, Jr. is a statistical assistant, ANDREW M. LIEBHOLD is a research entomologist, KURT W. GOTTSCHALK is a research forester, STEPHEN B. HORSLEY is a research plant physiologist, and EUGENE R. LUZADER is a computer specialist with the USDA Forest Service's Northeastern Research Station. Morin, Liebhold, Gottschalk, and Luzader are located in Morgantown, West Virginia. Horsley is located in Warren, Pennsylvania.

DANIEL B. TWARDUS is a forest health specialist, and ROBERT E. ACCIAVATTI is a forest entomologist with the Northeastern Area, State and Private Forestry, in Morgantown, West Virginia.

ROBERT L. WHITE is a forest silviculturist with Region 9, Allegheny National Forest, in Warren, Pennsylvania.

WILLIAM D. SMITH is an assessment coordinator with the USDA Forest Service's Southern Research Station, at Research Triangle Park, North Carolina.

Cover

Cherry scallopshell moth larvae (*Hydria prunivorata*) (upper left), elm spanworm larva (*Ennomos subsignarius*) (upper middle), gypsy moth larva (*Lymantria dispar*) (upper right), healthy sugar maple stand on a bottom slope (lower left), and extensive mortality in a ridgetop sugar maple stand (lower right).

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USDA FOREST SERVICE
NEWTOWN SQUARE CORPORATE CAMPUS
11 CAMPUS BLVD., SUITE 200
NEWTOWN SQUARE, PA 19073

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ABSTRACT

This publication describes the forest vegetation and health conditions of the Allegheny National Forest (ANF). During the past 15 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), the 1989 Forest Inventory and Analysis plot data, and the 1998/1999 Forest Health Monitoring plot data 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 Forest Health Monitoring plots and demonstrates the integration of aerial survey and plot data.

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INTRODUCTION

Objectives

Since 1987, as part of the Allegheny National Forest (ANF) plan, general changes in forest health and vigor have been monitored and reported (USDA For. Serv. 2001). This report is intended to provide more current and comprehensive information about forest health on the ANF, as well as information to be considered when making management decisions in preparation for forest plan revision. This report also provides an interim analysis of the first 2 years of data collected as part of the 4-year effort designed to assess forest health on the ANF.

The primary objective of this investigation was to gain a better understanding of the role of insects and diseases on the ANF during the last 10 to 15 years. A secondary objective was to describe certain forest conditions on the ANF. Specific questions investigated were:

1) What are the current forest conditions on the ANF?
2) How are forest insects and disease infestations contributing to change on the ANF?
3) To what extent does historical aerial survey defoliation data explain changes in forest conditions?
4) What kinds of forested areas are being affected?

The analyses compared plots located inside and outside defoliated and disease-infested areas. In addition, the analyses explored the extent to which site and stand characteristics explain the location and frequency of defoliation.

Location

The Allegheny National Forest, established in 1923 and located in northwestern Pennsylvania (Fig. 1) on the unglaciated portion of the Allegheny Plateau, comprises portions of Warren, Forest, McKean, and Elk Counties. The area within the forest proclamation boundary is approximately 740,500 acres, 70 percent of which is federal land (513,000 acres).

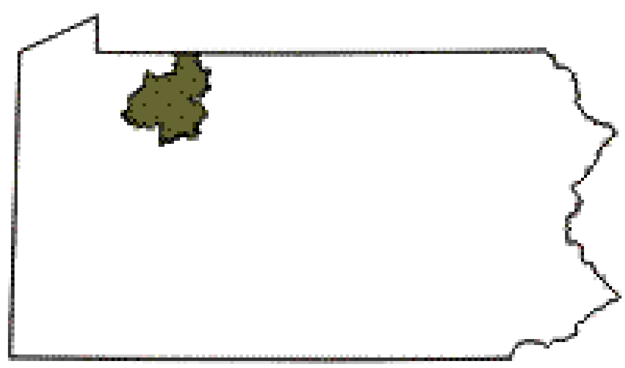

Figure 1. Location of the Allegheny National Forest in Pennsylvania.

Climate

The ANF sits in rugged plateau country where many creeks and streams cut deeply into the plateau, creating a rolling and sometimes steep topography ranging from 1,040 to 2,360 feet above sea level. Winters are long and cold, and summers are comparatively short. Precipitation usually is plentiful throughout the year and averages 40 to 45 inches per year; snow averages 55 to 85 inches per year. Average monthly precipitation ranges from 2.5 to 5 inches (Fig. 2, page 2). Precipitation generally peaks in June with a mean of almost 5 inches. Dry periods of varying duration and intensity are most likely during summer and fall. The Palmer Drought Severity Index for July over the last 60 years indicates drought events every 3 to 6 years (Fig. 3). The ANF experienced four significant droughts between 1988 and 1999 following a relatively drought-free period from 1972 to 1987. The droughts in the late 1980s and 1990s also coincided with several insect defoliator outbreaks.

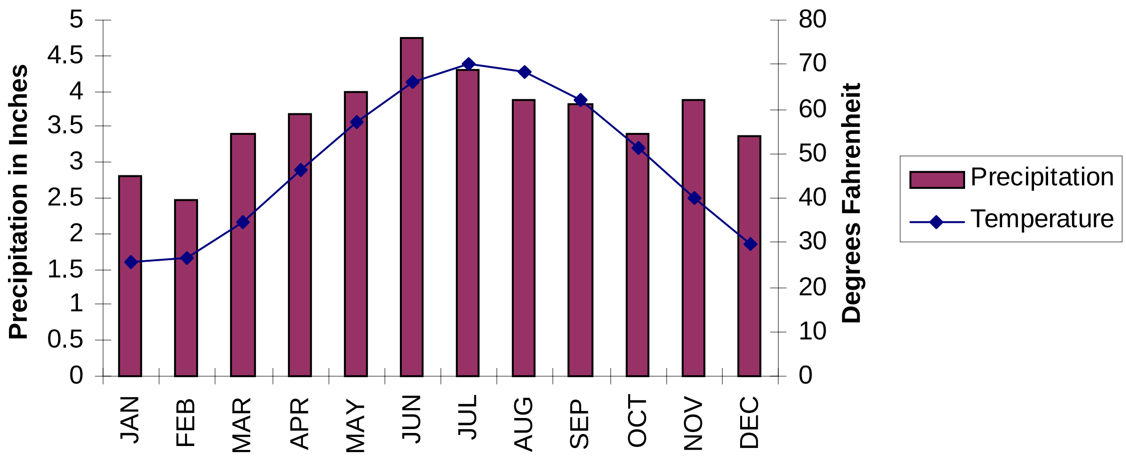

Figure 2. Average monthly precipitation and temperature for Warren, PA (1926-94) — data from Penn State University, College of Earth and Mineral Science, Department of Meteorology, Pennsylvania State Climatologist.

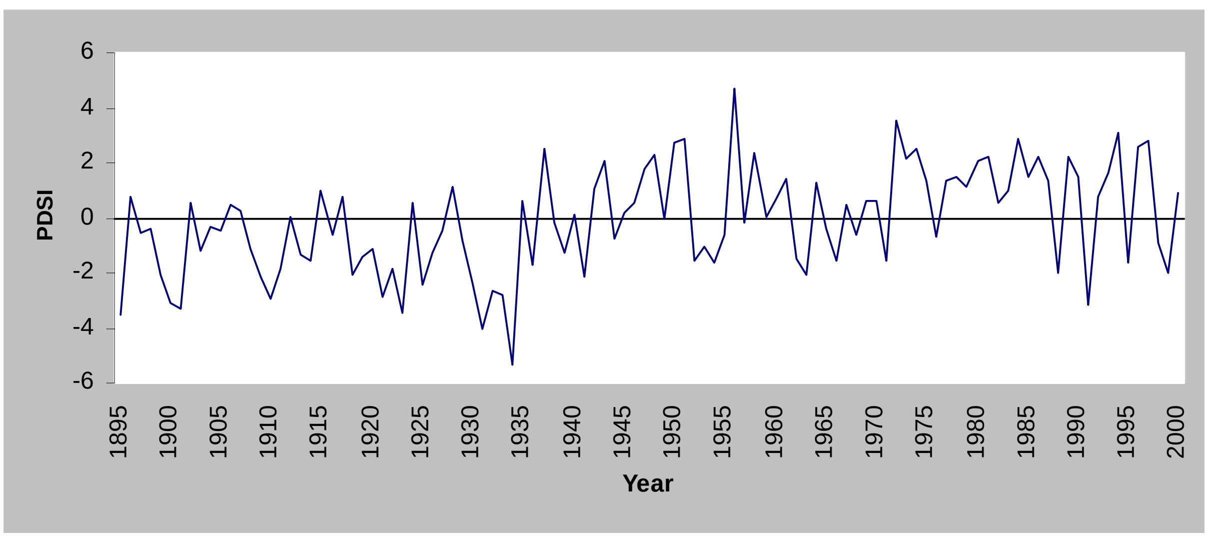

Figure 3. Palmer Drought Severity Index (July) for Warren, PA (1940-2000) — data from the National Climatic Data Center.

History

Forest conditions on the ANF have undergone dramatic change since the early 1800s. The pre-European settlement forest was dominated by eastern hemlock and American beech (Lutz 1930), but included small areas (tens of acres) of eastern white pine that originated following periodic stand replacement disturbances (Hough and Forbes 1943; Marquis 1975).

Today, the ANF vegetation is characterized by an abundance of black cherry, red and sugar maple, American beech, northern red oak, white oak, and other hardwoods. Most of the commercial black cherry timber in the world comes from the Allegheny Plateau (Marquis 1975). Development of the present forest has been influenced by historic events, including: the pattern and intensity of the widespread timber harvest at the turn of the 19th century, the decline and subsequent rebound of white-tailed deer (*Odocoileus virginianus*) populations, and multiple-use management practices by the USDA Forest Service during the past 75 years.

Early Timber Removals

The first European settlers reached the area around 1796 (Kussart 1938), marking the beginning of the period of change in forest vegetation. At first, trees were cut to clear land for agriculture and to provide timber for cabins and barns (Marquis 1975). Not long after the settlement of the area, forest-based industries were developed.

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

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. By the end of the 19th century, the local tanning industry was using massive quantities of hemlock bark. Figure 4 shows a chute for sliding hemlock bark down the hillside. Figure 5 shows a trainload of hemlock tanbark.

In the late 1800s, there was increased demand for lumber to build homes, stores, and furniture. The demand also increased for paper and other wood pulp products.

When band saws came into use around 1880, sawmills that could cut more than 100,000 board feet per day were constructed.

About 1890, the chemical wood industry began to change forest harvesting and utilization. Harvested timber was procured, refined, and used to make acetic acid, charcoal, wood alcohol, and other distillation products (Marquis 1975).

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

During the next 40 years, the chemical wood industry provided a market for nearly every size, species, and quality of tree in the area (Fig. 6).

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

The harvests during this era cleared nearly every tree that was accessible. The once large, contiguous forest on the Allegheny Plateau was virtually removed in what may have been the highest degree of forest utilization that ever occurred (Horst and Smith 1969; Taber 1974). Following removal of the pre-European settlement forest, the same species grew back, but in different proportions. Hemlock, beech, and white pine were less abundant; black cherry, the maples, and white ash increased; and the birches were similar in abundance (Whitney 1990). Thus, the second-growth forest was essentially even-aged, having arisen from nearly complete forest removals over a relatively short time period.

Population Dynamics of the White-tailed Deer

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 the period of intensive timber harvest that supported the chemical wood industry, deer populations were low (Fig. 7, page 6). Unregulated deer 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.

In the early 20th century, the passage of game laws, restocking of deer, and the regulation of antlerless deer harvests allowed the deer population to rebound. Deer densities increased rapidly in the presence of a virtually limitless supply of food during the 1920s and 1930s. As forest vegetation matured and grew above browsing height, food became more difficult to find. Deer populations crashed twice during the period from 1930 through 1980 following severe winters, but populations recovered despite the dwindling food supply. Since 1980, deer densities have remained more constant, largely due to the Pennsylvania Game Commission's efforts to regulate population levels, though deer density still remains above the level that will permit regeneration of many species.

The long-term impact from years of high deer densities has been the loss of understory and midstory vegetation over much of the ANF. Tree seedlings of many species are not abundant, and most understories are dominated by fern, grass, beech brush, or striped maple (USDA For. Serv. 1995). The most important factor limiting tree seedling establishment on the ANF is browsing by white-tailed deer (Stout et al. 1995). The maximum deer density that allows desirable tree seedlings to develop in northern Pennsylvania is about 20 per square mile (Tilghman 1989; deCalesta 1994). Winter 2000 to 2001 deer populations for the four county area, which includes the ANF, averaged from 23 per square mile for Elk County to 34 per square mile for Forest County, a decrease from populations estimated for the previous year (Pennsylvania Game Commission 2001, pers. commun.[1]).

Multiple-Use Forest Management

Since much of the land had been recently cut over, early management on the ANF focused on nurturing the development of the second-growth forest and reforesting areas where tree seedlings had failed to develop. 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 started growing about the same time, most of the trees on the ANF today are the same age (70 to 100 years old). Today, ANF management emphasizes forest ecosystem sustainability and multiple-use management.

Currently, the Forest Service performs a range of management and research activities designed to provide multiple benefits based on scientific principles. Forest managers rely heavily on the research and silvicultural guidelines established by the Northeastern Research Station. 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 on requirements for regenerating tree seedlings. Even-aged methods often are used to reproduce stands in the cherry/maple type.

Research showed that when few tree seedlings are present at the time of an even-aged regeneration harvest, inadequate numbers of tree seedlings developed following the harvest (Grisez and Peace 1973). Grisez and Peace (1973) reported that only 35 of 65 clearcuts from the early 1970s yielded satisfactory natural regeneration. Because of failed regeneration, clearcutting was largely abandoned except where adequate advanced regeneration was present or where coppice sprouts were anticipated (aspen). Shelterwood cutting usually is used to ensure that adequate regeneration is in place prior to final overstory removal (Marquis 1978). Reforestation activities (such as site preparation, fencing, planting, fertilization, and herbicide treatment) also play an important role in assuring seedling establishment and growth. Marquis et al. (1992) found that adequate regeneration was nearly impossible when fern stocking exceeded 30 percent. Striped maple seedlings and beech root suckers are other types of interference that can exclude desirable species (Horsley and Bjorkbom 1983), as can grass. If the number of stems of interfering vegetation, like striped maple and American beech, exceeds recommendations (or if ferns and grasses exceed threshhold amounts), herbicides often are used for control (Horsley and Bjorkbom 1983). The species composition of the advance seedlings largely determines the species composition of the resulting regenerating forest (Marquis et al. 1992).

Local land managers share similar concerns regarding future tree species composition and forest sustainability for areas where active reforestation or harvest activity is not permitted. Trees that die may not be replaced through natural processes by an adequate quantity of tree seedlings or appropriate tree species capable of growing up to replace them (USDA For. Serv. 2001). In 1994, aerial color infrared photographs of declining areas on the ANF revealed that nearly 90,000 acres were affected. During the same year, ground inventories of 12,000 of these affected acres showed that only 8 percent had adequate tree regeneration, and more than 70 percent had a fern understory stocking in excess of 30 percent (Stout et al. 1995). In a 6,000-plot survey on the

[1] Pennsylvania Game Commission. 2001. Personal communication with R. White.

ANF, it was reported that some type of interference was found on 70 percent of the survey area, and fern interference was present on 46 percent of the area (USDA For. Serv. 1995).

Recent Disturbance Events

During the past 15 years, ANF management has become increasingly challenging due to actions by both native and exotic disturbance agents (Stout et al. 1995). Pear thrips (*Taeniothrips inconsequens* Uzel), 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, and ash dieback are of particular concern. Many factors are involved in the cause-effect relationship of maple decline including soil moisture, soil aeration, nematodes, Armillaria root rot, sugar maple borer, high temperatures, Verticillium wilt, canker fungi, insect defoliators, root excavation, salt, injuries, and air pollution (Manion 1991). Ash viruses and canker fungi have been identified as factors in ash dieback (Manion 1991). Since 1985, nearly 86 percent of the ANF has been defoliated at least once. While gypsy moth defoliation peaked in the mid-1980s, damage was also observed between 1993 and 1995. Trees were also 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 demonstrated some recovery (USDA For. Serv. 2001).

For an initial characterization of mortality/decline in some of 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. Nearly 19 percent of the existing

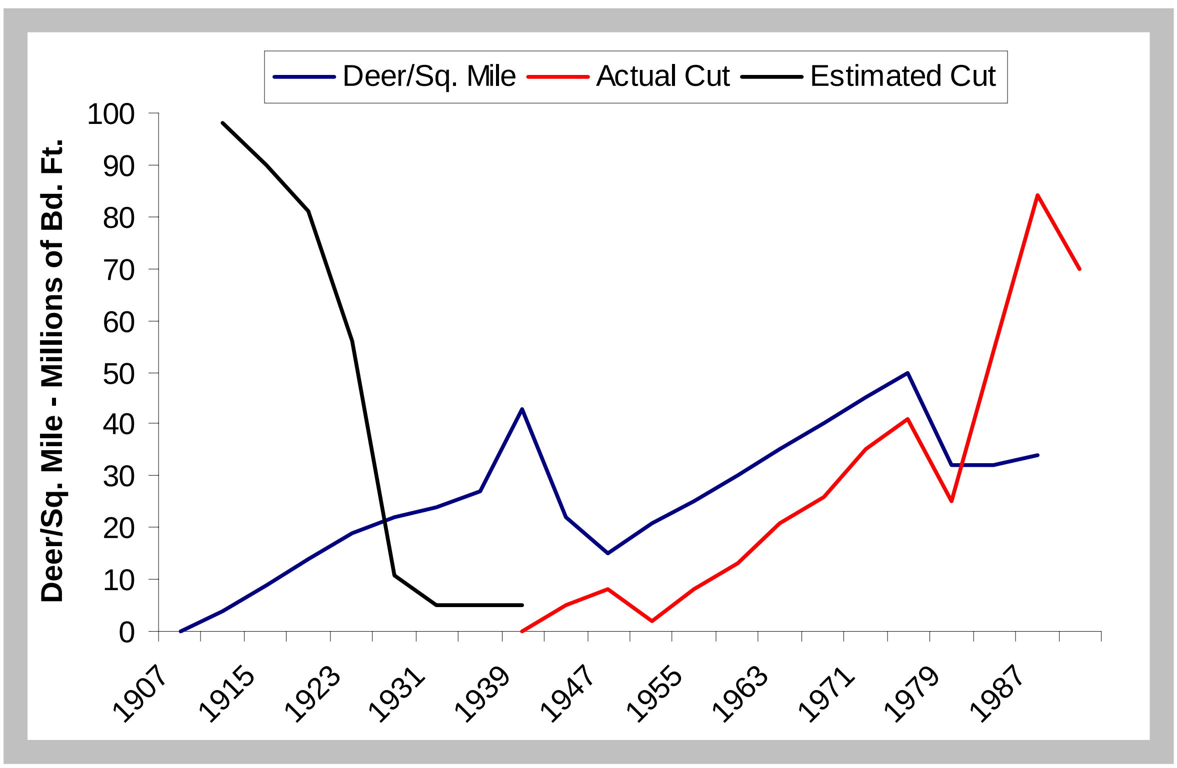

Figure 7. Deer population and timber cutting trends on the Allegheny National Forest (redrawn from Redding 1995).

basal area in these stands was classified as dead (12.3 percent) or at risk (6.4 percent). Tree status varied greatly among stands. In some stands, dead and at risk trees were a majority, and in other stands, they were a minor component. Black cherry, sugar maple, and red maple made up approximately 84 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 at-risk trees at 43.3 percent, 19.9 percent, and 13.4 percent of the basal area respectively.

McWilliams et al. (1999) also evaluated understory vegetation. Adequate numbers of tree seedlings are present on only 8 percent of the sampled stands. Vegetation that interferes with tree seedling development and growth is present in sufficient quantities to require treatment in 93 percent of the stands examined. Sparse regeneration and the abundance of interfering vegetation continue to raise serious 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 were mostly derived from three sources of data: 1) Forest Inventory and Analysis (FIA) plot data, 2) Forest Health Monitoring (FHM) plot data, and 3) aerial surveys of defoliation. This project focused on describing and quantifying the insect and disease problems and certain vegetation characteristics on the ANF, but another purpose of the study was to determine how useful the above mentioned data can be for explaining the relationships of these problems to the damage observed on trees and in stands and their impacts on forest health.

Forest Inventory and Analysis Data

The FIA program has been operating nationally since 1930. The first FIA inventory was collected in Pennsylvania in 1958. Plots were remeasured in 1968, 1977-78, and 1988-90 (Alerich 1993). The FIA objective is to periodically determine the extent, condition, and volume of timber in the Nation's forests. Inventories are conducted on a state-by-state basis. In the eastern United States, inventories are performed every 5 to 15 years. The FIA program is currently changing from a periodic to an annual measurement approach.

Aerial photos are used to classify each state's land into land-use classes (pasture, urban, forestland, water, etc.). For forested land, more detailed classes categorize areas based on forest type, volume, stand size, stand density, ownership, and stand age. The estimate of area in each class derived from the photo samples is used to determine the number of ground plots or to stratify the randomization of ground plots within each class.

Different arrangements of fixed-radius and variable radius plots have been used to select sample trees. For each sample tree, several variables are measured, including diameter at breast height (d.b.h.) for live and dead trees, species, and other variables that enable volume, growth rate, and quality to be estimated. There normally is approximately one FIA plot for every 6,000 acres (Hansen et al. 1992), but sampling intensity is higher on the ANF with about one plot for every 3,000 acres. For this survey, two different plot designs were used. Remeasured plots were a 10-point cluster of BAF 37.5 prism plots (Fig. 8, page 8). New plots were fixed radius with variable radius points (Fig. 9, page 8). Eighty-nine percent of the 168 plots visited in 1988-1990 were remeasurements from the 1978 inventory (Fig. 11, page 11) (Alerich 1993). Unless otherwise stated, the analyses in this report that used the 1989 FIA survey include all 168 plots.

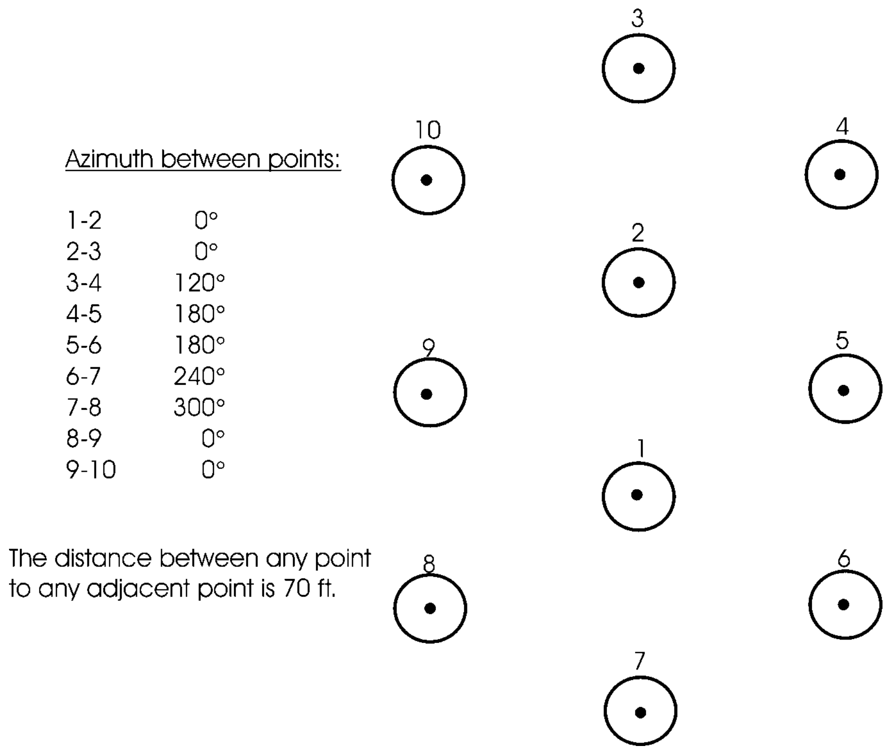

Figure 8. FIA plot design: remeasured 10-point cluster (37.5 BAF).

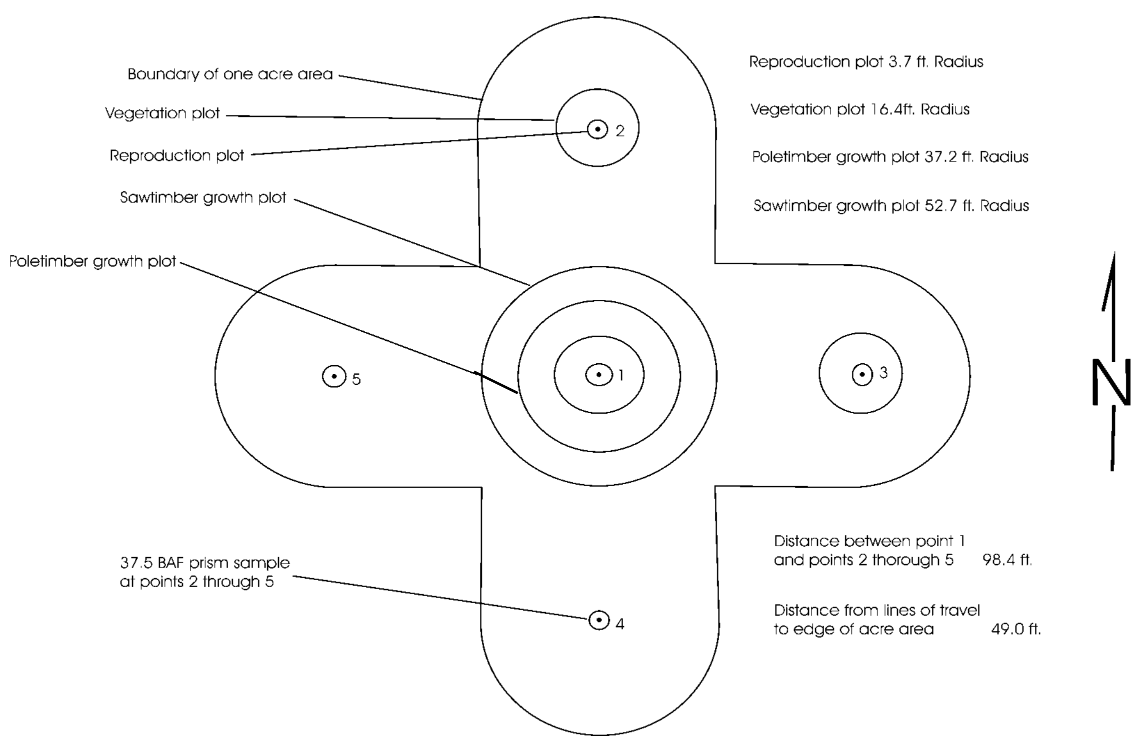

Figure 9. FIA plot design: new 5-point fixed- and variable-radius cluster.

Forest Health Monitoring Data

The national FHM program was first implemented in the New England States in 1990 (Brooks et al. 1991). The objective of the FHM program is 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 concern for the health of the Nation's forests with regard to pollution, insects, diseases, climatic change, and other stressors.

The FHM program consists of: detection monitoring, evaluation monitoring, and intensive site ecosystem monitoring. Each monitoring activity has specific goals and provides a different level of information; however, only the first two activities apply to this study.

The most extensive activity in FHM is detection monitoring, which annually collects information describing the condition of forest ecosystems and detecting short- and long-term changes. Detection monitoring has two components: the plot component and the survey component. Data from these components, along with other forest data, determine whether changes are within normal bounds, are improving, or are cause for concern. Evaluation monitoring is implemented only in situations where a forest health concern is identified with detection monitoring.

The plot component is a network of about 4,600 permanent plots covering all 50 states. Each year, a systematic sample of one-third of the plots is measured, and most forested acres are surveyed aerially. Each permanent plot has four fixed-area, circular subplots (Fig. 10, page 10) (USDA For. Serv. 1998).

FHM crews take measurements or groups of measurements called "indicators" at each plot. An 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. The set of 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 debris, fuel loading, and soils. The data-collection method for each indicator is described elsewhere in this report.

Throughout most of the country, FHM plots are located on a hexagonal grid with one plot per 26,000 acres. An intensified network of 168 FHM plots, established to achieve evaluation monitoring objectives, was located in the ANF in 1998. ANF, FHM, and FHP (Forest Health Protection) personnel initiated this cooperative effort to assess ANF forest ecosystem health. These 168 plots (one for every 3,000 acres) are distributed throughout the forest, 93 of which were measured in 1998 and 1999. These 93 plots were chosen because they previously were used as FIA plots. Although FIA and FHM plots were co-located, the shapes of plots and specific trees sampled differed due to different sampling methods. Fifty-four were sampled in 1998, and 53 were sampled in 1999. Fourteen of the 1999 plots were remeasurements of plots measured in 1998. The locations of the FHM and FIA plots are shown in Figure 11, page 11.

Aerial Survey Data

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

Forest defoliation is usually documented through the use of a remote sensing technique known as sketchmapping. For more than 50 years, aerial sketch-map surveys have been used as an economical and efficient way of detecting and monitoring events of forest defoliation. Sketchmapping is an art form, as well as a scientific method of data collection. It is subjective, because a human observer must delineate a damaged area as accurately as possible. A sketchmap is created by looking at topographic maps while flying in an aircraft and drawing in where damage is visible. Aerial surveys are relied upon to supply a landscape-level overview of forest health conditions at a relatively low cost (McConnell et al. 2000).

The cumulative defoliation frequency (1984-98) for the ANF is shown in Figure 12, page 11. About 86 percent of the ANF was defoliated at least once. All acreage values in this report include the entire area within the proclamation boundary of the ANF (not just public land).

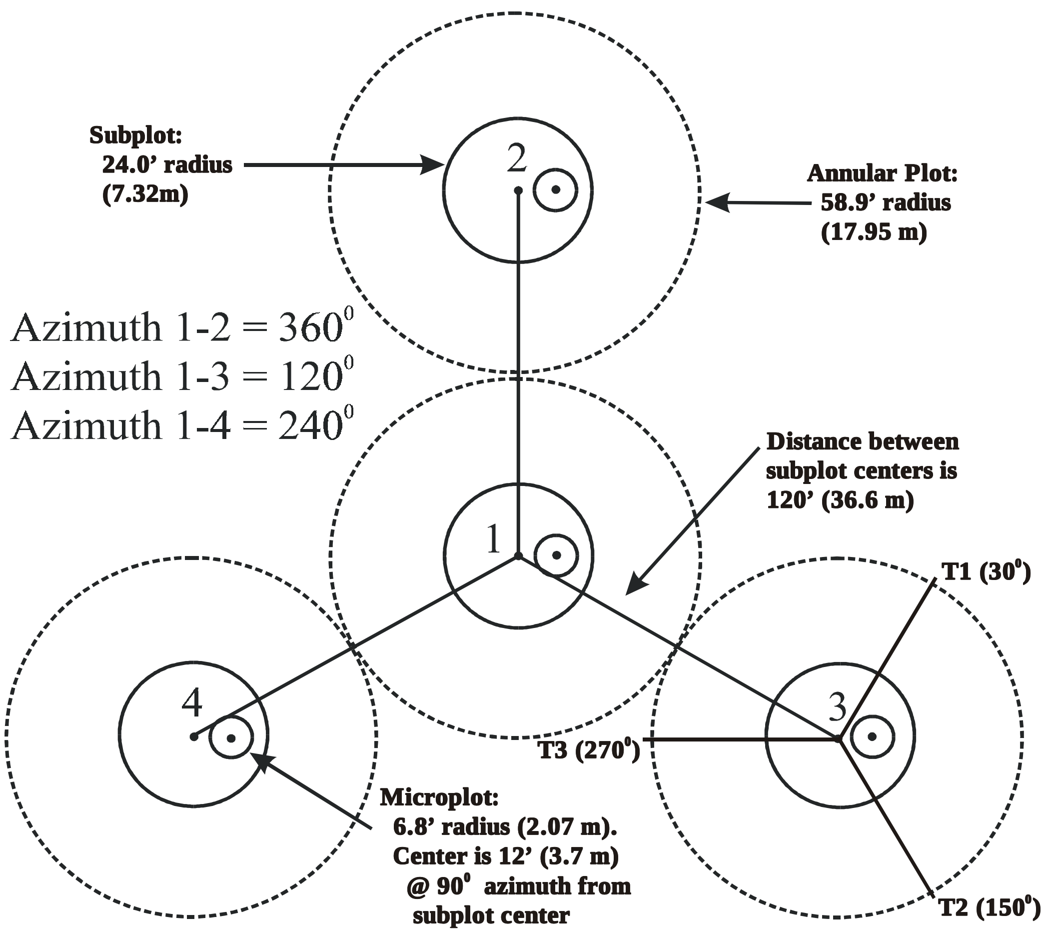

Figure 10. FHM Field Plot Design.

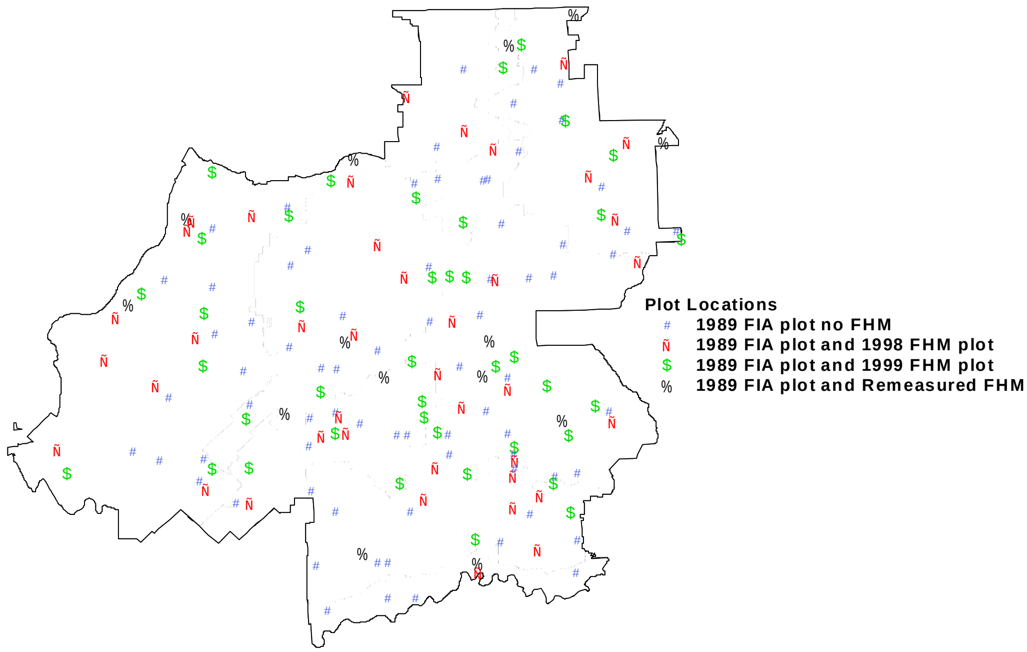

Figure 11. FIA and FHM plot locations on the ANF.

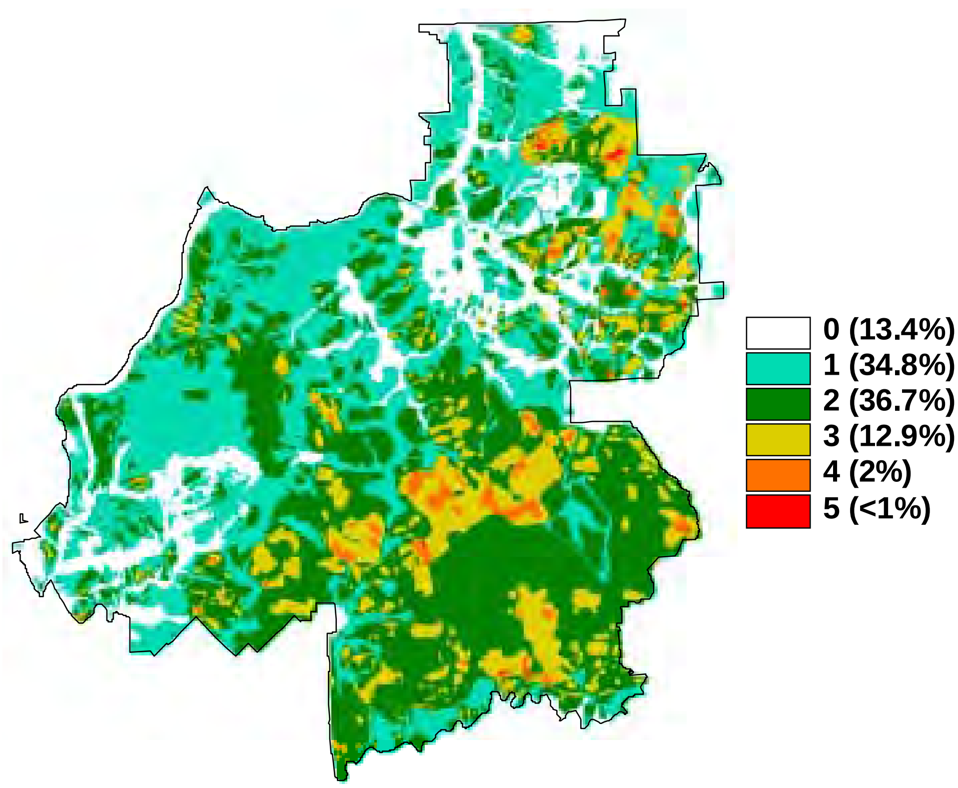

Figure 12. Years of defoliation by all damaging agents (1984-98), numbers in parentheses are percentages of land area in each category.

The area defoliated by each major insect pest on the ANF is shown in Figure 13.

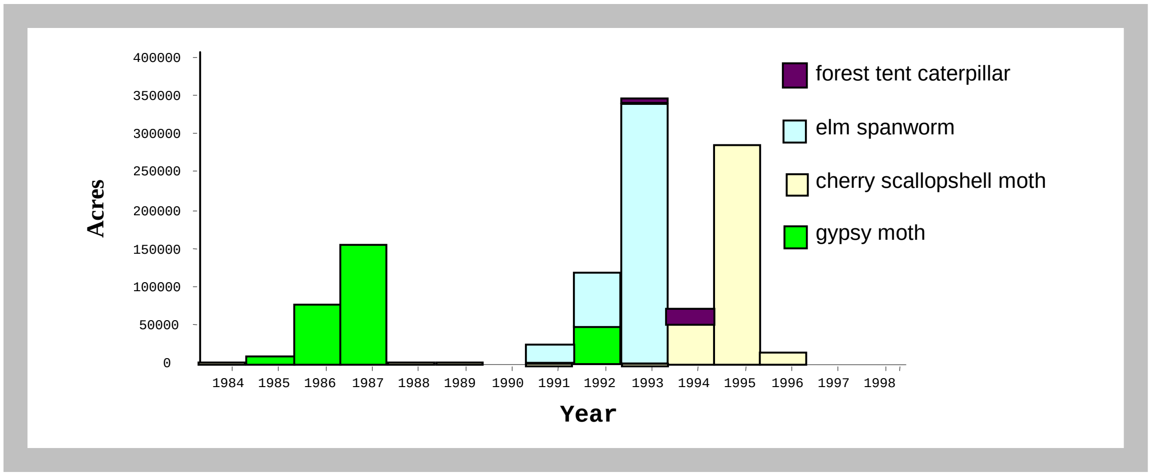

Figure 13. Area defoliated by major insect pests since 1984.

CURRENT FOREST CONDITIONS

In this section, we address two broad categories of the forest ecosystem: understory and overstory conditions. Most of the discussion centers on the tree component; additional information on shrub and herbaceous components will be provided in another publication.

OVERSTORY CONDITIONS

This section assesses current overstory conditions across the ANF using the 1998/1999 FHM data. It also examines the 1989 FIA data together with the 1998/1999 FHM data to assess overstory vegetation changes that may have occurred during that 10- to 11-year period. Features discussed include forest type, tree species abundance and diameter distribution, average tree age and size class and stocking for each plot, tree crown dieback and tree damage, abundance and composition of standing dead trees, and components of dead and live trees that are important to the Indiana bat (*Myotis sodalis*).

Forest Type Groups and Forest Types

Forest type is recorded in both FIA and FHM plot records using a method derived from the Society of American Foresters (SAF) classification system (Eyre 1980). In this system, forest types are named after the predominant species in the stand based on basal area. We used these data to characterize the distribution of forests in the ANF into forest types. The associates for each FHM forest type are listed in Appendix B. Each forest type represents a portion of a more generalized SAF forest type group, which also was recorded.

The largest component of the ANF is the maple/beech/birch forest type group. About 83 percent of the FIA and FHM plots fell into this category (Table 1, page 13). The forest types within this group on the ANF include sugar maple/beech/yellow birch, black cherry, red maple/northern hardwoods, red maple/central hardwoods, and mixed northern hardwoods. According to the 1989 FIA survey, the next largest forest type group was oak/hickory (13.4 percent). Patterns of forest type were similar in the FIA and FHM data. Minor differences probably were due to the 1989 survey having 75 more plots, sampling error, or differences in classification assigned by observers.

Black cherry is the most common forest type on the ANF. It covers approximately 40 percent of the forested land area according to the 1989 FIA data and the 1998/1999 FHM data (Table 2). The black cherry forest type falls into the maple/beech/birch forest type group. As indicated by both surveys, the second most abundant cover type is red maple/northern hardwoods (also part of the maple/beech/birch forest type group), which nearly doubled from 1989 (16 percent) to 1999 (31 percent). The sugar maple/beech/yellow birch cover type made up approximately 15 percent of the forested land area according to the 1989 data; by 1998/1999, this cover type accounted for only 1.5 percent. These changes in forest type designation could be the result of sugar maple decline/mortality. No other forest type made up more than a 10 percent component in either survey. As was the case for the data in Table 1, some of the differences in values shown in Table 2, particularly where the values are small, may have resulted from the smaller 1998/1999 sample size (75 fewer plots).

Forest Type Group	1989 FIA Data	1998/1999 FHM Data
Maple/beech/birch	83.4	82.7
Oak/hickory	13.4	7.9
Spruce/fir	1.1	0
White/red/jack pine	1.0	8.2
Oak/pine	0.7	0
Aspen/birch	0.4	1.2

Table 1. Distribution of FIA and FHM plots on the ANF by FHM forest type groups, in percent.

Forest Type	1989 FIA Data	1998/1999 FHM Data
Black cherry	38.6	38.3
Red maple/northern hardwoods	16.0	31.0
Hemlock	0.9	8.1
Mixed northern hardwoods	5.2	7.5
Other	17.2	7.3
White oak/red oak/hickory	2.0	5.7
Sugar maple/beech/yellow Birch	15.0	1.5
Nonstocked	5.1	0.6

Table 2. Distribution of FIA and FHM plots on the ANF by FHM cover types, in percent.

Distribution of Major Tree Species

A kriged surface of percent basal area was created for each of the four major species and the oaks on the ANF. Kriging is a geostatistical method that provides unbiased estimates at unsampled locations as weighted averages of values from nearby locations (Issaks and Srivistava 1989). In this analysis, we generated maps from the plot data by calculating kriged estimates on a 5-km grid. Estimates were computed from 1989 FIA data, because the sample size was significantly larger.

Figure 14 shows a kriged surface of percent black cherry basal area on the ANF. The largest black cherry components were located in the central and southeastern parts of the forest.

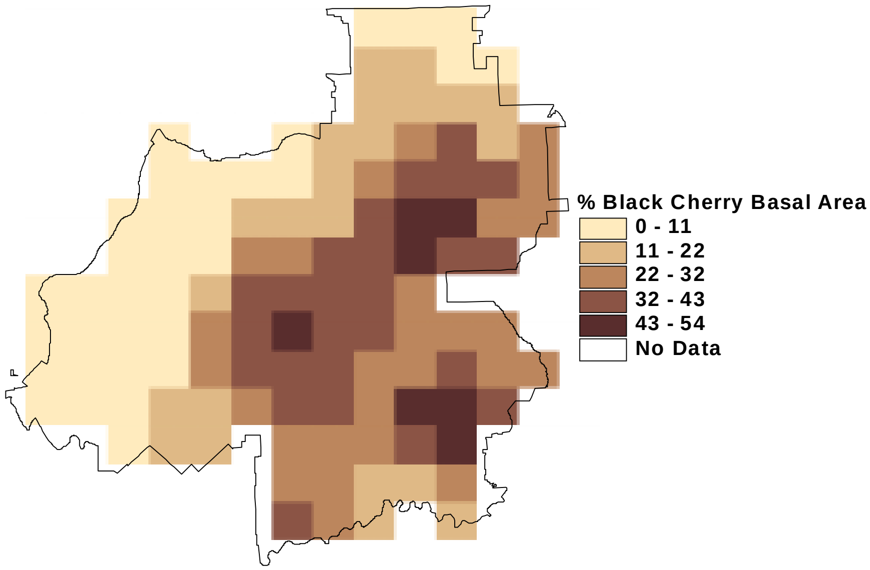

Figure 14. Kriged surface of percent black cherry basal area (exponential model, nugget=84, sill=504)(1989 FIA data).

The estimated distribution of red maple is shown in Figure 15. No cell was estimated at less than 4 percent red maple. A section in the northeast corner of the ANF had the smallest component of red maple.

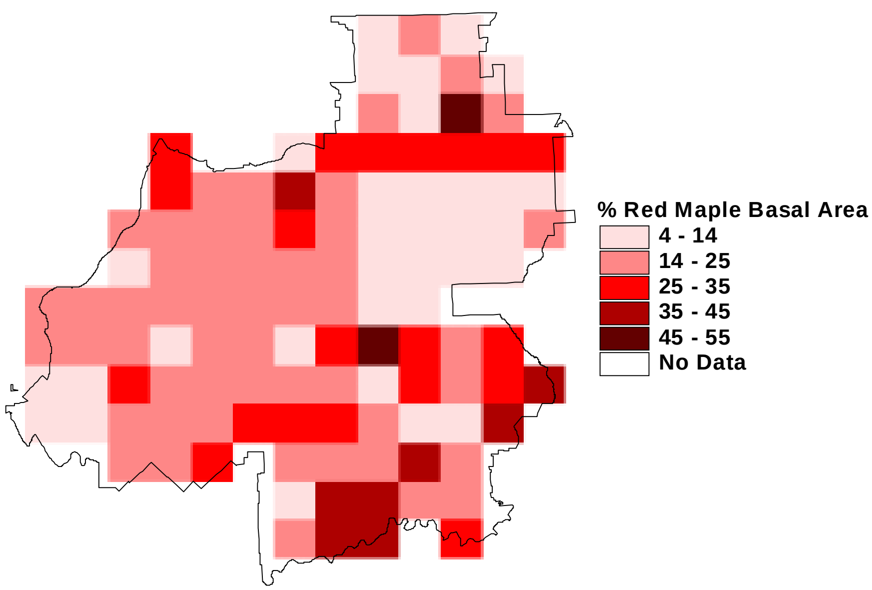

Figure 15. Kriged surface of percent red maple basal area (exponential model, nugget=0, sill=2250)(1989 FIA data).

Figure 16 shows an estimate of sugar maple distribution. Most of the forest was estimated at less than 8 percent sugar maple basal area. The highest estimates were in the eastern half of the forest.

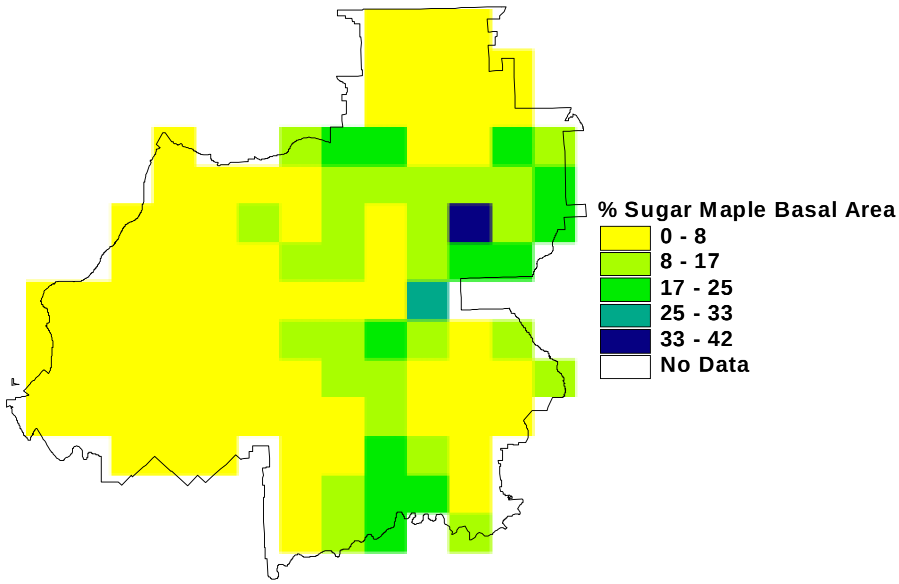

Figure 16. Kriged surface of percent sugar maple basal area (exponential model, nugget=0, sill=2400)(1989 FIA data).

The estimated distribution of American beech is shown in Figure 17. Beech makes up a small component over most of the ANF, but in the northeast corner some areas were estimated to have 38-47 percent beech basal area.

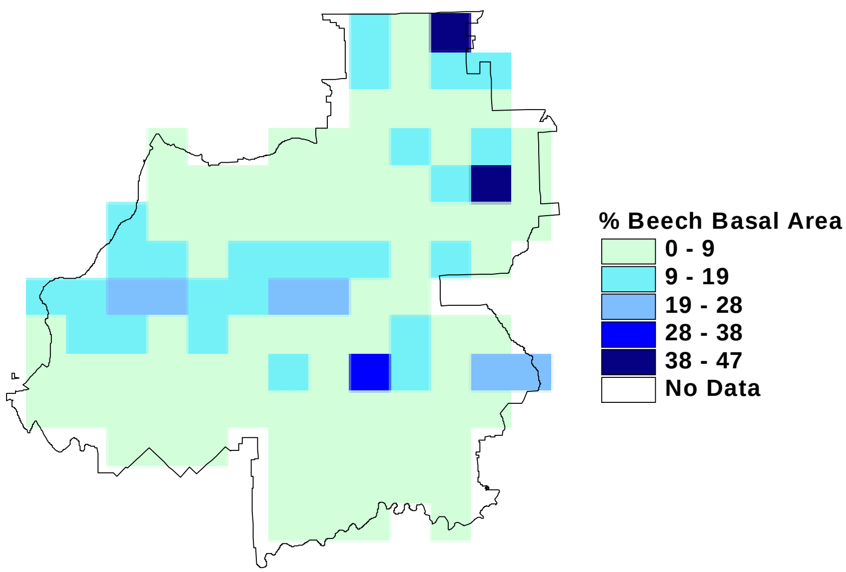

Figure 17. Kriged surface of percent American beech basal area (exponential model, nugget=0, sill=20)(1989 FIA data).

The estimated oak distribution is shown in Figure 18. The majority of the oak is located on the western third and along the southern and northern boundaries of the ANF.

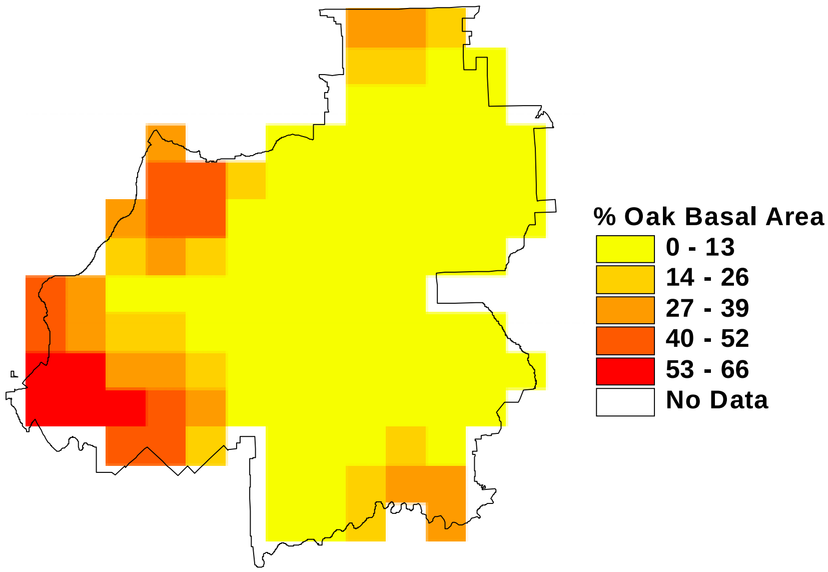

Figure 18. Kriged surface of percent oak basal area (exponential model, nugget=0.108, sill=0.4)(1989 FIA data).

Tree Species Abundance and Diameter Distribution

Individual tree data collected on the plots has been used to estimate the abundance and diameter distribution of tree species on the ANF.

Tree Species Abundance

Figure 19, page 17, shows the average live basal area per acre calculated from the two surveys for the 10 most abundant tree species on the ANF. Both surveys indicate that black cherry and red maple were the most abundant. This agrees with the earlier forest type classification information. Other less abundant tree species include eastern white pine, black oak, yellow-poplar, cucumbertree, chestnut oak, American basswood, American hornbeam, scarlet oak, quaking aspen, eastern hophornbeam, striped maple, white spruce, sassafras, red pine, blackgum, silver maple, blue spruce, apple sp., American elm, hawthorn sp., pin cherry, slippery elm, American chestnut, chokecherry, pignut hickory, and eastern redbud.

Tree Species Diameter Distribution

Figure 20, page 17, shows the diameter distributions of the major tree species on the ANF calculated by the 1998/1999 FHM data. Eastern hemlock had the most uniform distribution with nearly as much basal area in the 5- to 10-inch class as in the over 20-inch class. Basal area increased with diameter class for all other species.

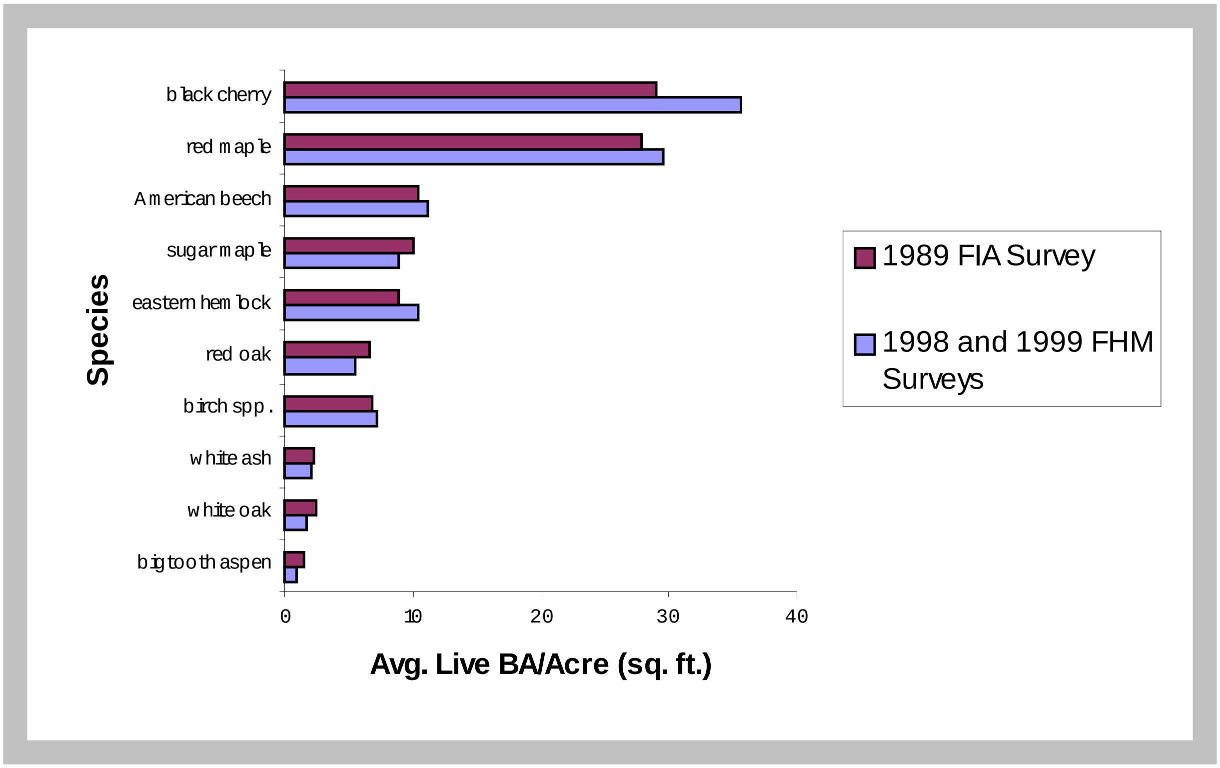

Figure 19. Average live basal area per acre in square feet for major species on the ANF.

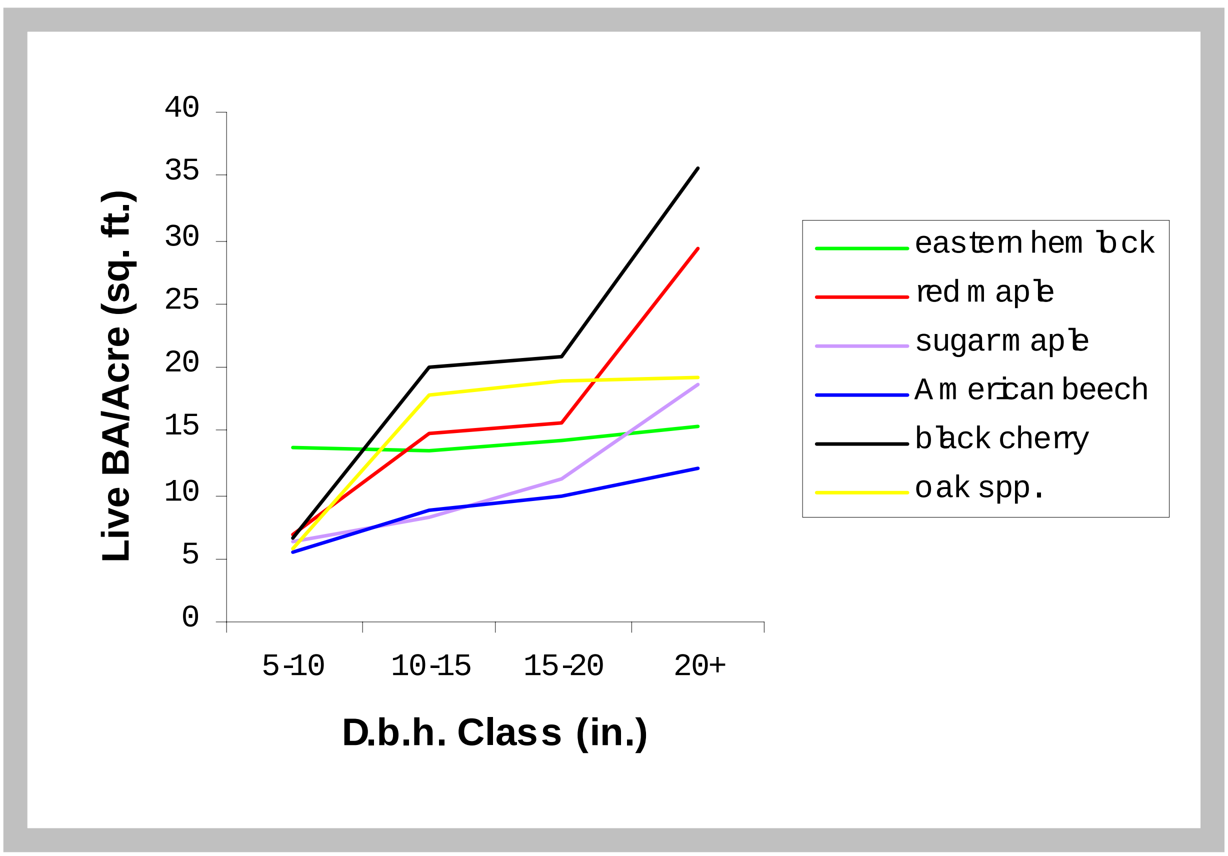

Figure 20. Diameter distribution of live basal area of major tree species on the ANF (1998/1999 FHM data).

Plot Age Class, Size Class, and Relative Density

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

Plot Age Class Distribution

The land area in each age class (based on plot level data) stratified by forest type is shown in Figure 21. The majority of the area (67 percent) is characterized by 60- to 100-year old forests. Most of this mature forest is the black cherry or red maple/northern hardwood forest type. The black cherry forest type had a substantial component in the zero- to 40-year age class. The bimodal distribution is likely because of widespread harvesting at the turn of the 19th century and harvesting in the last 20 to 30 years. The black cherry forest type is absent from the 100- to 120-year age class. Probably due to succession, black cherry has been replaced by longer-lived species like sugar maple and American beech in the oldest age class.

Plot Size Class Distribution

During FHM surveys, plots were classified as either seedling/sapling, poletimber, or sawtimber size class based on the average d.b.h. of all living trees that are not overtopped. The sizes are as follows: sawtimber, 11 inches d.b.h. or larger; poletimber, 5 to 10.9 inches d.b.h.; and seedling/sapling, less than 5 inches d.b.h. Figure 22, page 19, shows the distribution for each size class. About 73 percent of the total land area was classified as sawtimber and had basal area between 40 and 240 ft^2/acre. The majority of seedling/sapling area has less than 40 ft^2/acre; a value considered well stocked for a regenerating stand.

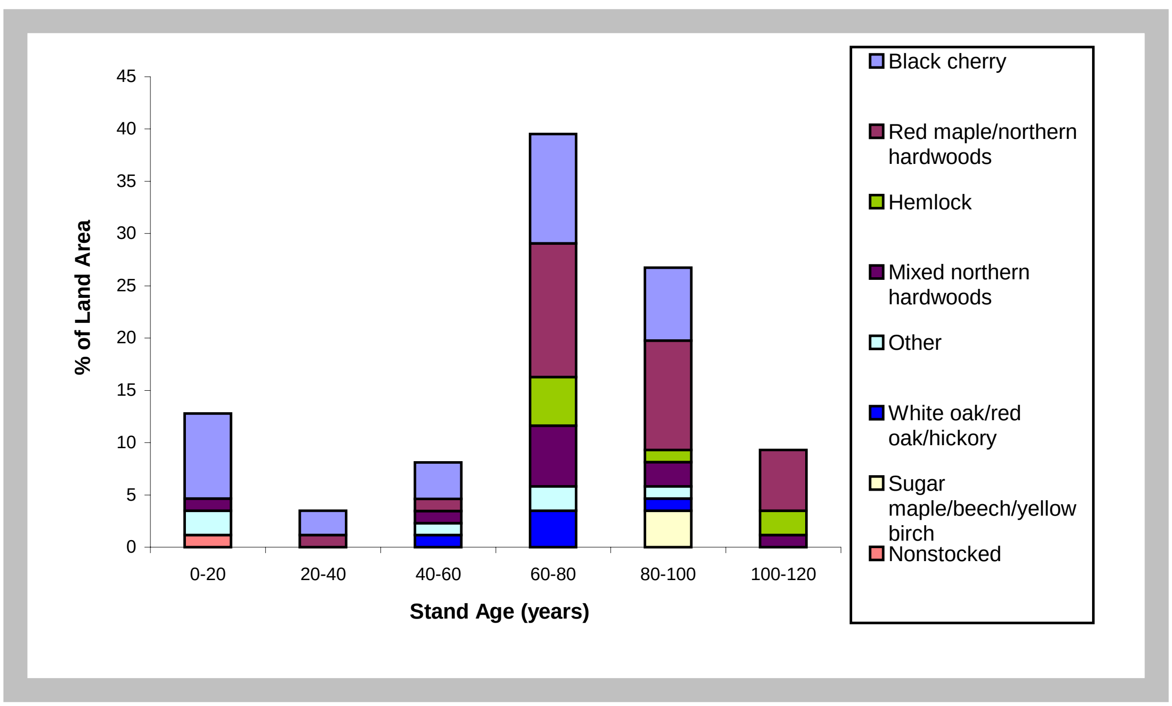

Figure 21. Distribution of the age of FHM plots by forest type.

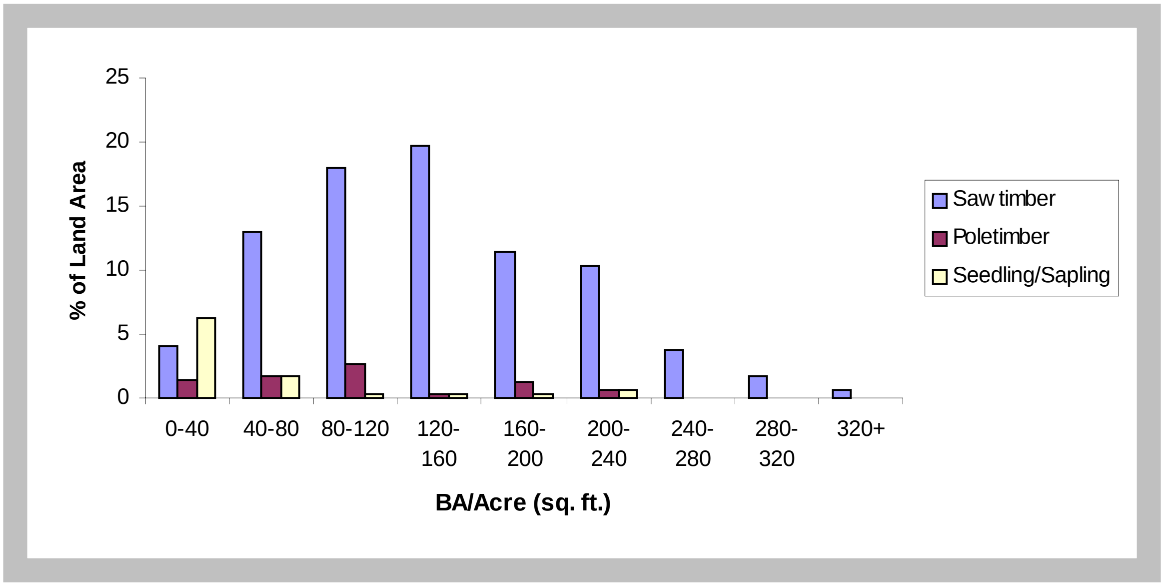

Figure 22. Percent of land area occupied by each size class in basal area categories (1998/1999 FHM data).

Plot Relative Density

Relative plot density was calculated using a method devised by Stout and Nyland (1986). Plots were classified as understocked, fully stocked, or overstocked according to percent relative density as described in Gingrich (1967), Roach (1977), and Marquis et al. (1992) (Fig. 23). A relative density between 50-100 percent was considered fully stocked. Seedling/sapling stands were not included because the method was inappropriate. Overstocking in some stands may be due to lack of management or a thick understory of beech and hemlock.

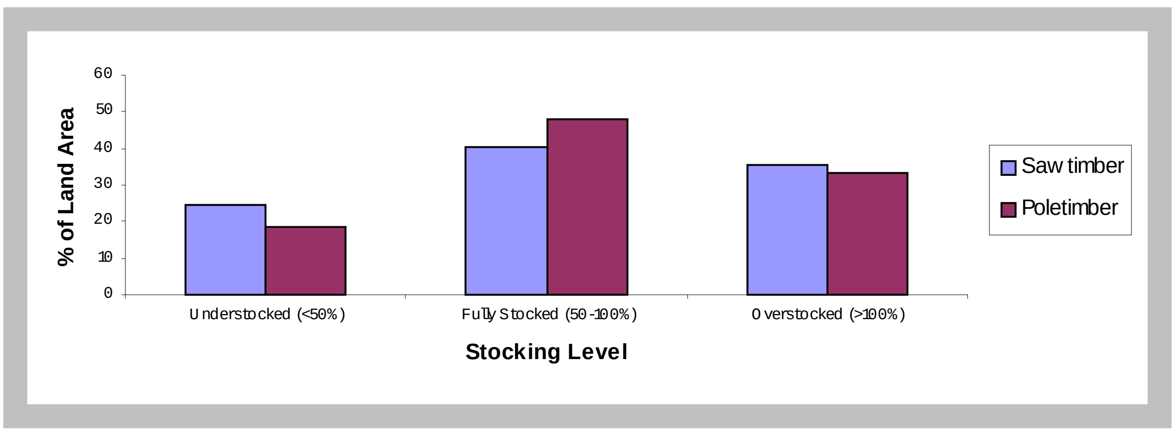

Figure 23. Percent of land area occupied by sawtimber and poletimber size classes by percent relative density classes (1998/1999 FHM data)

Live Tree Distribution by Size Class for Indiana Bat Habitat

Live trees provide important habitat for a variety of insects and wildlife. The Indiana bat, a species listed as threatened and endangered by the U.S. Fish and Wildlife Service, is one species that has recently been a concern of the ANF. Consequently, this analysis summarizes information regarding its habitat. The ANF Forest Plan, as amended (USDA For. Serv. 2000b), lists specific factors which can be used to evaluate Indiana bat roosting habitat. These include specific criteria for numbers and sizes of live trees per acre (Table 3). For habitat to be considered suitable, 5 percent of the landscape under consideration must be forested and must meet the criteria shown in the "suitable" column. For habitat to be classified as optimal, 30 percent of the landscape must be forested and must meet the criteria in the "optimal" column (Romme et al. 1995). Table 3 also includes estimates of these live-tree densities on the ANF.

Indiana Bat Requirements (# live trees)			**ANF Conditions**
D.b.h. Class	***Suitable***	***Optimal***	***(Mean ± SE)***
>9	8 per Acre	16 per Acre	77.7 ± 4.05
>20	1 per Acre	3 per Acre	7.8 ± 0.98

Table 3. Indiana bat live tree habitat requirements and existing conditions on the ANF (1998/1999 FHM data).

The information in Table 3 suggests that the average condition across the ANF is 73.6 to 81.8 live trees greater than 9 inches d.b.h. per acre and 6.8 to 8.8 live trees greater than 20 inches d.b.h. per acre (α=0.05). Thus, it is likely that most of the ANF area meets both suitable and optimal habitat conditions.

Crown Dieback and Tree Damage

Data summarized in this section originates from individual tree measurements and observations.

Crown Dieback

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. Although it serves as one indicator of tree damage, crown dieback may only be measurable for several years. Dead fine twigs or branches usually remain on the tree for a relatively short 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 for each tree (USDA For. Serv. 1998).

The percent basal area of major species in crown dieback categories from the 1998/1999 FHM surveys is shown in Table 4, page 21. A tree with up to 10 percent crown dieback is considered healthy. Standing dead trees or dead trees that have been harvested, have fallen over, or have blown down are not included in Table 4, even though they could be considered as having 100 percent dieback. Salvage harvests, particularly of trees with the most dieback, can also serve to reduce the amount of dieback tallied.

Crown dieback was generally low in most species. White ash had the largest amount of basal area (10.6 percent) categorized with greater than 75 percent dieback. 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 some areas where ash is declining (Sinclair et al. 1996). However, not all dying trees are infected with phytoplasma-like organisms (Matteoni and Sinclair 1985). Currently, ash decline is thought to result from multiple causes (Schlesinger 1990).

Species	0-10%	11-24%	25-49%	50-74%	75-100%
black cherry	89.1	6.4	2.7	0.8	1
red maple	94.2	2.3	3.1	0.1	0.3
American beech	95.3	3.9	0.4	0.1	0.3
sugar maple	92.8	3.1	2.2	0.8	1.1
eastern hemlock	98.1	1.2	0.7	0	0
Northern red oak	97.7	2.3	0	0	0
Sweet birch	99.5	0.5	0	0	0
Yellow birch	93.2	1.1	5.7	0	0
White oak	100	0	0	0	0
White ash	89.4	0	0	0	10.6
Bigtooth aspen	100	0	0	0	0

Table 4. Percent basal area of major tree species on ANF by crown dieback class, in percent (1998/1999 FHM data).

A kriged surface of percent crown dieback for all species is shown in Figure 24. The highest estimated dieback values were located on the southeastern two-thirds of the ANF, as is the case with standing dead trees (Fig. 27, page 25).

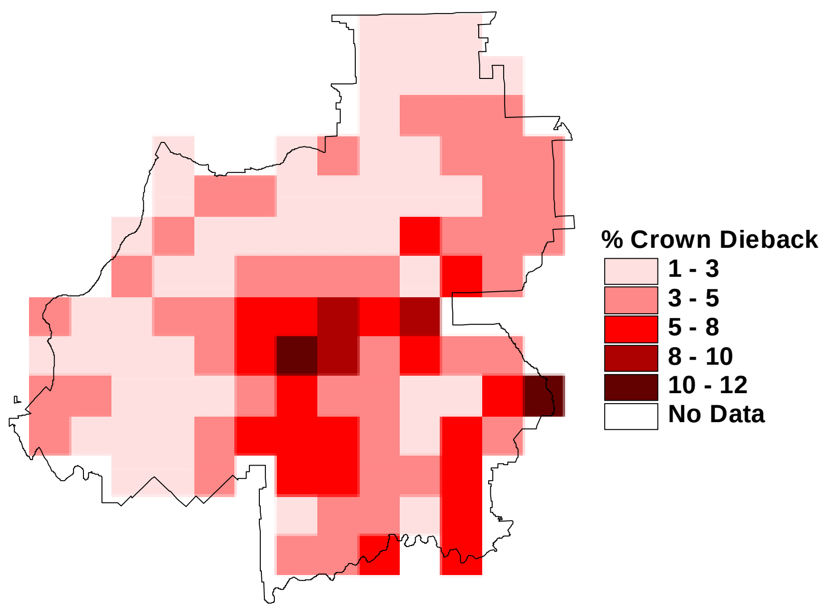

Figure 24. Kriged surface of percent crown dieback (exponential model, nugget=0, sill=17) (1998/1999 FHM data).

Tree Damage

The damage distribution for the major tree species on the ANF is shown in Figure 25.

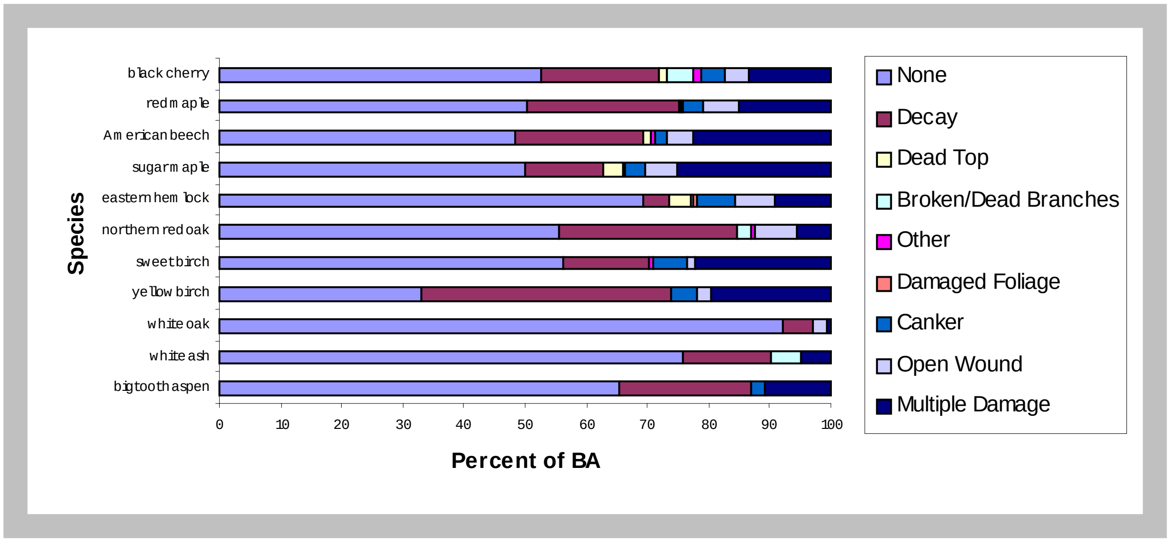

Figure 25. Distribution of major tree species on ANF by damage signs and symptoms (1998/1999 FHM data).

During FHM surveys, damage signs and symptoms were recorded for trees 5 inches d.b.h. and larger. The percentage of trees without signs or symptoms ranged from 33 for yellow birch to 92.2 for white oak. Decay was the most frequently observed category of damage, ranging from 4.3 percent for eastern hemlock to 40.8 percent for yellow birch. 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 yellow birch (Erdmann 1990). Therefore, much of the decay on yellow birch may be due to infection by the *Nectria* fungus.

Summary of Standing Dead

Standing dead trees (at normal background levels) are a natural component of healthy forest ecosystems, playing an important role in nutrient cycling and providing wildlife habitat. Tree mortality is increasingly affected by factors such as disease and insect damage as a forest ages (Grief 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, the amount of standing dead can provide an indirect measure of mortality.

In the discussion that follows, the basal area of standing dead trees, by species, is first contrasted to the total standing basal area, including a comparison with commonly used diameter classes. The recently amended ANF Forest Plan (USDA For. Serv. 2000b) now contains specific recommendations for suitable and optimal dead-tree roosting habitat for Indiana bat using other tree size classes. Questions about the abundance of Indiana bat habitat have been the subject of recent local debate. The latter portion of this section on standing dead trees displays an estimate of how current ANF dead tree numbers compare with these recommendations. Kriged surface figures display their estimated spatial distribution.

Percent Dead Basal Area

The percentage of standing basal area that is dead for the 10 most abundant species on the ANF is shown in Table 5. Standing dead trees can be harvested, fall down naturally, or remain standing. Among the five most dominant species, mortality appeared to be proportionally greatest in sugar maple. The increase in the percentage of dead sugar maple is likely due to a general decline in sugar maple on the ANF (Horsley et al. 2000). Beech bark disease and elm spanworm defoliation contributed to the increase in the percentage of dead American beech. The increase in white oak mortality is likely due to gypsy moth defoliations. Effects of these disturbance processes are discussed in more detail in subsequent sections. Bigtooth aspen is a short-lived species, so high mortality rates were expected in the mature stands of the ANF. Most birch trees are infected with the *Nectria* fungus and die by about 60 years of age. The decrease in the percent of standing dead birch and aspen could be due to many of the standing dead trees from the 1989 FIA survey falling down, and therefore, it was not measured in the 1998/1999 FHM surveys.

	1989 FIA Data				***1998/1999 FHM Data***			
Species	**Total BA**	**Live BA**	**Dead BA**	**% Dead**	**Total BA**	**Live BA**	**Dead BA**	**% Dead**
black cherry	31.3	29.0	2.4	7.5	37.8	35.6	2.3	6.0
red maple	29.9	27.8	2.1	7.0	31.8	29.5	2.3	7.1
American beech	10.6	10.5	0.2	1.7	12.0	11.1	0.9	7.3
sugar maple	11.2	10.1	1.1	9.4	10.9	8.9	2.0	18.2
eastern hemlock	9.3	9.0	0.3	3.4	11.0	10.5	0.5	4.2
red oak	7.2	6.6	0.6	8.3	5.5	5.4	0.1	1.2
birch spp.	9.3	6.9	2.4	25.9	8.1	7.1	0.9	11.4
white oak	2.7	2.4	0.3	11.2	2.1	1.8	0.4	17.4
white ash	2.6	2.3	0.3	12.3	2.2	2.0	0.2	8.7
bigtooth aspen	2.6	1.5	1.1	43.3	1.4	1.0	0.4	25.8

Table 5. Total, live, dead BA (sq. ft./acre), and percent BA that is dead for the 10 most abundant species on the ANF.

Table 6 provides a more detailed picture of the latest survey data (1998/1999 FHM Data) by tree-size class. It shows the percent standing basal area distribution by diameter class for the five most abundant species and all oak species.

Percent of Total Standing BA That is Dead By D.b.h. Class (inches)				
	5-10	**10-15**	**15-20**	**20+**
black cherry	29.6	7.2	3.8	0.0
red maple	13.8	7.9	4.7	5.0
American beech	3.8	5.1	7.6	48.7
sugar maple	23.2	16.4	16.7	0.0
eastern hemlock	3.0	2.1	14.9	0.0
oak spp.	12.3	3.7	3.1	6.4

Table 6. Percent of total standing basal area that is dead, by d.b.h. class, for major species on ANF (1998/1999 FHM data).

Nearly one-third of the black cherry basal area in the 5- to 10-inch d.b.h. class was dead. Standing dead was low (less than 8 percent) in the other diameter classes. The high percent of standing dead in the smallest class is likely due to self-thinning of a shade-intolerant species.

The distribution of standing dead for red maple was highest in the 5- to 10-inch diameter class (nearly 14 percent). The proportion of standing dead was low (less than 8 percent) in the other classes.

The proportion of standing dead American beech was highest in the largest d.b.h. class. Nearly half of the basal area in the greater than 20-inch class was dead, possibly due to beech bark disease, which tends to kill large trees. Also, defoliation by gypsy moth and elm spanworm is most likely a factor in beech mortality. Standing dead beech basal area was less than 8 percent for the other diameter classes.

The greatest proportion of standing dead basal area was in sugar maple. More than 16 percent of the basal area in each of the three smallest diameter classes was dead with nearly one-quarter mortality in the smallest class. Sugar maple decline is discussed in detail in a subsequent section.

Standing dead oak was minimal in most classes. The only class that had more than 10 percent standing dead basal area was the 5- to 10-inch class. For other classes, the standing dead basal area was less than 7 percent. Since most oak mortality on the ANF occurred more than 12 years ago, a combination of tree blowdown and salvage operations performed since the 1985 through 1988 gypsy moth outbreaks could account for lower proportions of standing dead.

Fifteen percent of the eastern hemlock basal area in the 15- to 20-inch class was dead. The proportion of standing dead was low (less than 3 percent) in the other d.b.h. classes.

Spatial Distribution of Dead Tree Basal Area

A kriged surface of percent standing dead basal area (all species) from the 1989 FIA data is shown in Figure 26, page 25. This data set provided a significantly larger sample size (+75 plots) than the 1998/1999 FHM data set. The greatest proportion of standing dead was located on the western half of the forest.

The estimated distribution of percent standing dead basal area (all species) from the 1998/1999 FHM data is shown in Figure 27, page 25. The southeastern two-thirds of the ANF now has the highest proportion of standing dead, a shift from the pattern observed in 1989 (Fig. 26). The distribution of percent crown dieback in Figure 24 was similar.

Number and Distribution of Standing Dead Trees per Acre

Standing dead trees add to the structure of the forest, provide nesting or roosting sites for a number of wildlife species, and are important foraging sites for some species that rely on insects for food. Table 7, page 26, shows the number of standing dead trees per acre by species and d.b.h. class. Tree species vary in the time they remain standing after they die. Black cherry and oak species generally remain standing longer than maples and beech.

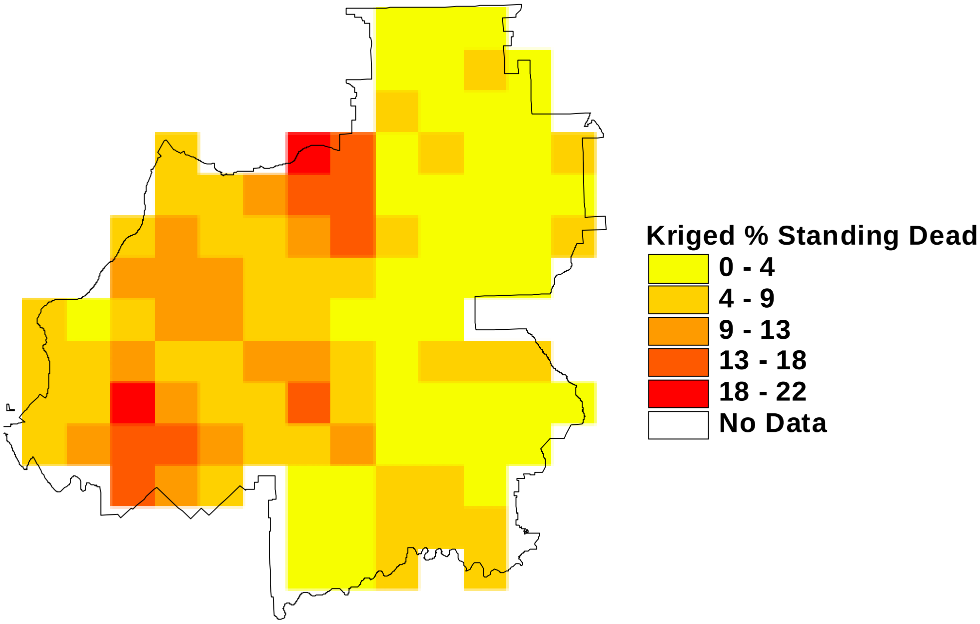

Figure 26. Kriged surface of percent standing dead basal area, all species (spherical model, nugget=0.328, sill=0.655)(1989 FIA data).

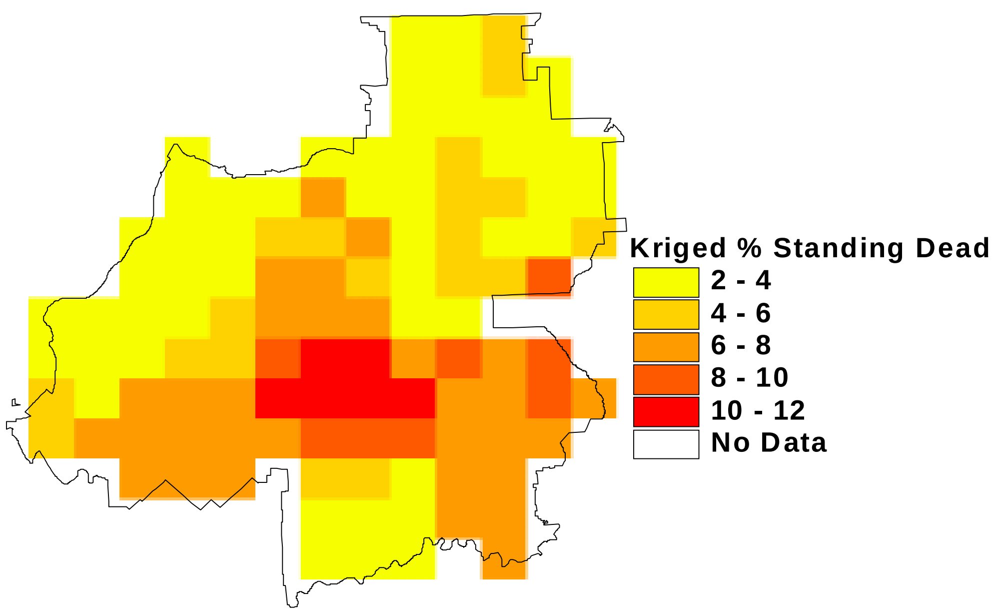

Figure 27. Kriged surface of percent of total basal area that is dead, all species (spherical model, nugget=0.803, sill=0.288) (1998/1999 FHM data).

	D.b.h. Class			
Species	**≥9"**	**≥12"**	**≥20"**	**Total**
black cherry	1.5	0.5	0	2.0
red maple	1.7	0.8	0.1	2.6
American beech	0.5	0.3	0.1	0.9
sugar maple	1.4	0.3	0	1.7
eastern hemlock	0.3	0.2	0	0.5
oak spp.	0.3	0.3	0.1	0.7
other	1.8	0.5	0	2.3
all	7.5	2.9	0.3	10.7

Table 7. Number of standing dead trees per acre by species and d.b.h. class (1998/1999 FHM data).

Dead Tree Distribution (number of trees) by Size Class (D.B.H) for Indiana Bat Habitat

The amended ANF Forest Plan (USDA For. Serv. 2000b) lists specific factors for evaluating Indiana bat roosting habitat. These include criteria for numbers and sizes (d.b.h.) of dead trees per acre (Table 8). For habitat to be considered suitable, 5 percent of the landscape under consideration must be forested and must meet the criteria shown in the “suitable” column. For habitat to be classified as optimal, 30 percent of the landscape must be forested and must meet the criteria in the “optimal” column. Table 8 also reports the current condition of the dead tree habitat on the ANF using these criteria.

Table 8 suggests that the likelihood of finding 5 percent of the area meeting suitable habitat conditions is quite high. Because the estimated average number of dead trees in the largest size class, 20” d.b.h., is below the threshold for optimal habitat, ANF conditions are less certain of meeting that criterion. However, only 30 percent of a landscape needs to provide more than one tree greater than 20 inches d.b.h. per two acres, so it is quite possible (since the ANF is 94 percent forested) that the optimal dead tree habit condition would be met as well (USDA Forest Service 2000a).

Indiana Bat Habitat Requirements			
(# Dead Trees)			**Current Conditions**
D.b.h. Class	**Suitable**	**Optimal**	**(Mean ± SE)**
>9	3 per Acre	5 per Acre	7.5 ± 0.92
>12	1 per 10 Acres		2.9 ± 0.58
>20		1 per 2 Acres	0.3 ± 0.15

Table 8. Comparison of Indiana bat dead tree habitat requirements with existing conditions on the ANF (1998/1999 FHM data).

Figures 28 through 31 display kriged surface representations of the spatial arrangement of the estimated number of dead trees per acre in these d.b.h.-class categories.

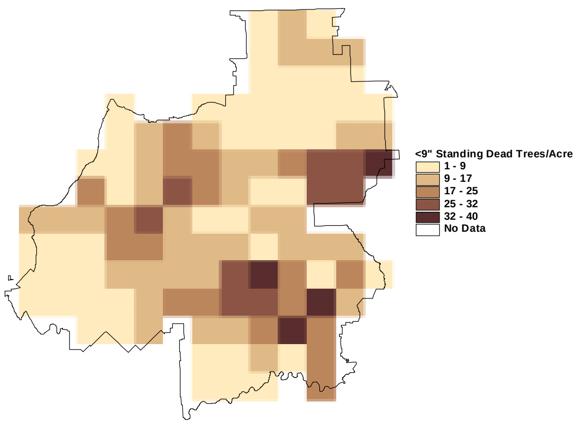

Figure 28. Kriged surface of number of standing dead trees less than 9 inches d.b.h. (exponential model, nugget=0, sill=250) (1998/1999 FHM data).

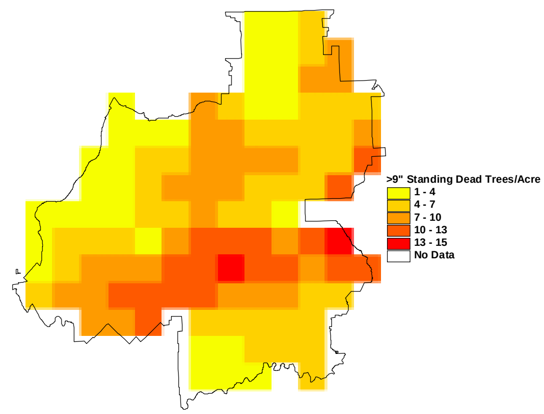

Figure 29. Kriged surface of number of standing dead trees greater than 9 inches d.b.h. (spherical model, nugget=48.76, sill=27.32.)(1998/1999 FHM data).

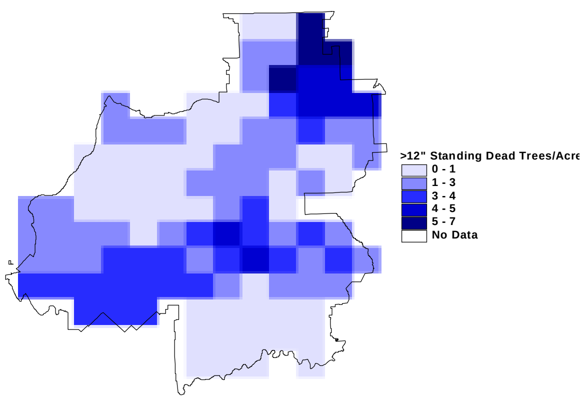

Figure 30. Kriged surface of number of standing dead trees greater than 12 inches d.b.h. (power model, nugget=27.04, power=0.83) (1998/1999 FHM data).

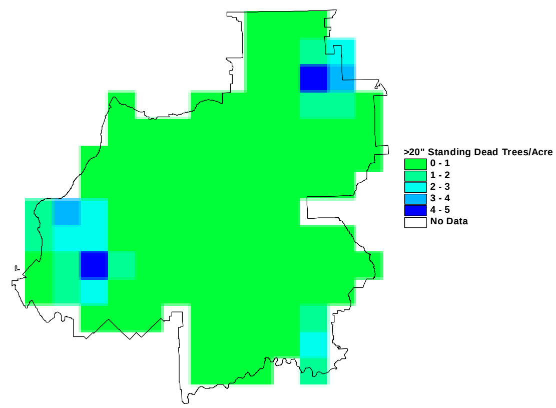

Figure 31. Kriged surface of number of standing dead trees greater than 20 inches d.b.h. (exponential model, nugget=0, sill=1.4) (1998/1999 FHM data).

UNDERSTORY CONDITIONS

This section assesses current understory conditions across the ANF using 1998/1999 FHM data for seedling and sapling abundance and for general ground cover (93 Plots). Down woody debris information is summarized for the only year it has been collected, 1999 (38 Plots). When the complete data set is available, a more extensive analysis of understory conditions will be provided in a later publication.

Seedling and Sapling Counts

Several other analyses have reported the low stocking of seedlings/saplings in forested stand understories on various portions of the ANF (USDA For. Serv. 1995; McWilliams et al 1996; McWilliams 1999; USDA For. Serv. 2000a). Tree seedlings and saplings are an important part of the forest ecosystem. Browsing associated with high deer populations for more than 60 years, has resulted in a lack of understory conditions that would normally exist. Deer have selectively removed herbaceous plants, shrubs, and tree seedlings. When those desired native plants were removed or died, other vegetation (beech brush thickets, striped maple, ferns, and grass) moved in to occupy much of the vacant growing space interfering with tree seedling development and growth.

When interfering plants are abundant, it is difficult for tree seedlings (and other native plants) to become established. This has important consequences when natural catastrophic events 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 (1998/1999) are classified into three stand size categories, previously described, and based on the average d.b.h. of all live trees that are not overtopped. For this analysis, we calculated the number of seedlings and number of saplings per acre for each of the three forested stand size categories. The oak type is most distinctly different from the forest types in the rest of the ANF, and much concern has been expressed in regenerating oak stands. This separation is important because of the distinct differences between these forest ecosystems, and because of concerns related to the sustainability of the oak forest type group in the eastern United States. Therefore, we calculated seedling and sapling density separately in non-oak and oak areas. Seedling and sapling data is collected at 6.8-foot radius microplots. A seedling was defined as a tree at least 12 inches tall but less than 1-inch in diameter. Saplings were defined as live trees between 1- and 4.9-inches in diameter. It should be noted that seedlings less than 12 inches tall are not counted according to FHM protocol. This may affect the estimated species distribution.

<u>Sawtimber Plots</u> (87,858 acres represented)

Data were divided into oak and non-oak categories for sawtimber-size plots. As shown in Figure 32, page 29, American beech was the most abundant species from non-oak sawtimber plots followed by black cherry, red maple, birch, striped maple, and serviceberry. Most of the beech stems probably originated from root sprouts. Species with an average of fewer than 100 seedlings per acre included American hornbeam, blackgum, sugar maple, chokecherry, white ash, mountain maple, eastern hemlock, American chestnut, eastern hophornbeam, red oak, and white oak.

American beech also was the most abundant sapling on non-oak sawtimber plots followed by sugar maple and red maple (Fig. 33, page 29). Sugar maple and beech saplings most likely were older, suppressed, poor-quality trees that were outcompeted by faster growing black cherry and red maple following forest removals at the turn of the 19th century. Species with fewer than 10 saplings per acre were not included: American hornbeam, birch, serviceberry, eastern hophornbeam, eastern hemlock, and striped maple.

In contrast to the non-oak plots, red maple was the most abundant seedling on oak sawtimber plots followed closely by American beech (Fig. 34, page 30). Higher levels of light generally reach the understory in oak stands, allowing for regeneration of species that are intermediate in shade tolerance such as red maple. Species with fewer than 90 seedlings per acre included white oak, serviceberry, sassafras, chestnut oak, scarlet oak, pignut hickory, cucumbertree and American chestnut.

American beech was the most abundant sapling on oak sawtimber plots followed closely by red maple (Fig. 35, page 30). The average number of saplings per acre was much higher on oak plots than on non-oak plots, possibly due to higher light conditions in the understory.

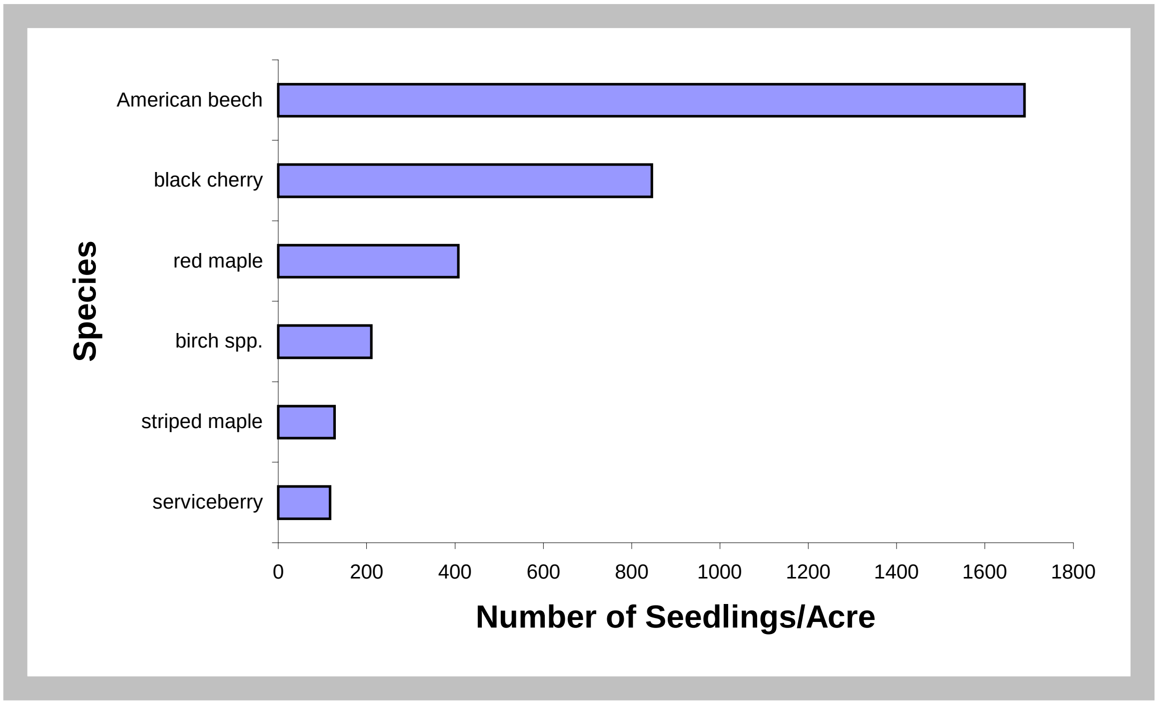

Figure 32. Number of saplings per acre on non-oak sawtimber plots (266 microplots).

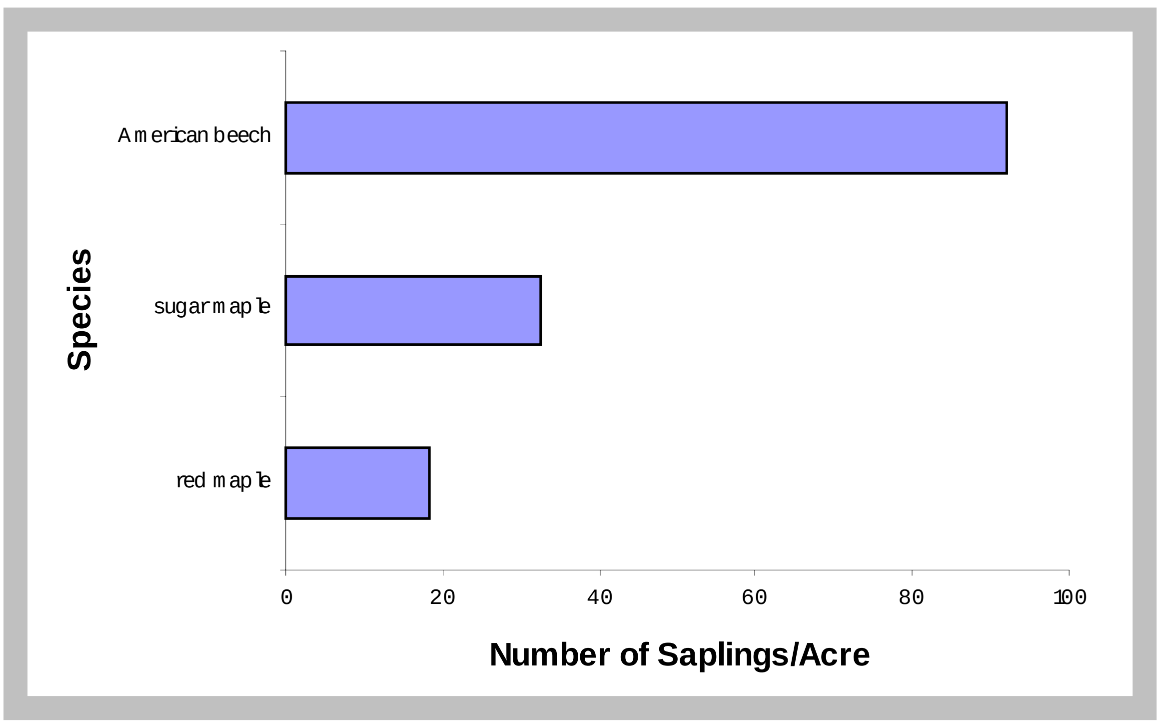

Figure 33. Number saplings per acre on non-oak sawtimber plots (266 microplots).

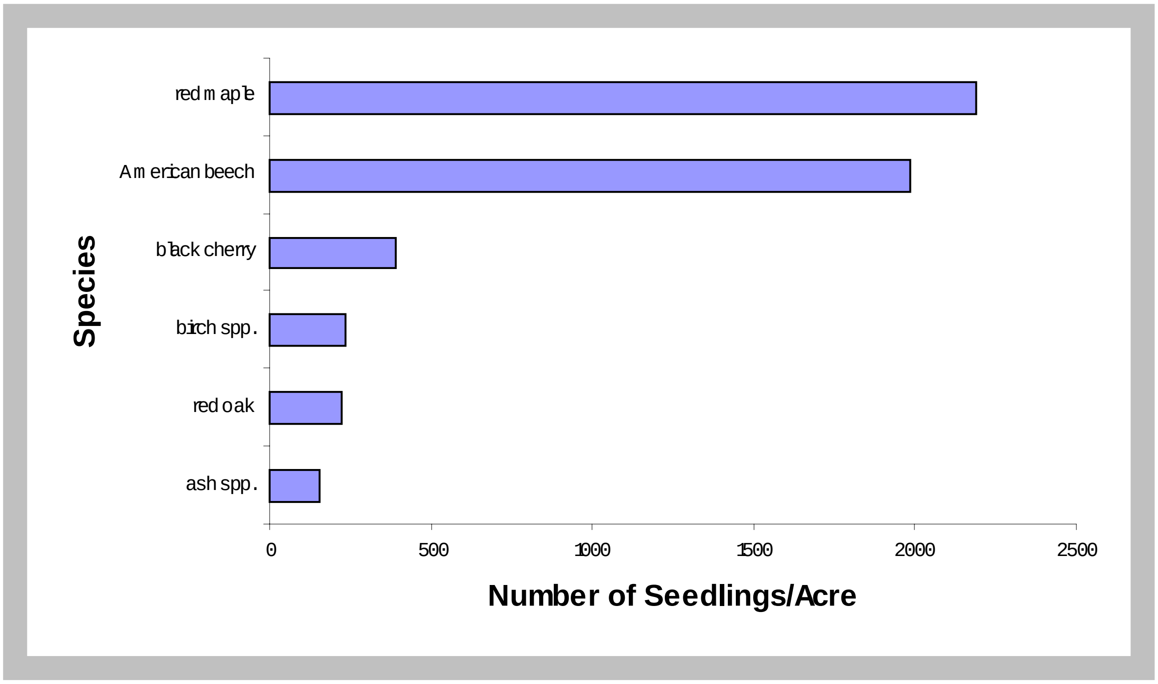

Figure 34. Number of seedlings per acre on oak sawtimber plots (27 microplots).

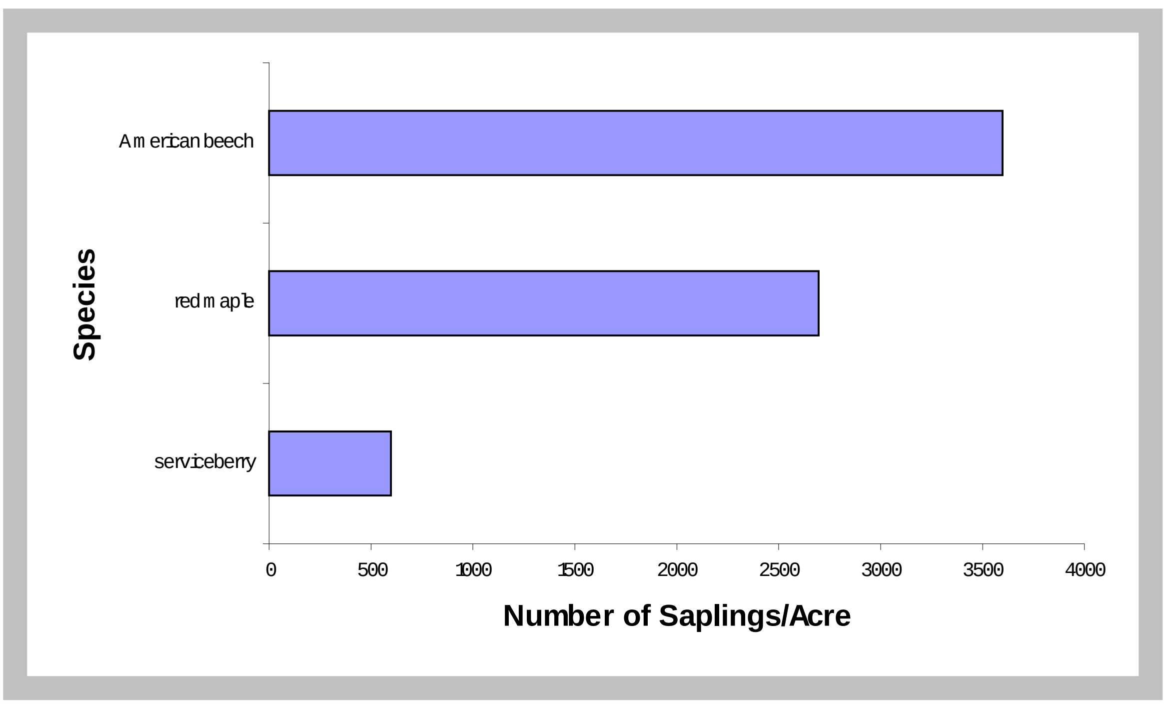

Figure 35. Number of saplings per acre on oak sawtimber plots (27 microplots).

Poletimber Plots (oak and non-oak — 8,396 acres represented)

In contrast to the sawtimber plots, black cherry, striped maple, American beech and sassafras were the most abundant seedlings on poletimber plots (Fig. 36).

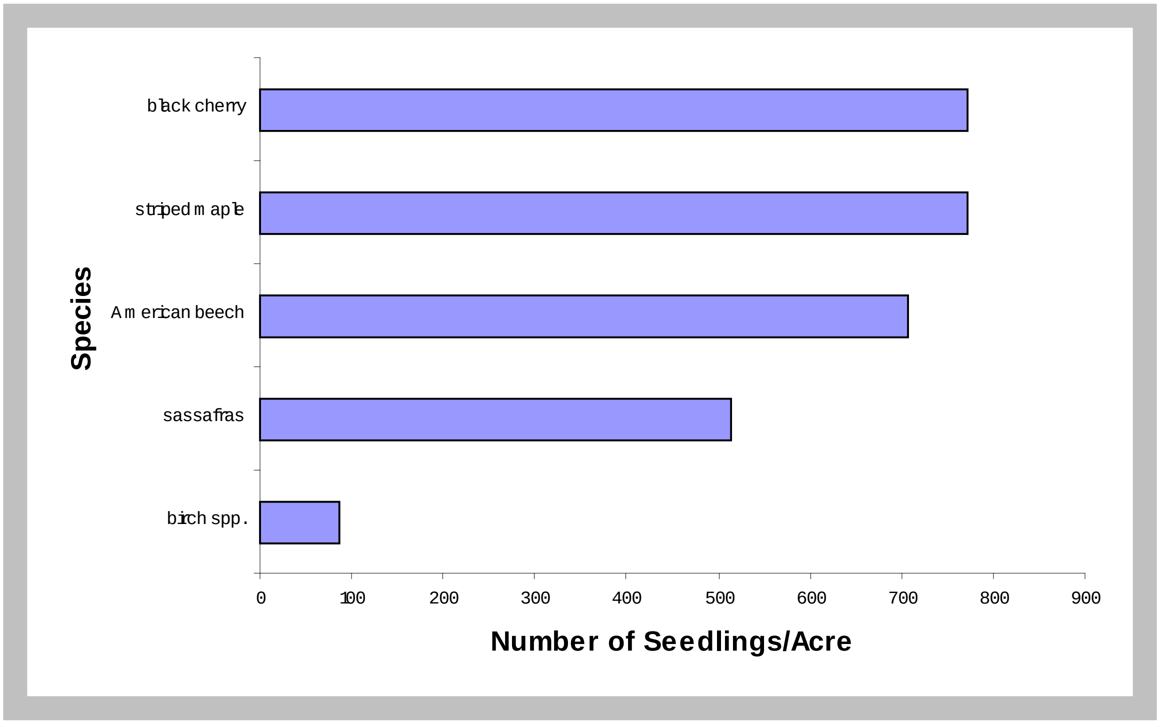

Figure 36. Number of seedlings per acre on poletimber plots (27 microplots).

Black cherry was the most abundant sapling on poletimber plots followed by birch and eastern hemlock (Fig. 37, page 32). Species not included because they had fewer than 50 saplings per acre were American beech, sassafras, red maple, quaking aspen, and pin cherry.

Seedling/Sapling Plots (oak and non-oak — 11,994 acres represented)

Black cherry also was the most abundant seedling on seedling/sapling plots (Fig. 38, page 32). Black cherry seedlings were more than twice as abundant as those of American beech. Forest canopy openings favor black cherry, because it is considered a pioneer species. Species with fewer than 500 seedlings per acre not included in Figure 38 were pin cherry, northern red oak, striped maple, white oak, eastern hophornbeam, bigtooth aspen, American hornbeam, ash spp., and eastern hemlock.

Black cherry saplings were virtually the only ones found on seedling/sapling plots on the ANF (Fig. 39, page 33) and were five times as abundant as the next species. Once black cherry establishes itself as a seedling in an opening, it grows rapidly and takes over the site. Probably the most important factor in the dominance of black cherry is that it is not preferred by white-tailed deer. Species with fewer than 100 saplings per acre that were excluded in Figure 39 were American beech, pin cherry, northern red oak, sugar maple, serviceberry, striped maple, white oak, eastern hophornbeam, and ash species.

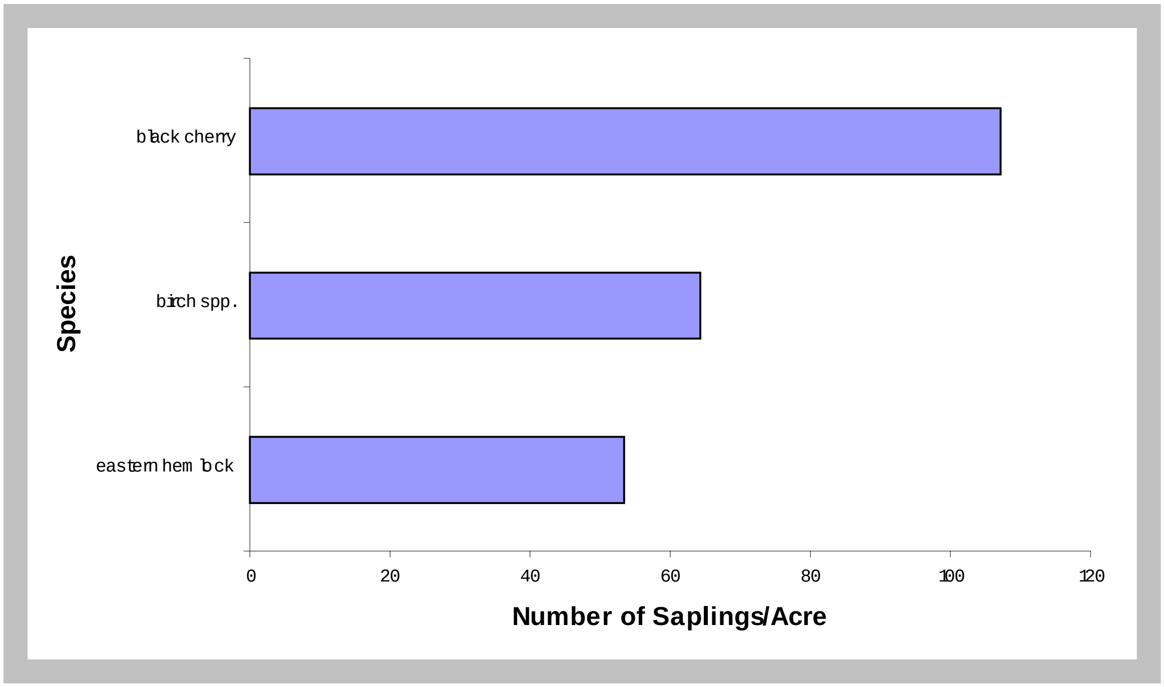

Figure 37. Number of saplings per acre on poletimber plots (27 microplots).

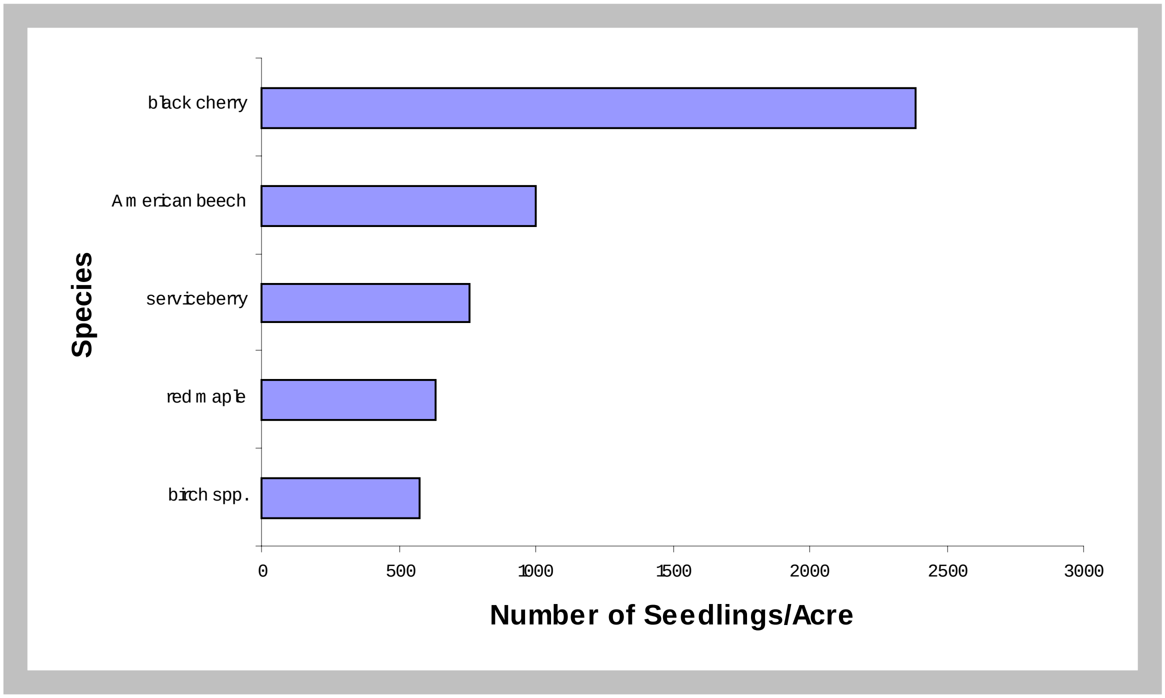

Figure 38. Number of seedlings per acre on seedling/sapling plots (41 microplots).

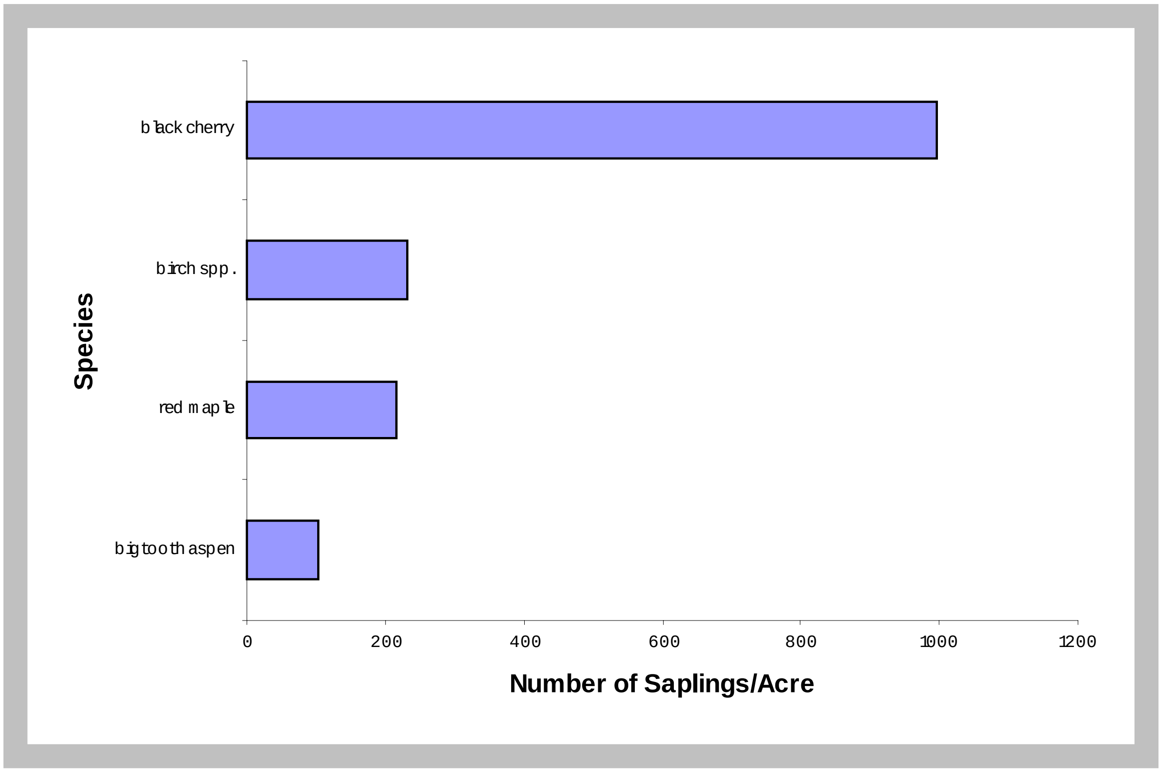

Figure 39. Number of saplings per acre on seedling/sapling plots (41 microplots).

These data suggest that black cherry is likely to increase in dominance in the ANF over the next century. 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. The absence of sugar maple in Figures 32 through 39 suggests that this species is also decreasing in dominance in reproducing stands. Marquis et al. (1992) outlined standards for achieving desirable regeneration in Allegheny hardwood forests based upon 6-foot radius plots. The standards were adjusted and applied to the 6.8-foot radius FHM microplots. Using these standards, only 21 of 372 FHM microplots (5.6 percent) would be considered stocked with desirable regeneration.

This information underscores the impact of deer (Tilgman 1989), as well as the need to implement other reforestation practices designed to enhance seedling development and diversity, e.g., herbicide/fencing (Horsley et al. 1994) and release treatments (Ristau and Horsley 1999).

Understory Vegetation

Ground cover of understory vegetation was recorded at each 6.8-foot radius FHM microplot (Fig. 10, page 10). Percent cover was assessed for mosses, ferns, herbs, shrubs, and tree seedlings. Mosses include moss and lichens. Herbs include forbs (herbaceous broad-leaved plants), grasses, and vines. Shrubs include all woody plants not measured as tree seedlings or vines. Studies have shown that if more than 30 percent of the ground cover is stocked with interfering plants, then adequate regeneration of desirable species is unlikely (Marquis et al. 1992). Ferns and herbs together cover greater than 30 percent of the ground area in all stand types. Therefore, interfering vegetation may be considered a major impediment to desirable regeneration.

Figure 40 presents an overview of the type of plot ground cover, including its abundance by overstory vegetation size class. For the sawtimber-size class, ground cover abundance is also shown for each of three overstory stocking levels (see Fig. 23).

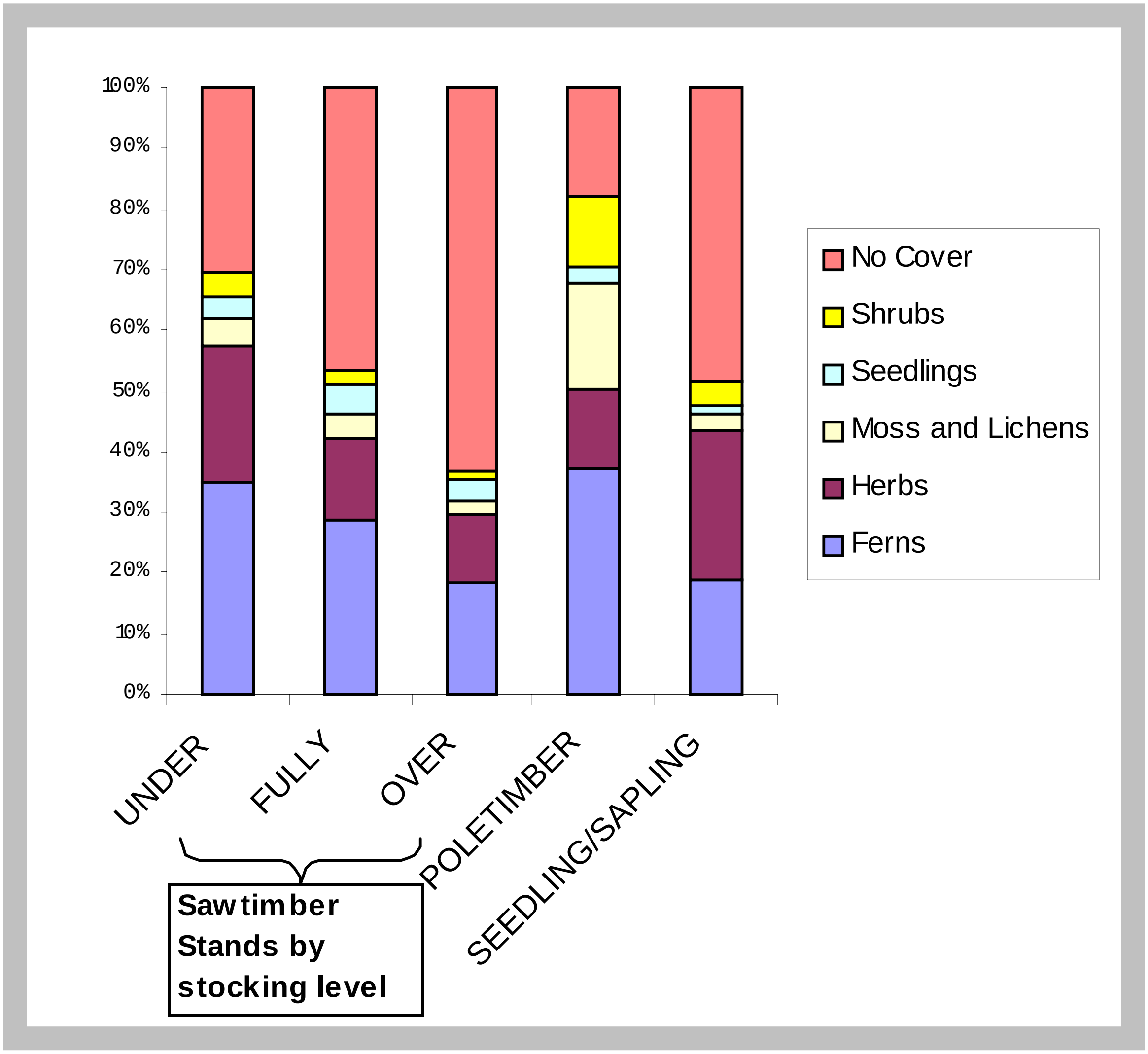

Figure 40. Percent cover of understory vegetation by stand size (1998/1999 FHM data).

Down Woody Debris

In 1999, the FHM program began including the collection of data on down woody debris. Down woody debris (DWD) consists of dead tree parts or downed pieces of wood. Like live trees and other vegetation, it is a component of vegetative structural diversity (Busing et al. 2000), and it plays an important role in carbon and nutrient cycling, carbon sequestration, wildlife behavior and habitat, stream channel morphology, and plant reproduction (Heath and Chojnacky 2001). Martin (1976) described a line intersect method that provides reliable and unbiased estimates of the hardwood residue volume. This method uses a sample line that may be continuous or segmented and can be measured in any units. The diameter of any piece of residue that crosses the line is measured at the point of intersection. Three 59-foot transect lines are placed at 30-, 150-, and 270-degree azimuths from the center of each FHM subplot (Fig. 10) (Busing et al.

1999). DWD data were collected at 38 FHM plots in 1999. Various data, including species, diameter, and decay class, were collected along each transect line. The illustration in Figure 41 shows the 4 decay classes (see Table 9 for descriptions). The classification system is based on bark condition, structural integrity, approximate age (length of time the DWD has been on the ground), and other factors.

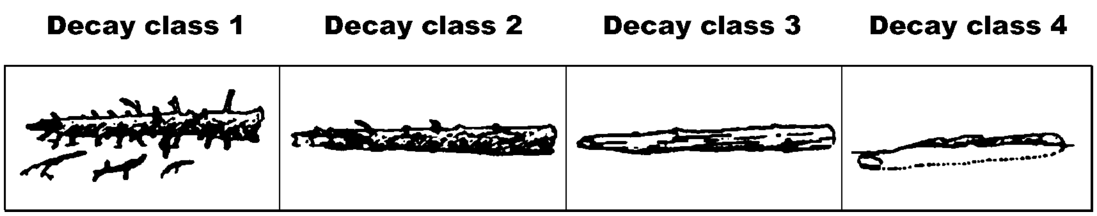

Figure 41. Illustrations of the DWD decay classes (Reproduced from Heath and Chojnakcy 2001).

	Decay Class			
Characteristic	***1***	***2***	***3***	***4***
Bark	Intact	Generally intact to sloughing	Generally intact to sloughing	Generally intact to completely absent
Structural Integrity	Intact	Sound/some decay	Significant decay/punky	Mostly decayed
Branch System	Fine twigs present(<.5 inches)	Twigs absent; most branches present	Large branches present, length>d.b.h.	Branch stubs present, length<d.b.h.
Approximate Age (years)	1-3	3-10	10-20	20-50

Table 9. Decay class descriptions for snags and logs.

Figure 42, page 36, displays the volume of DWD per acre by species divided into diameter classes. Most of the debris on the ANF (nearly 300 ft^3/acre) was in the 6- to 12-inch diameter range. Red maple and black cherry together had more DWD volume than all other species combined. This was expected, since these two species made up the majority of the overstory basal area.

The majority of the DWD on the ANF (nearly 400 ft^3/acre) was classified as decay class 3 (Fig. 43, page 36).

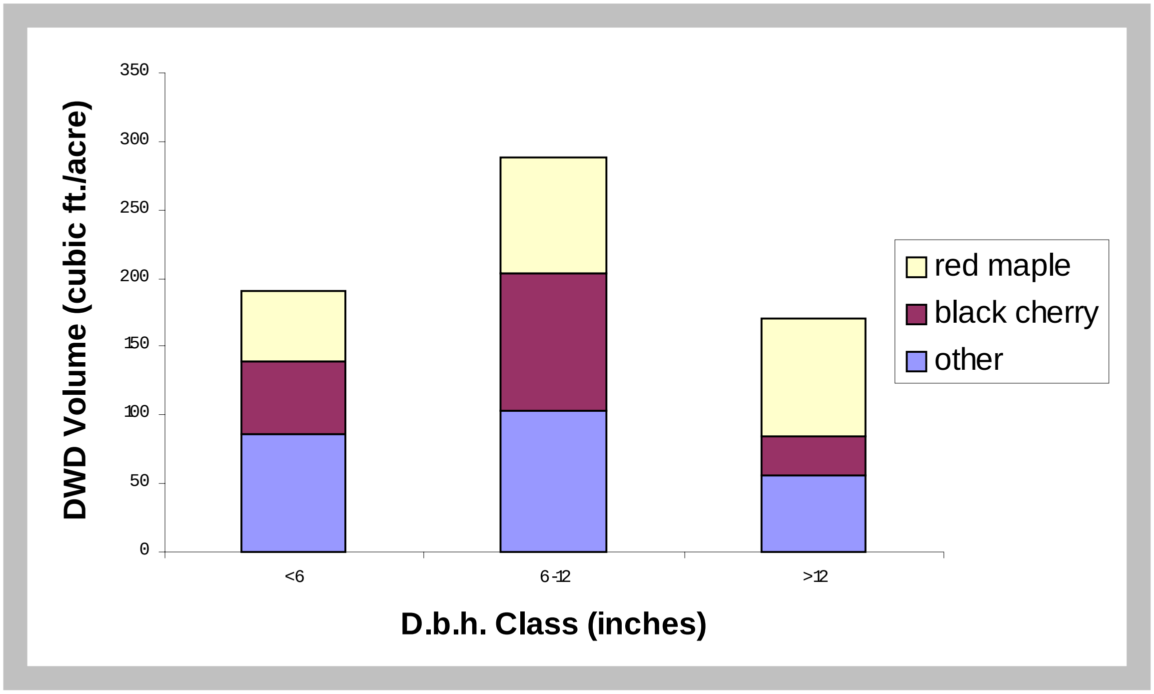

Figure 42. DWD volume/acre on the ANF by species and divided into diameter classes (1999 FHM data).

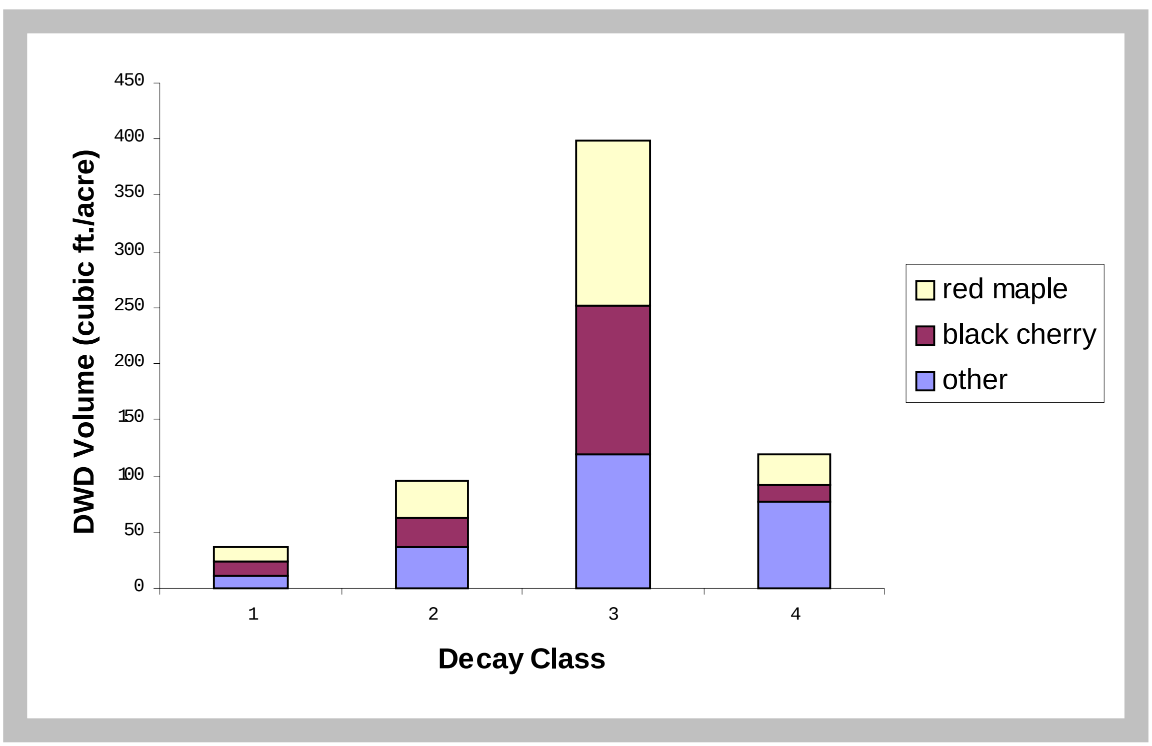

Figure 43. DWD volume/acre on the ANF by species and divided into decay classes (1999 FHM data).

The volume of DWD per acre separated into overstory plot-age classes is shown in Figure 44. The majority of the DWD on the ANF was in younger stands (11 to 50 years old) and stands older than 110 years.

Figure 45 shows the average DWD volume/acre for various overstory forest types on the ANF. The hemlock type has an average of more than three times as much DWD as any other forest type.

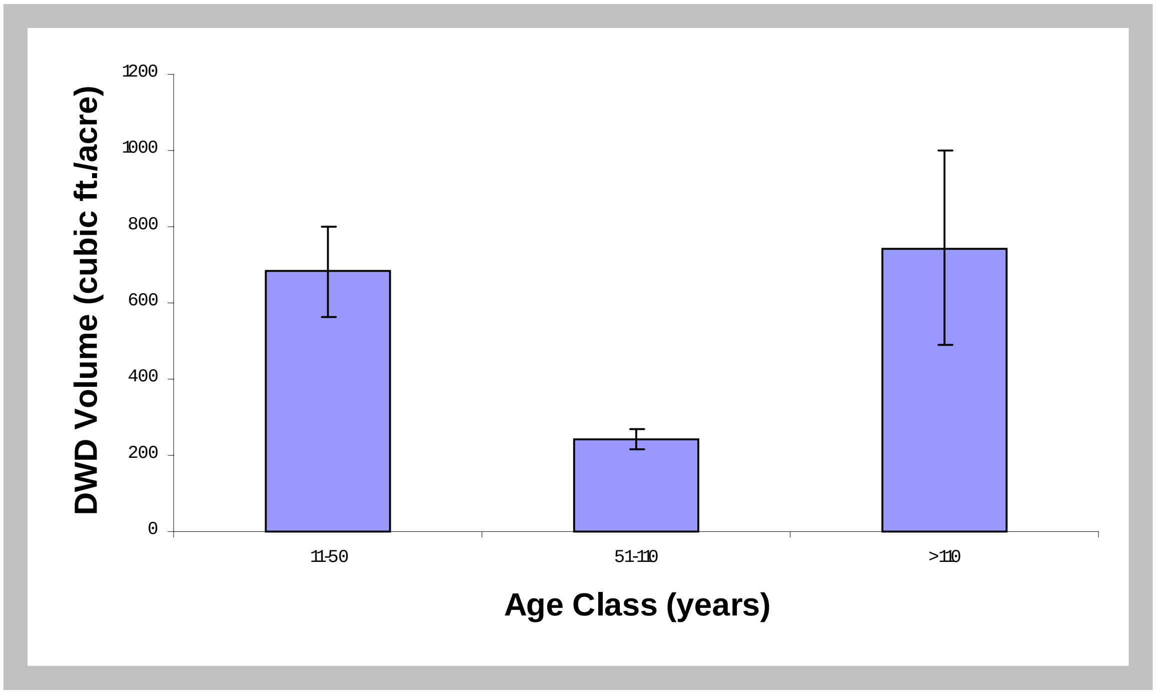

Figure 44. DWD volume/acre on the ANF divided into overstory plot stand age classes (1999 FHM data).

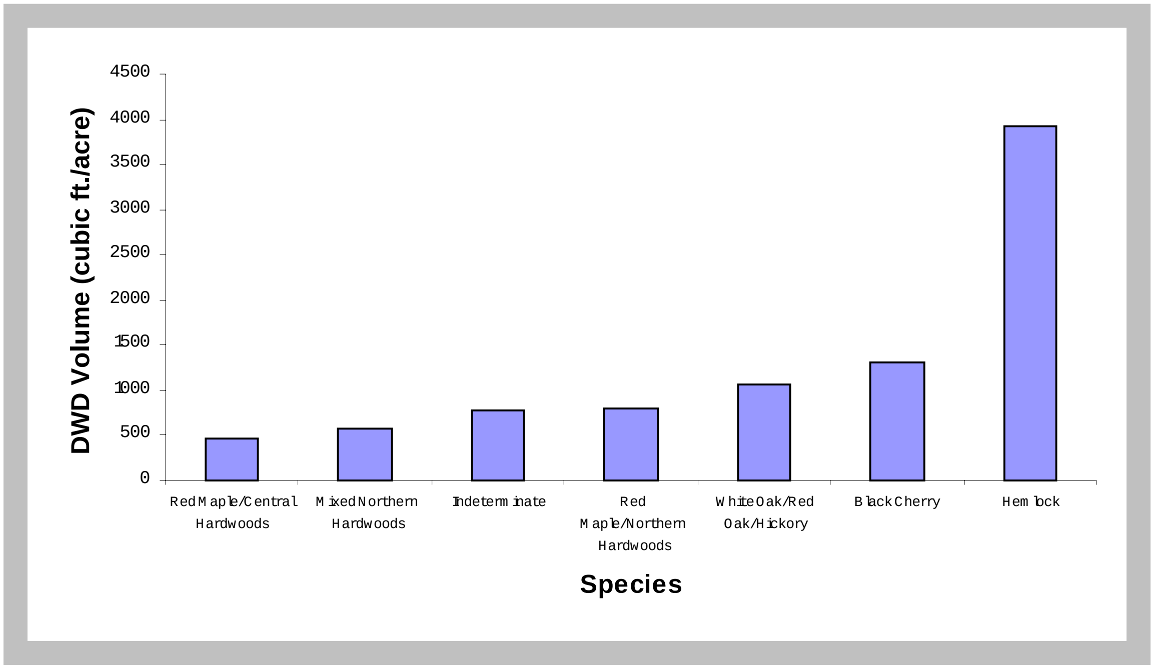

Figure 45. DWD volume/acre on the ANF divided into forest types (1999 FHM data).

Determining what the "correct" amount of DWD should be, or what might be expected in a forest, is difficult. Some correlations can be made with old-growth stands, and some insights can be gained by understanding the dynamics of forest succession.

The large amount of DWD in the 6- to 12-inch diameter class (Fig. 42) and the 11- to 50-year age class may be attributed to the period when even-aged stands are in the process of self-thinning. In the case of very young stands, it could be attributed to woody debris left on the ground following the final harvest. The large volume of DWD in the 110+ years age class (Fig. 44) may be explained by the tendency of some tree species reaching the end of their life span.

Preliminary investigations of DWD on the ANF revealed a low volume of DWD in second-growth stands compared with the amount found in the old growth Tionesta Scenic and Research Natural Areas (D. deCalesta and C. Nowak 2001, pers. commun.[2]). The volume of DWD in old-growth stands ranged from 866 to 1,659 ft^2/acre, whereas the volume in second-growth forests ranged from 342 to 413 ft^2/acre. The trends in these data (increasing DWD as forests move from middle age to the late-successional stage) correspond to the information in Figure 44. Volumes of DWD are lower in Figure 44 than those found by deCalesta and Nowak, but that may partly be explained by how they grouped the data for analysis (the 51-110 age class in Figure 44 may not correspond precisely to the second-growth age class used by deCalesta and Nowak, and stands were much older in deCalesta and Nowak than in Figure 44). Maturing forests are expected to have less DWD than late-successional forests, but the differences have not been quantified.

DISTURBANCE PROCESSES ON THE ALLEGHENY NATIONAL FOREST

Insects and pathogens are an important part of any forest ecosystem. Their natural role in disturbance dynamics is normally positive — cycling nutrients from foliage to soils, killing weak or noncompetitive trees, and decomposing dead trees (Haack and Byler 1993). Most insects and diseases rarely reach epidemic levels, but some insect species can cause significant damage when their numbers reach 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 (Stout et al. 1995).

Exotic organisms are a serious threat to the ecological balance that has developed through thousands of years of coexistence among native insects, pathogens, and host tree species (Haack and Byler 1993; Liebhold et al. 1995). At least part of the reason non-native pest species have more frequent outbreaks is the lack of natural enemies. Damaging exotic organisms on the ANF include gypsy moth, beech bark disease, and pear thrips. Between 1985 and 1996, exotic insects have affected 317,000 acres. Moreover, the beech scale *Nectri*a complex has been expanding its range south from New England and New York for many years, reaching the ANF in the early 1980s. Beech mortality first became evident on the ANF in 1986. The disease 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 its complete absence in uninfected forests (Houston 1994).

Recently, natural climatic disturbance (particularly drought) has also played a substantial role in helping to shape the forest ecosystems on the Allegheny Plateau. Four significant drought events between 1988 and 1999 have coincided with these insect defoliator outbreaks.

[2] deCalesta, D.; Nowak, T. 1998. Personal communication with R. White.

Cherry Scallopshell Moth

This native species, distributed widely in the Eastern United States and Canada, is not considered to be a serious pest in most areas. Larvae (Fig. 46) form shelters by fastening margins of leaves together. Within these shelters, larvae aggregate 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). The cherry scallopshell moth has one generation per year. Pupae overwinter in the leaf litter or in the upper soil layer. 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).

Figure 46. Cherry scallopshell moth larva.

The most recent cherry scallopshell moth outbreak on the ANF was from 1993 through 1996 (Fig. 47). Historically, outbreaks occur approximately 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 sometimes tree decline/mortality follows after an outbreak. On the ANF, decline seems to occur when repeated defoliation (including defoliation by other insects, e.g. elm spanworm) or other stresses (e.g. severe drought) occur concurrently or in successive years. Figure 48, page 39, shows the area of the black cherry/red maple type defoliated by the cherry scallopshell moth on the ANF during the last outbreak. The most severe defoliation occurred in 1995 when nearly 290,000 acres were affected (205,000 on federal land). Most of the defoliation occurred on the southeastern two-thirds of the ANF. The remainder of the ANF experienced only light or no defoliation, even though there is a significant black cherry component scattered throughout the northern portion.

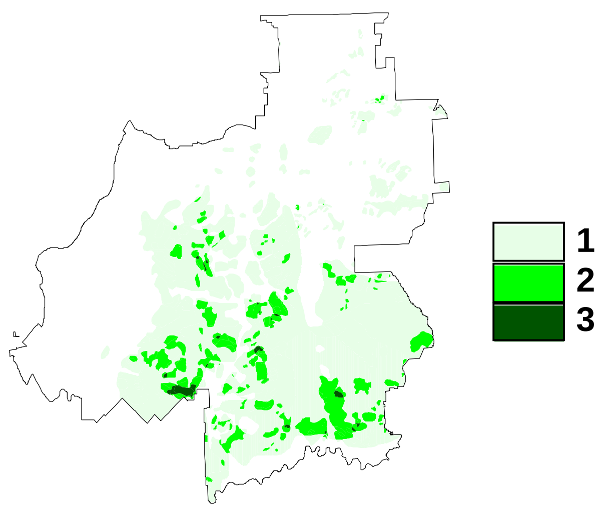

Figure 47. Map of years of cherry scallopshell moth defoliation from 1993 to 1996 on the ANF (aerial sketch maps).

The preferred host for this species on the ANF is black cherry. Therefore, black cherry dominated stands are normally the most heavily defoliated during cherry scallopshell moth outbreaks (Fig. 49, page 40). There was evidence of a statistically significant increase in years of cherry scallopshell moth defoliation with percent black cherry basal area (*p*=0.0001). Areas with at least 10 percent black cherry basal area are more likely to suffer defoliation in an outbreak.

The average percent standing dead black cherry on plots with more than 10 percent black cherry basal area was larger in areas that were defoliated for 2 years, but the trend was not significant (*p*=0.1548) (Fig. 50, page 41). Plots defoliated twice had an average percent dead black cherry more than 2.5 times that of plots that were not defoliated or defoliated once. Plots with less than 10 percent black cherry basal area were not included, because sampling error in estimates of mortality would be disproportionally high.

The average crown dieback value reported for black cherry trees was similar as the number of years of defoliation increased (*p*=0.8560) (Fig. 51, page 41).

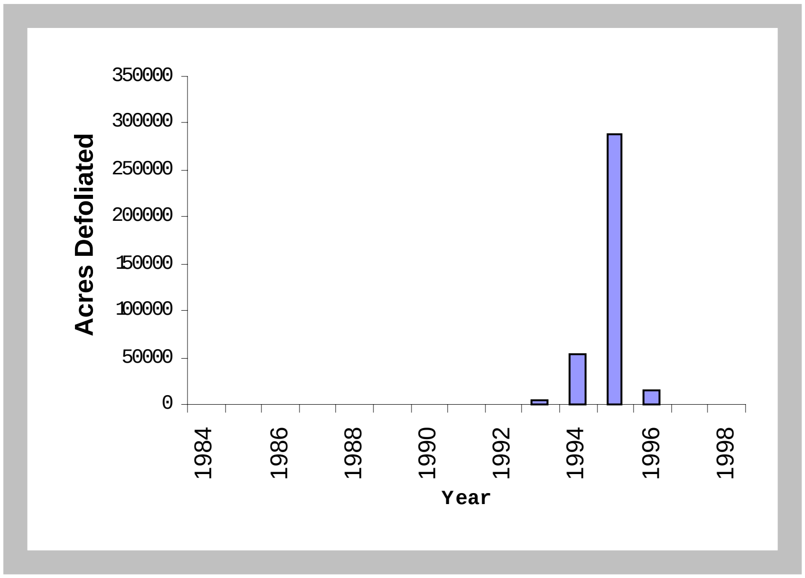

Figure 48. Acres defoliated by cherry scallopshell moth (aerial sketch maps).

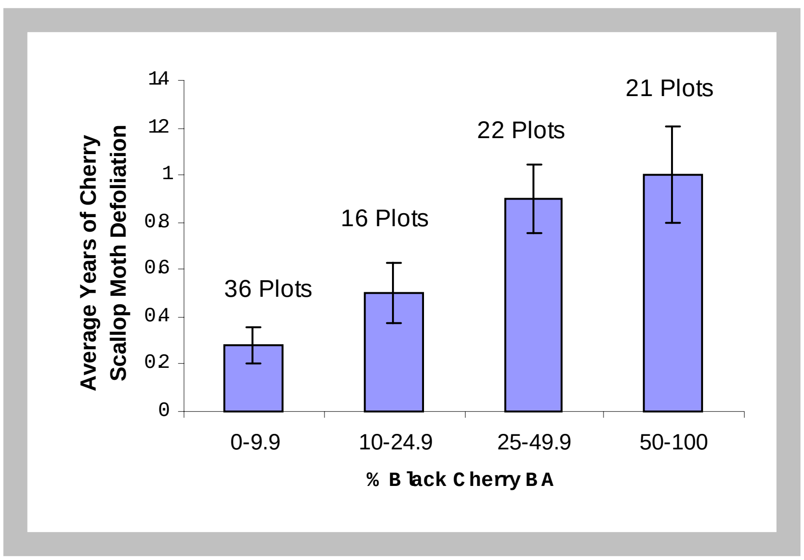

Figure 49. Percent black cherry basal area (1998/1999 FHM data) plotted against the average years of cherry scallopshell moth defoliation (aerial sketch maps).

Elm Spanworm

The elm spanworm, a native species, is found throughout the Eastern United States and into Canada. Outbreaks are relatively uncommon, though major multiyear elm spanworm outbreaks have occurred in Connecticut and North Carolina. The pest is responsible for periodical severe defoliation of hardwoods such as ash, hickory, walnut, beech, black cherry, elm, basswood, red maple, sugar maple, and yellow birch. One year of defoliation usually has little impact, but 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. 52) feed on the lower surface of leaves, but eventually consume everything but the veins (Fig. 53, page 42) (USDA For. Serv. 1979). This species is highly polyphagous, and nearly all major tree species on the ANF are hosts except for yellow-poplar, cucumbertree, and white ash. The preferred hosts for elm spanworm on the ANF during this outbreak were American beech, red maple, sugar maple, and black cherry.

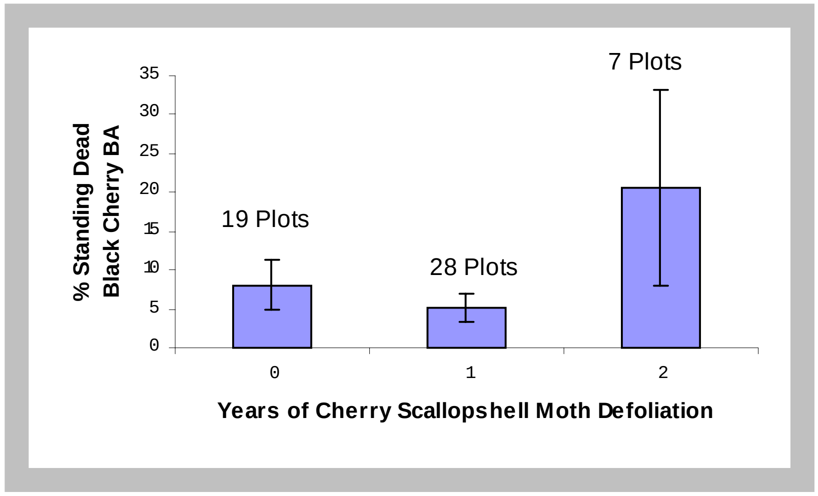

Figure 50. Percent standing dead black cherry basal area on plots with greater than 10 percent black cherry basal area (1998/1999 FHM data) plotted against years of cherry scallopshell moth defoliation (aerial sketch maps).

The most recent elm spanworm outbreak on the ANF occurred from 1991 through 1993 (Fig. 54, page 42). The insect population collapsed early in 1994. It is interesting to note that the western one-third of the ANF had little defoliation even though preferred host tree species were relatively abundant there.

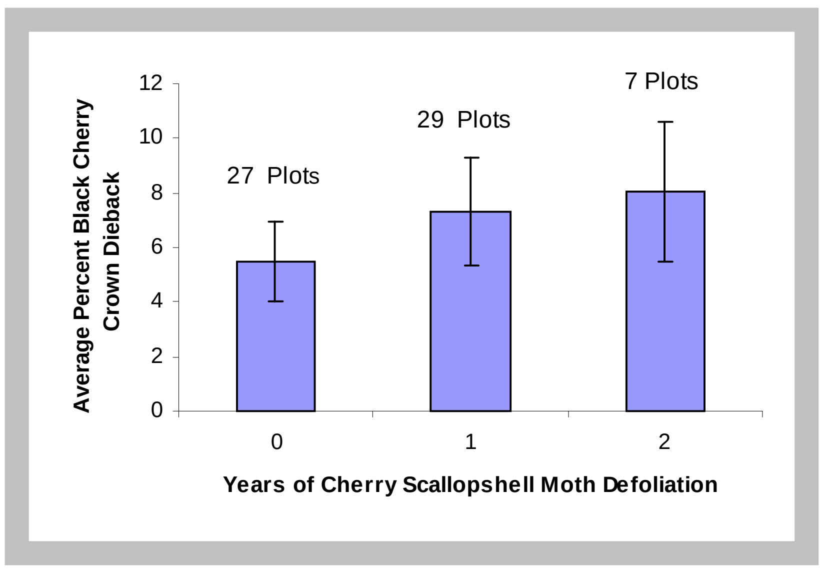

Figure 51. Average crown dieback for black cherry trees (1998/1999 FHM data) against years of cherry scallopshell moth defoliation (aerial sketch maps).

The area defoliated by the elm spanworm within the proclamation boundary of the ANF covered nearly 340,000 acres in 1993 (Fig. 55, page 42). In 1992, substantial defoliation occurred after the aerial mapping survey was completed. The acreage reported in Figure 55 underestimates total defoliation for that year.

Percent basal area for each of these species plotted against the average number of years of elm spanworm defoliation is shown in Figure 56, page 43. The average duration of defoliation was significantly greater on plots with more

Figure 52. Elm spanworm larva.

Figure 53. Elm spanworm defoliation.

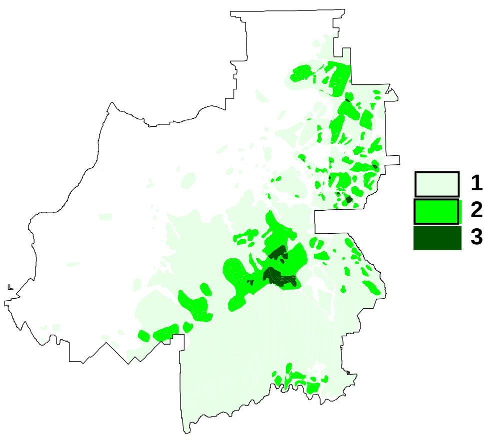

Figure 54. Map of years of elm spanworm defoliation on the ANF (aerial sketch

than 50 percent black cherry basal area. There was a significant linear trend between percent black cherry basal area and years of elm spanworm defoliation (p=0.0001). This trend was not significant for red maple, sugar maple, or American beech.

Plots defoliated more often by elm spanworm did not have greater proportions of standing dead black cherry basal area (p=0.7037) (Fig. 57, page 43).

Figure 58, page 44, shows the average crown dieback for black cherry trees plotted against years of elm spanworm defoliation. Trees on plots defoliated three times had a higher average crown dieback value, but the difference was not statistically significant (p=0.1738).

The elm spanworm also had an effect on the amount of standing dead red maple on the ANF (Fig. 59, page 44). Plots that were defoliated twice had highest proportion of standing dead red maple basal area. There was evidence of a significant trend between percent standing dead red maple basal area and years of elm spanworm defoliation (p=0.0359).

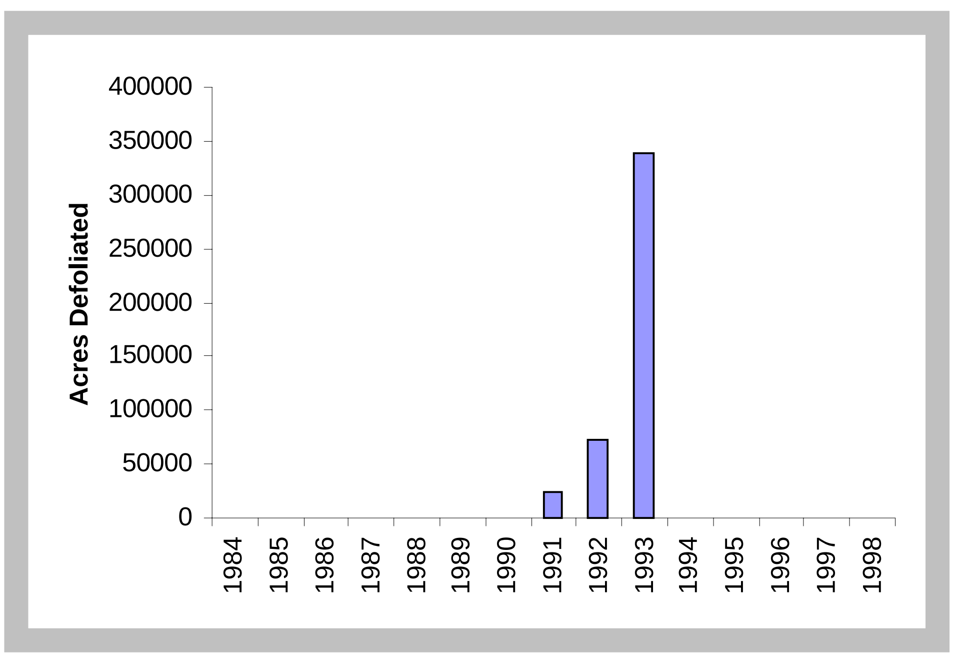

Figure 55. Acres defoliated by elm spanworm (aerial sketch maps).

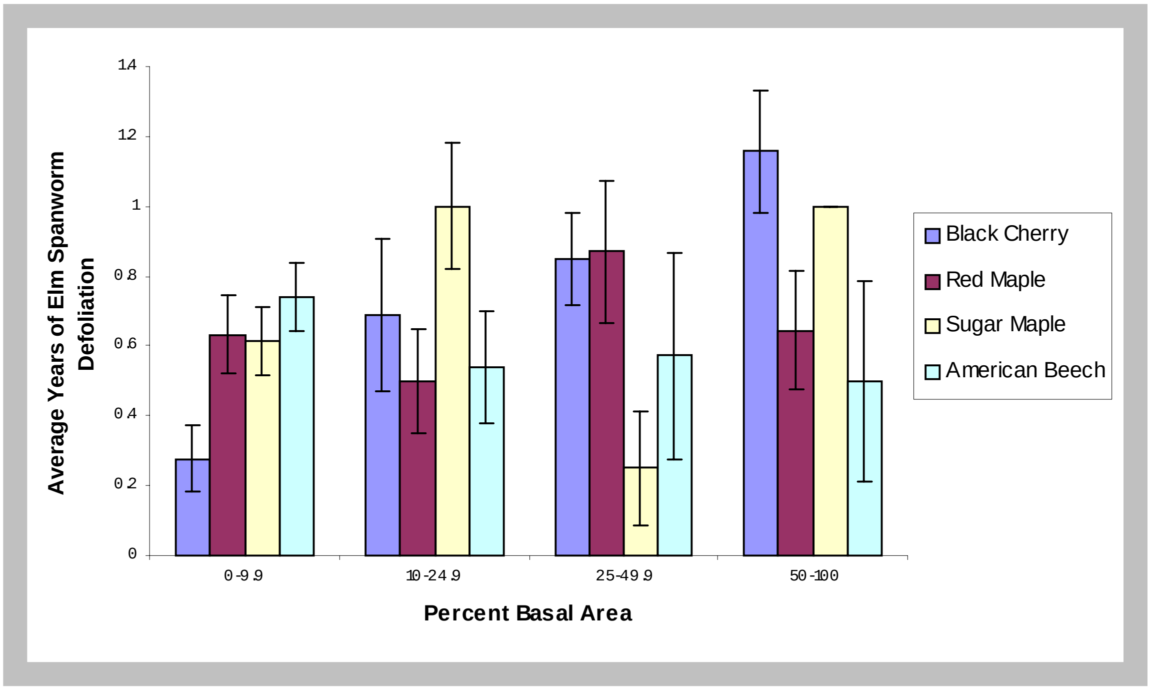

Figure 56. Percent black cherry, red maple, sugar maple, and American beech basal area (1998/1999 FHM data) plotted against average years of elm spanworm defoliation (aerial sketch maps).

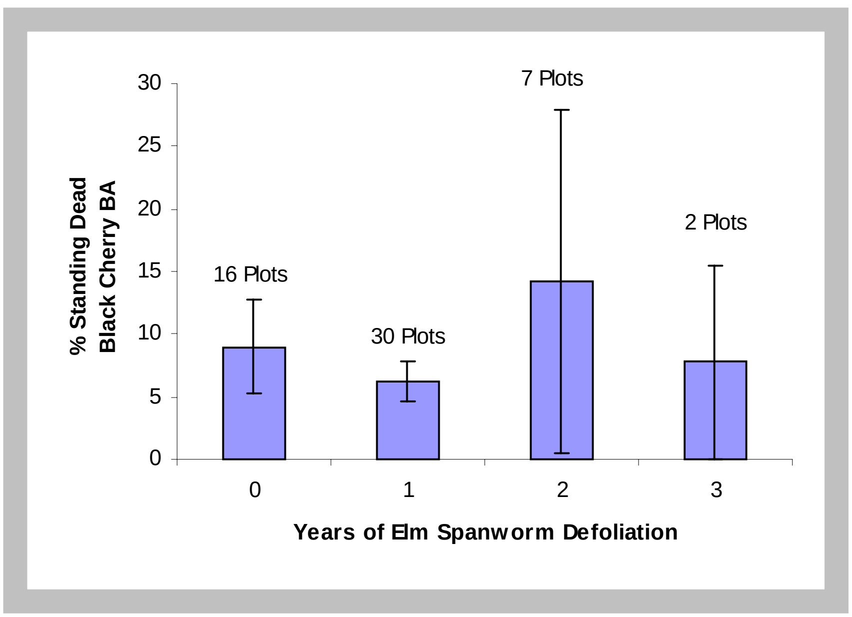

Figure 57. Percent standing dead black cherry basal area on plots with more than 10 percent black cherry (1998/1999 FHM data) plotted against years of elm spanworm defoliation (aerial sketch maps).

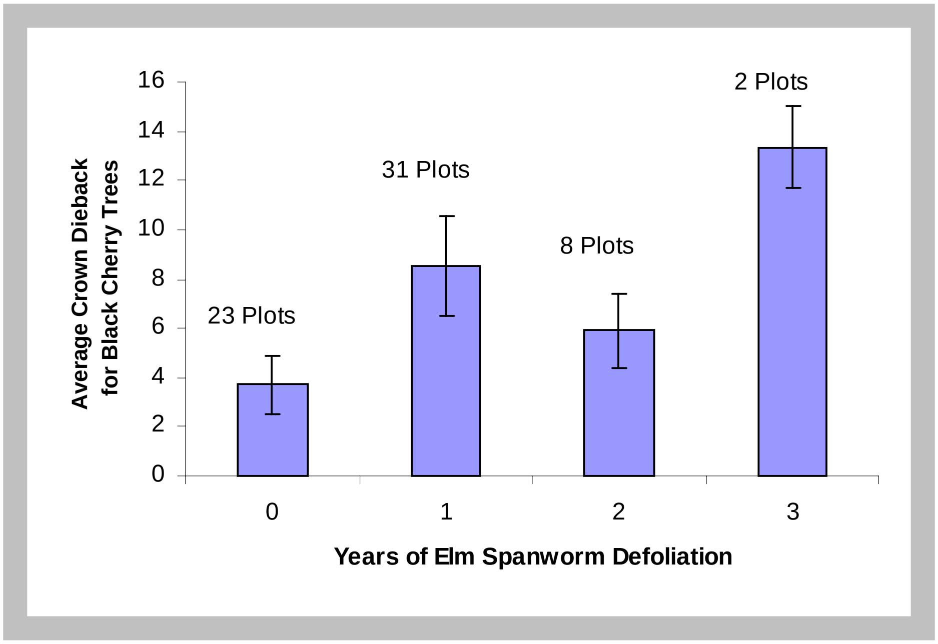

Figure 58. Average crown dieback for black cherry trees (1998/1999 FHM data) versus years of elm spanworm defoliation (aerial sketch maps).

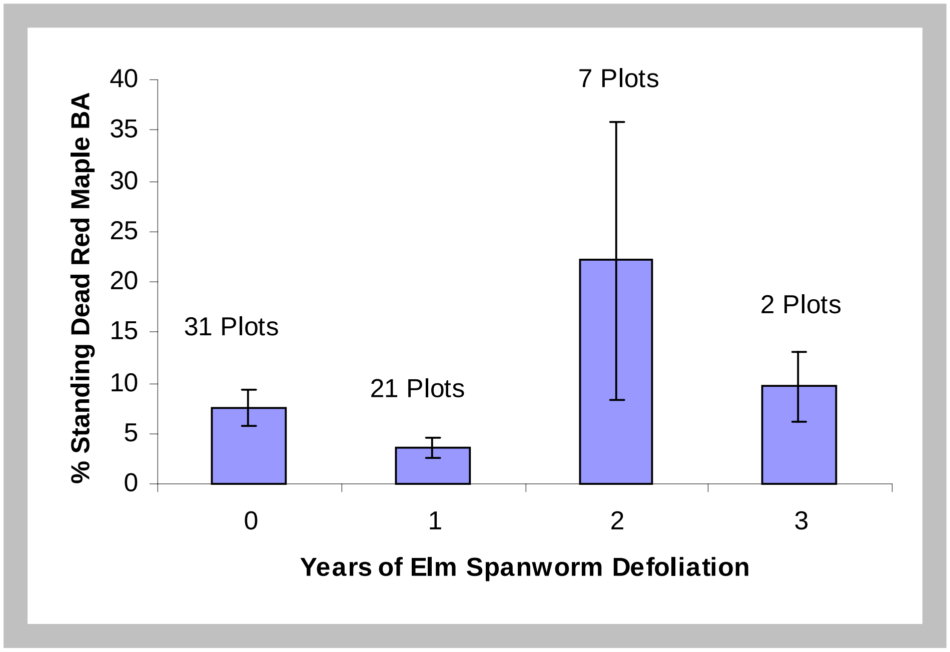

Figure 59. Percent standing dead red maple basal area on plots with more than 10 percent red maple (1998/1999 FHM data) plotted against years of elm spanworm defoliation (aerial sketch maps).

Figure 60 shows that crown dieback for red maple trees increased with years of defoliation. There was evidence of a statistically significant increase (*p*=0.0044).

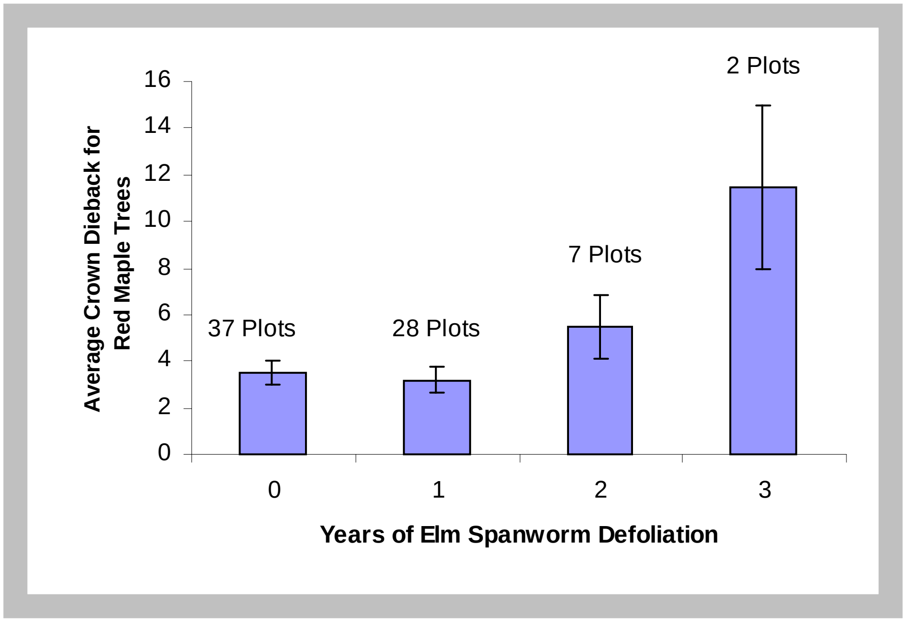

Figure 60. Average crown dieback for red maple trees (1998/1999 FHM data) versus years of elm spanworm defoliation (aerial sketch maps).

The relationship between standing dead sugar maple basal area and elm spanworm defoliation is shown in Figure 61. Plots that suffered 1 year of defoliation had a greater percentage of standing dead sugar maple than plots not defoliated, but the difference was not significant (*p*=0.2781).

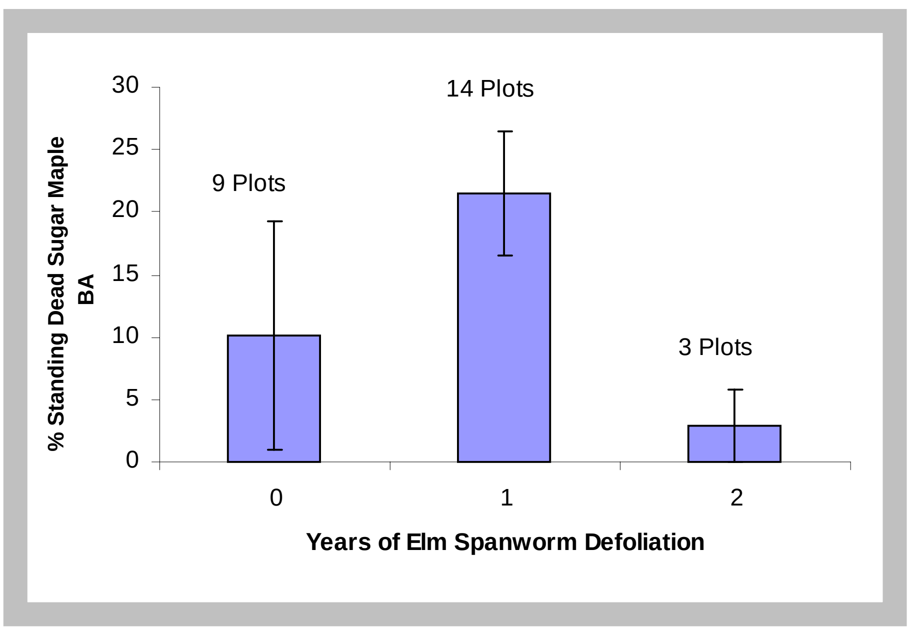

Figure 61. Percent standing dead sugar maple basal area on plots with more than 10 percent sugar maple (1998/1999 FHM data) plotted against years of elm spanworm defoliation (aerial sketch maps).

Sugar maple trees in plots that experienced elm spanworm defoliation exhibited more crown dieback than trees that were not defoliated, but the relationship was not statistically significant (p=0.2260) (Fig. 62).

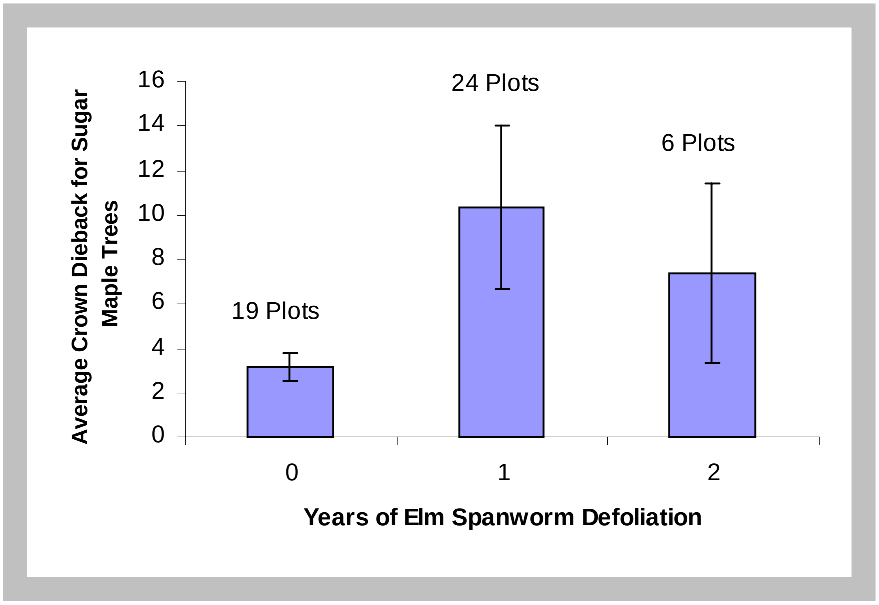

Figure 62. Average crown dieback for sugar maple trees (1998/1999 FHM data) versus years of elm spanworm defoliation (aerial sketch maps).

Plots defoliated more often by elm spanworm did not have greater proportions of standing dead American beech basal area (p=0.4005) (Fig. 63).

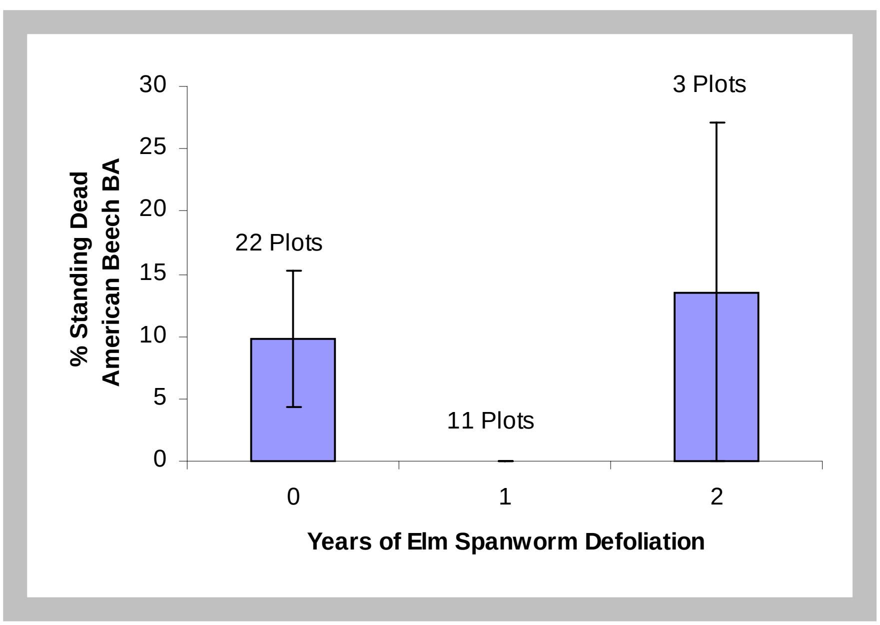

Figure 63. Percent standing dead American beech basal area on plots with more than 10 percent American beech (1998/1999 FHM data) plotted against years of elm spanworm defoliation (aerial sketch maps).

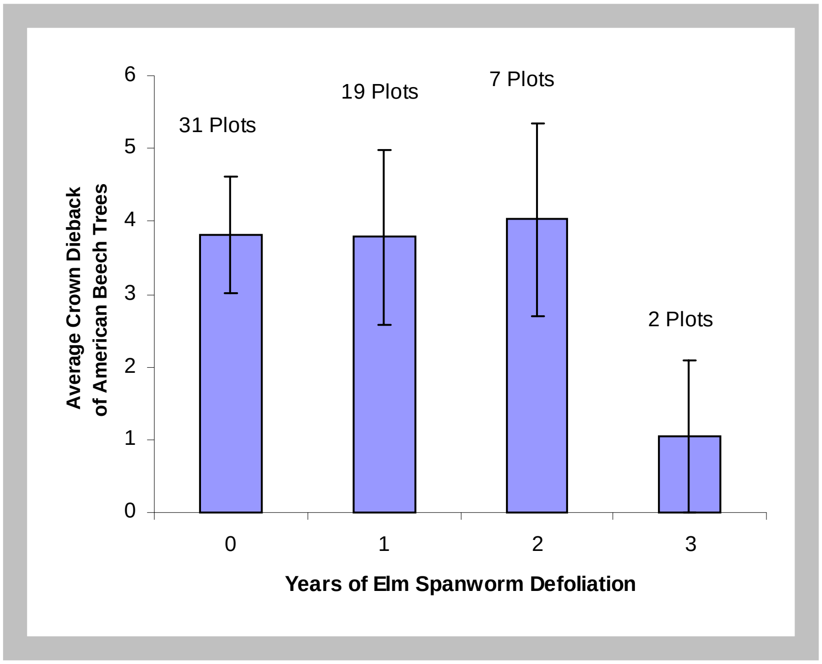

Figure 64. Average crown dieback for American beech trees (1998/1999 FHM data) versus years of elm spanworm defoliation (aerial sketch maps).

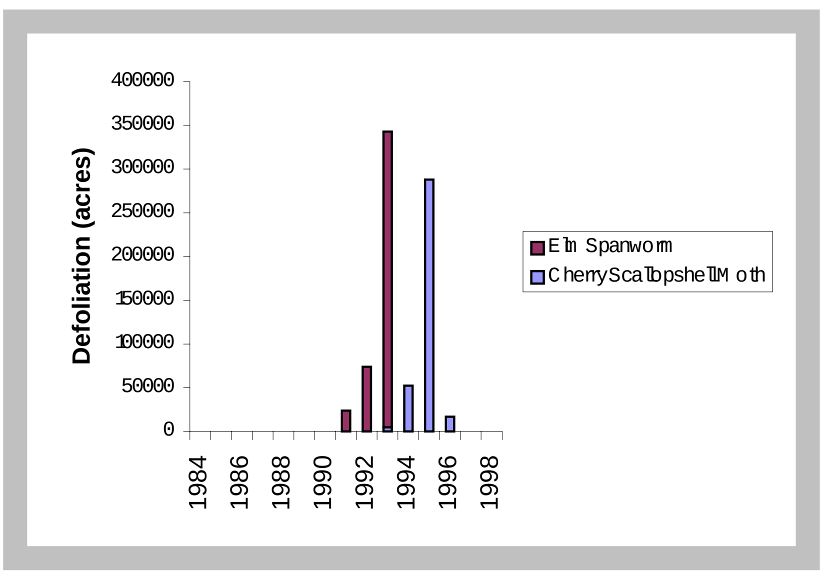

Figure 65. Acres defoliated by elm spanworm and cherry scallopshell moth (aerial sketch maps).

American beech crown dieback did not appear to be related to the number of years of elm spanworm defoliation (*p*=0.8672) (Fig. 64).

Combined Effects of Cherry Scallopshell Moth and Elm Spanworm

Between 1991 and 1996, black cherry on the ANF was affected by outbreaks of elm spanworm and cherry scallopshell moth. Black cherry was the primary host of the cherry scallopshell moth, and one of the elm spanworm hosts along with red maple, sugar maple, and American beech. Because outbreaks of cherry scallopshell moth and elm spanworm occurred consecutively, the black cherry condition in the 1998/1999 FHM surveys might be most clearly understood by considering the combined effects of both species.

Nearly 339,000 acres were defoliated by elm spanworm in 1993, and more than 287,000 acres were defoliated by cherry scallopshell moth in 1996 (Fig. 65).

There was evidence of a statistically significant increase in years of cherry scallopshell moth and elm spanworm defoliation with percent black cherry basal area (*p*=0.0001) (Fig. 66, page 48).

Plots defoliated four times by elm spanworm and cherry scallopshell moth had the highest proportion of standing dead black cherry (Fig. 67, page 48). There was evidence of a significant relationship between years of defoliation and percent standing dead black cherry basal area (*p*=0.0302).

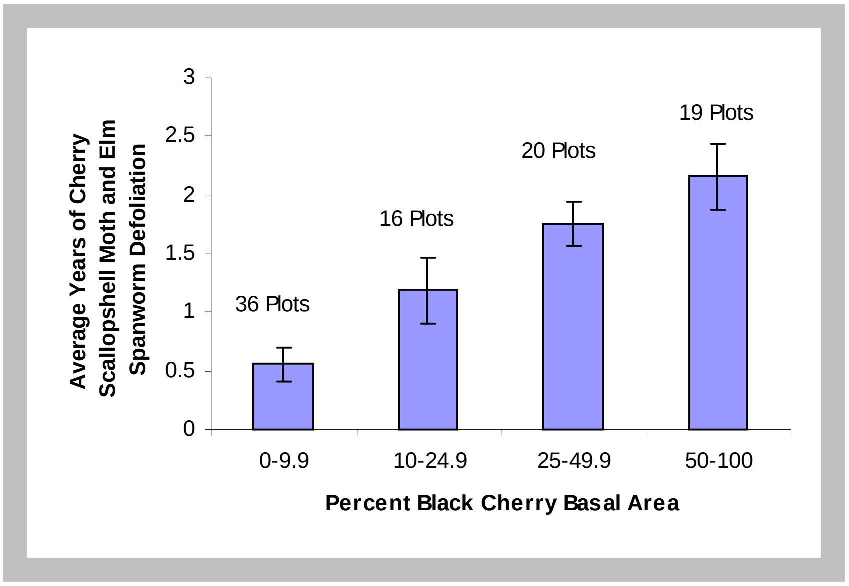

Figure 66. Percent black cherry basal area (1998/1999 FHM data) plotted against the average years of cherry scallopshell moth defoliation and elm spanworm (aerial sketch maps).

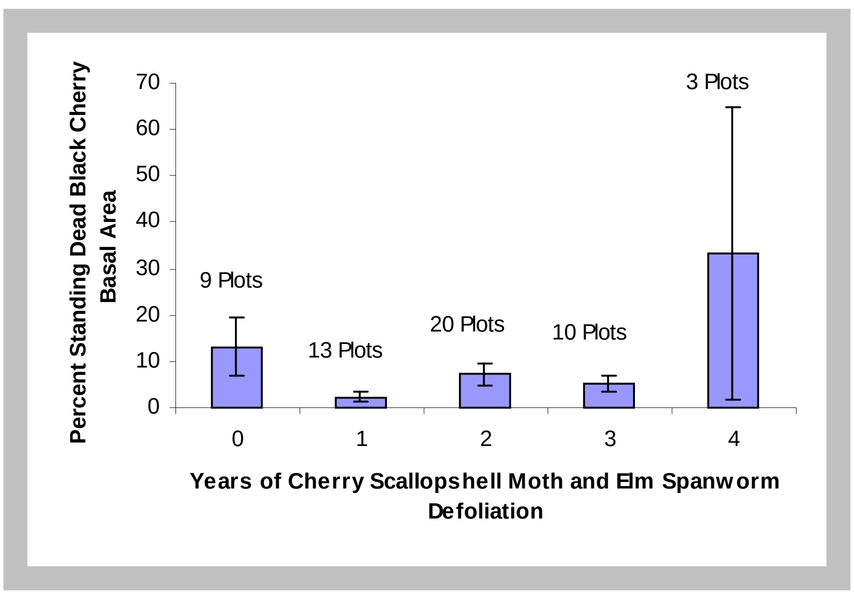

Figure 67. Percent standing dead black cherry basal area on plots with more than 10 percent black cherry basal area (1998/1999 FHM data) plotted against years of cherry scallopshell moth and elm spanworm defoliation (aerial sketch maps).

There was no clear relationship between average crown dieback values reported for black cherry and years of defoliation (*p*=0.2688) (Fig. 68).

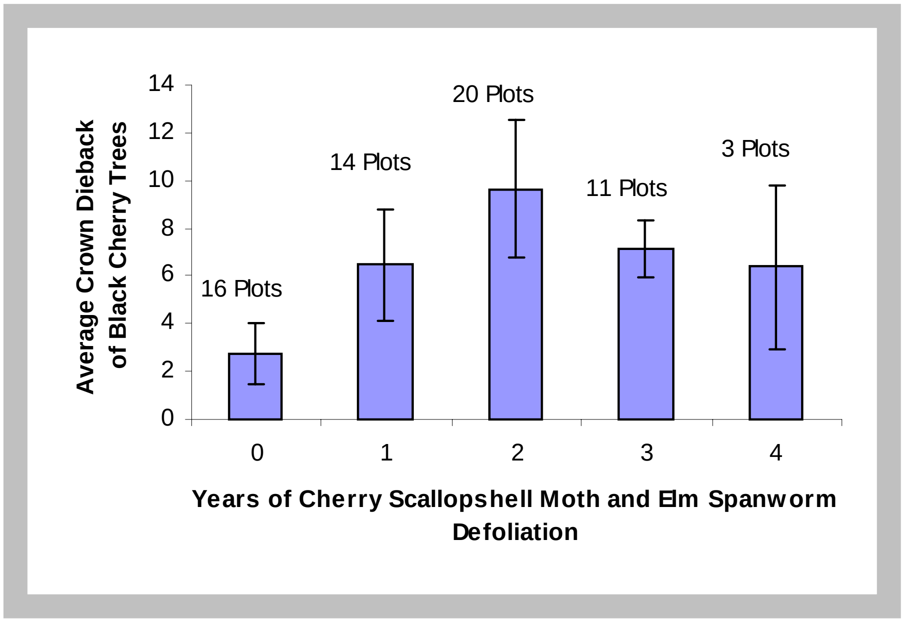

Figure 68. Average crown dieback for black cherry trees (1998/1999 FHM data) against years of both cherry scallopshell moth and elm spanworm defoliation (aerial sketch maps).

Sugar Maple Decline

Sugar maple dominates the northern hardwood forest type, where the species accounts for 50 percent or more of the basal area. The largest contiguous area of this forest type spreads 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 one or more predisposing stress events reduces resistance to invasion by opportunistic, secondary organisms that cause the death of tissues. Episodes of maple dieback/decline have been associated with insect defoliation, drought, lack of nutrition (particularly of Ca, Mg, and K), stand density, logging, and root freezing (Long et al. 1997; Houston 1999; Horsley et al. 2000).

Sugar maple can occupy a variety of sites, but grows best on moderately fertile and well-drained soils (Godman 1957). Sugar maple is particularly abundant on lower slope positions or coves enriched by leaf litter, colluvium, or nutrient-rich water moving from upslope (Leak 1982: Pregitzer et al. 1983: Smith 1995). Foresters in northern Pennsylvania began noticing a decline in sugar maple health in the early to mid-1980s. They observed higher mortality of large trees, decreased crown vigor, and crown dieback. Sugar maple growing on the lower slopes of unglaciated sites and in any topographical position on glaciated sites seemed unaffected or only slightly affected. In contrast, trees located on the upper slopes of unglaciated sites were the most affected. Defoliated stands were more likely to be unhealthy. Conversely, all sites that were defoliated did not have unhealthy sugar maple. It was concluded that some factor or factors 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 that resulted in trees with low foliar Ca and Mg and high Mn. The study suggests that sugar maple decline occurs on sites with an imbalance of Mg nutrition and excessive defoliation stress (Horsley et al. 2000).

The 1998 FHM data was used to compare live and dead sugar maple basal area to the terrain position of the trees, and whether trees had been defoliated by elm spanworm. The 1999 data could not be included in this analysis, because the terrain position variable was not collected. As shown in Figure 69, the most standing dead sugar maple was located on the upper slopes whether or not the areas were defoliated. This suggests that the less nutrient rich upper slopes are less suitable for sugar maple. Mortality was greater in defoliated than in undefoliated areas regardless of slope position. These results agree with the results reported by Horsley et al. (2000).

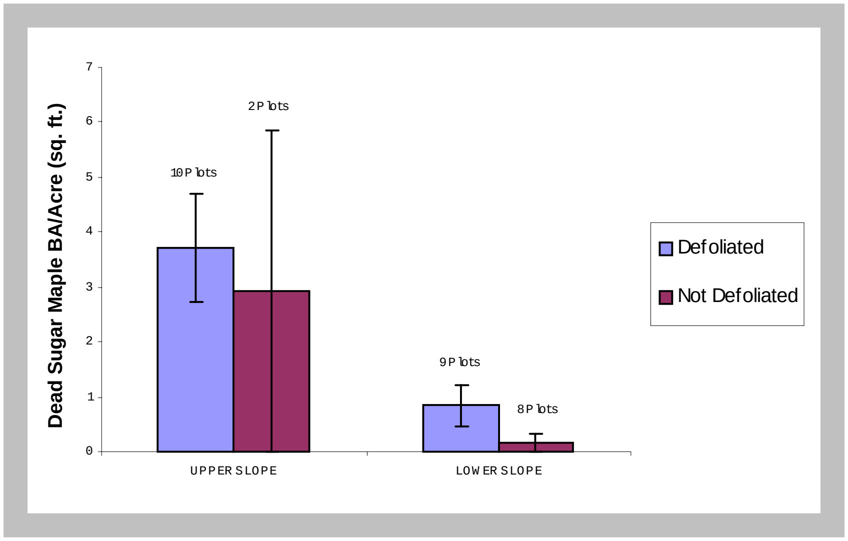

Figure 69. Dead sugar maple basal area per acre on upper versus lower slope positions (1998 FHM data) and in defoliated and nondefoliated stands (aerial sketch maps).

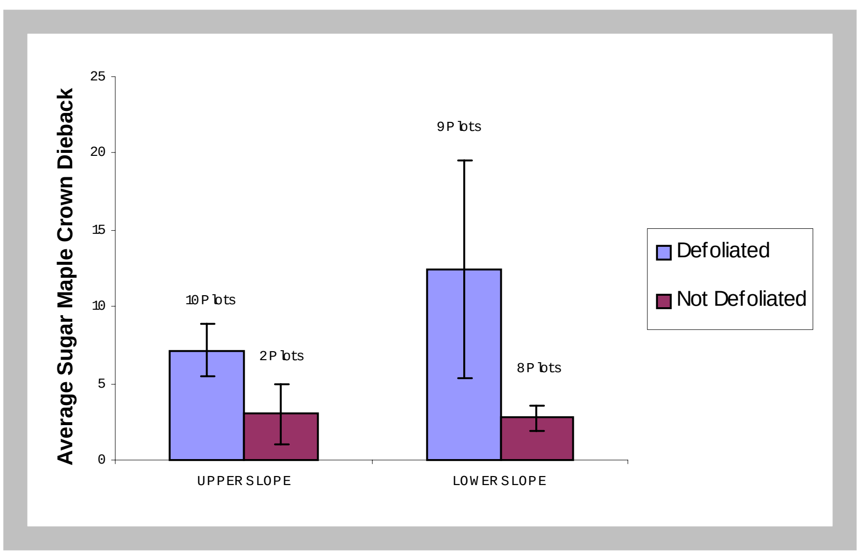

Figure 70. Average sugar maple crown dieback on upper versus lower slope positions (1998 FHM data) and in defoliated and nondefoliated stands (aerial sketch maps).

Surprisingly, the average crown dieback value for sugar maple trees from plots defoliated by elm spanworm was greater on lower slope plots (Fig. 70). Conversely, crown dieback was similar on upper and lower slope plots that were not defoliated. Figures 71 and 72 show a difference in mortality of sugar maple stands on upper and lower slopes.

Figure 71. Upper slope sugar maple stand showing extensive *mortality (photo by Kurt Gottschalk)*.

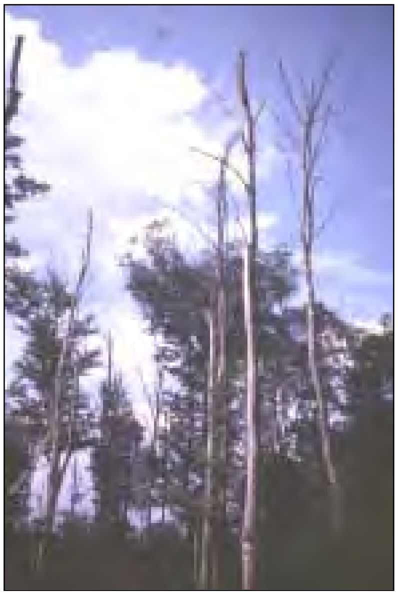

Figure 72. Lower slope sugar maple stand showing healthy trees *(photo by Kurt Gottschalk).*

Gypsy Moth

The gypsy moth was introduced 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 as Wisconsin (Fig. 73). 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 as embryonated eggs. In April or early May, the eggs hatch and larvae (Fig. 74) 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).

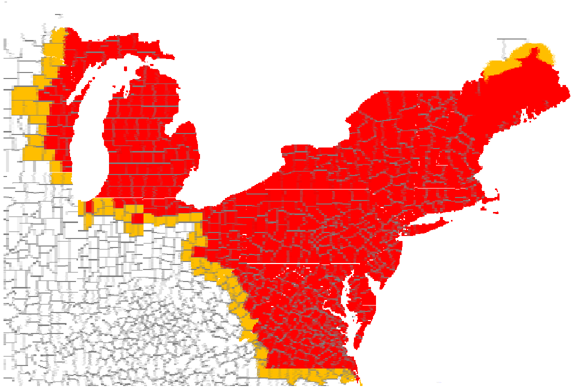

Figure 73. The 1999 gypsy moth quarantine of USDA APHIS (red-regulated area, yellow-transition area).

Figure 74. Gypsy moth larva.

The gypsy moth primarily defoliates hardwood trees, particularly oak and aspen and occasionally beech. It is interesting to note that in 1986 and 1987, gypsy moths defoliated many overstory beech throughout the ANF. On the ANF, plots with a higher percentage of oak were defoliated more often by gypsy moth (Fig. 75). There was evidence of a significant linear trend between percent oak basal area and years of gypsy moth defoliation ($p \le 0.0001$). Oak dominated stands were targeted for spraying, though many of them were not sprayed every time they were threatened with defoliation.

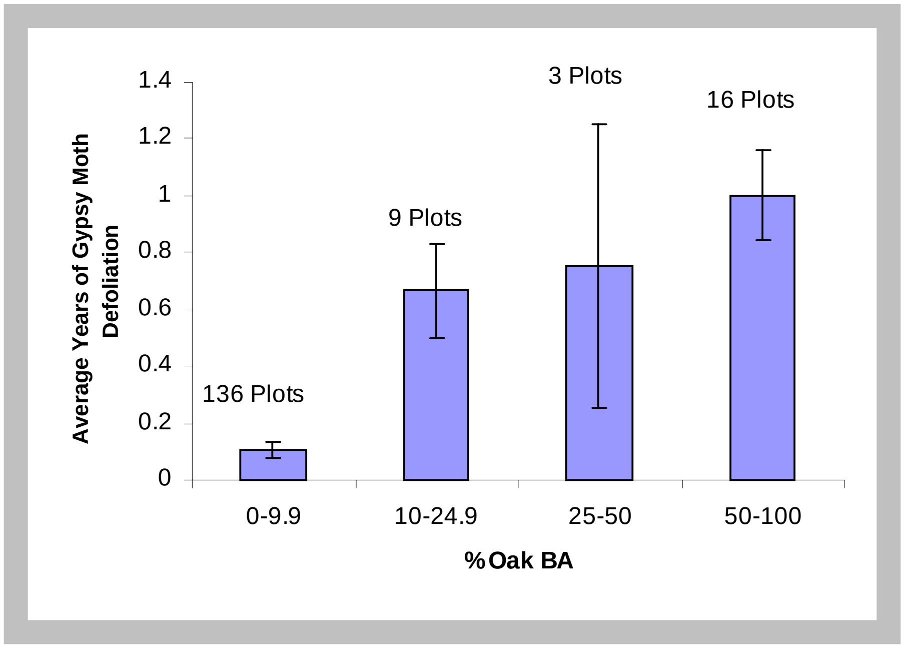

Figure 75. Percent oak BA (1989 FIA data) against years of gypsy moth defoliation (aerial sketch maps).

The most recent major outbreak of gypsy moth occurred on the ANF from 1984 to 1989. A second, less intense outbreak occurred from 1991 to 1993 (Fig. 77, page 53). Figure 76 shows the area of defoliation from 1984 to 1993. This distribution is similar to the geographical distribution of oak shown in Figure 16. The southern portion of the ANF, just north of the southern boundary, shows little repeated gypsy moth defoliation even though substantial oak exists. Gypsy moth populations peaked in that region later than the rest of the ANF. Areas in the southern portion which were

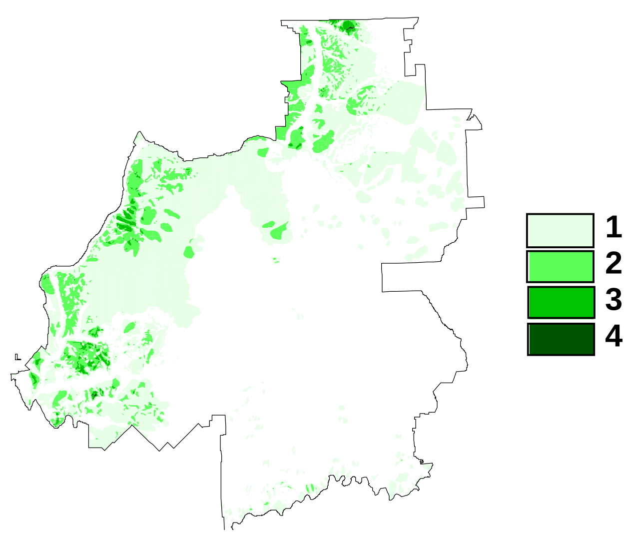

Figure 76. Map of years of gypsy moth defoliation of the ANF from 1984 to 1993 (aerial sketch maps)

threatened with repeated severe defoliation were treated more aggressively with biological insecticide (*Bacillus thuringiensis*) to avoid the higher rates of tree mortality/decline observed elsewhere on the ANF where treatment was less intense.

The area defoliated by gypsy moth is shown in Figure 77. The worst year during the first episode was 1987 when nearly 160,000 acres were defoliated. Nearly 50,000 acres were defoliated in 1992 during the second outbreak.

The average amount of standing dead basal area of oak increased with frequency of defoliation though the trend was not statistically significant (p= 0.28) (Fig. 78).

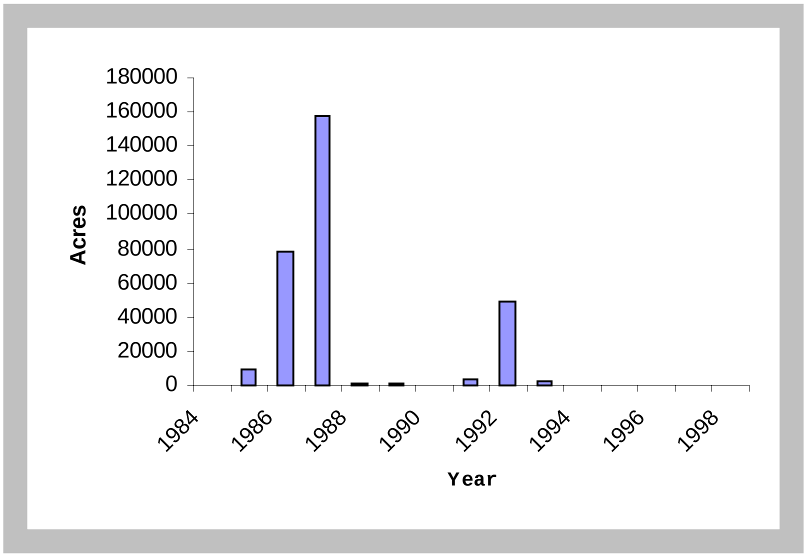

Figure 77. Acres defoliated by gypsy moth (aerial sketch maps).

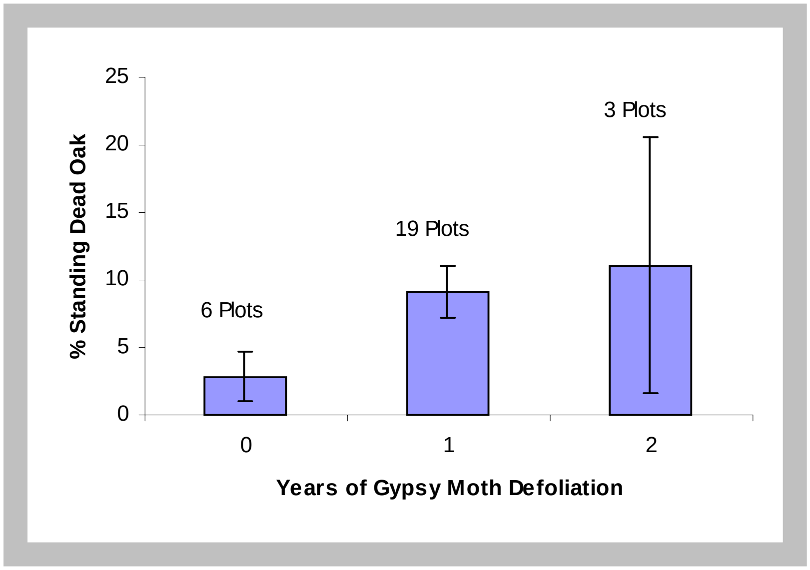

Figure 78. Standing dead oak basal area on plots with more than 10 percent oak BA (1989 FIA data) versus years of gypsy moth defoliation (aerial sketch maps).

Beech Bark Disease Complex

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

Wingless young scale insects are attracted to rough areas on the smooth bark of beech trees. They insert their stylets through the bark and into the phloem to feed. Once they begin feeding, they cease to move. Each insect then secretes a white, woolly, protective covering to overwinter. The insects may cover the entire trunk (Fig. 79). Female insects reproduce parthenogenetically (in the absence of fertilization), causing the population to increase rapidly. One generation occurs annually.

Figure 79. Beech scale insects covering the trunk of an American beech tree.

The feeding of the scale insects produces wounds for a *Nectria* fungus to invade. During wet weather in the summer, the *Nectria* asexual stage produces white spores that resemble the woolly secretions of the beech scale insect. The small, red fruiting bodies are found in clusters and mature in the fall (Fig. 80).

Fungal invasion occurs about 3 to 5 years after the scale insects appear. Sites of *Nectria* infection become walled off with callus tissue, which gives the tree a pockmarked appearance (Fig. 81). Extensive mortality often occurs in the year that *Nectria* becomes evident; some trees may survive for several years. The leaves of survivors turn yellow early in the growing season, and the crowns are thin.

Figure 80. Masses of red perithecia produced by the *Nectria coccinea* var. *faginata* fungus.

Figure 81. *Nectria* cankers caused by walled off callus tissue.

Figure 82. "Beech snap" caused by wind acting on wood weakened by decay fungi.

Wood that is killed by beech bark disease often is invaded by other insects and wood-decay fungi. Ambrosia beetles (*Scolytidae*, *Platypodidae*) bore into the canker areas allowing other fungal agents to enter. Species of *Hypoxylon*, a sapwood decay fungus, often are among the first to invade. The shoestring root rot fungus, *Armillaria mellea*, sometimes invades weakened trees and hastens death or causes breakage, termed "beech snap" (Fig. 82).

Beech bark disease was discovered in Pennsylvania in 1958. Currently, the killing front is moving across the northeast corner of the ANF (Fig. 83).

Beech tree mortality on the ANF was first reported in 1985 by Acciavatti and Dropp (unpublished report on file at Morgantown, WV).

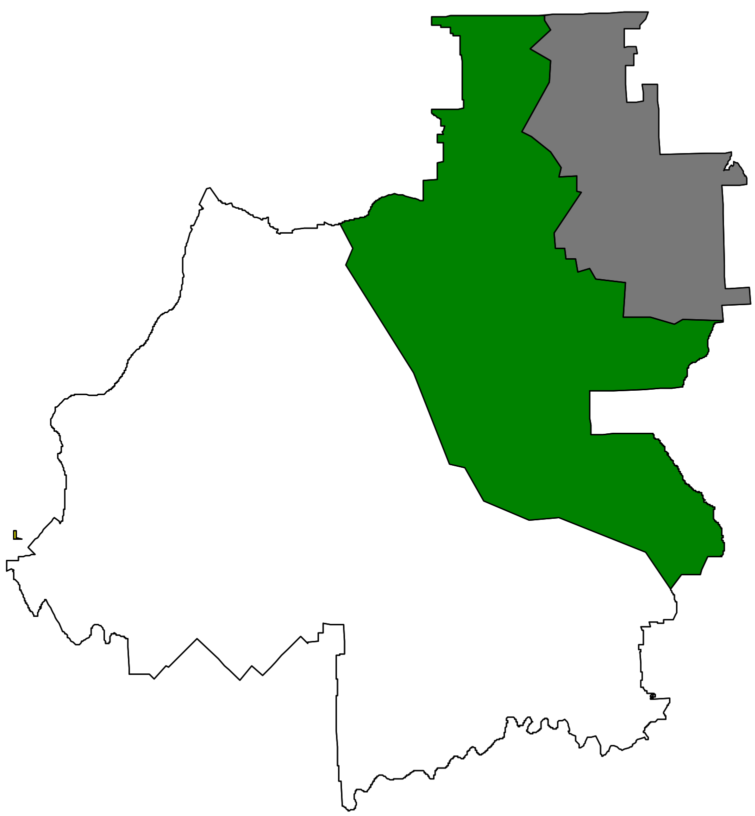

Figure 83. Map of the beech bark disease killing front on the ANF from surveys completed by the USDA Forest Service, Forest Health Protection staff (gray-1989, green-2000).

Table 10 shows the percentage of dead American beech basal area from both FIA data and FHM data inside and outside both killing fronts. Percent standing dead beech was nearly twice as great inside the 1989 killing front compared to outside the front, according to the 1989 FIA data. The percent standing dead beech is more than 10 times greater inside the 2000 killing front compared to outside as indicated by the 1998/1999 FHM data.

	1989 Killing Front		**2000 Killing Front**	
	In	***Out***	***In***	***Out***
1989 FIA	2.9% (19 Plots)	1.4% (145 Plots)	1.8% (62 Plots)	1.6% (102 Plots)
1998/1999 FHM	2.6% (10 Plots)	5.5% (50 Plots)	9.7% (30 Plots)	0.9% (30 Plots)

Table 10. Percent dead American beech inside and outside of the beech bark disease-killing front (1989 FIA data and 1998/1999 FHM data).

Ozone Injury

Ozone is a byproduct of industrial development and is found in the lower atmosphere. Ozone forms when nitrogen oxides and volatile organic compounds react in the presence of sunlight (Brace et al. 1999). Ground-level ozone is known to have a detrimental effect on forest ecosystems. Certain plant species exhibit visible, easily diagnosed foliar symptoms to ozone. Ozone stress in a forest environment can be detected and monitored by using these plants as bioindicators. The FHM program uses ozone bioindicator plants to monitor changes in air quality across a region, and to evaluate the relationship between ozone air quality and the indicators of forest condition (USDA For. Serv. 1998). Black cherry and blackberry are two species abundant on the ANF which are sensitive to ozone damage. Seven ozone bioindicator plots were measured on the Allegheny in 1999.

At each ozone bioindicator plot (Fig. 10), one to three ozone-sensitive plant species are sampled, if present. As many as 30 plants of each species are evaluated for the amount and severity of foliar ozone injury. The amount of injury is determined by percent of leaves affected, and the severity of injury is the mean percent of leaf area affected on injured leaves (USDA For. Serv. 1998). Symptoms of ozone injury were reported nearly exclusively on blackberry.

The percentage of black cherry and blackberry plants exhibiting foliar ozone injury is shown in Figure 84, page 57. Only a small portion of black cherry trees showed signs of ozone damage. In contrast, more than 40 percent of blackberry plants suffered some ozone damage. More than 25 percent of the blackberry plants that were evaluated had symptoms of ozone injury on more than 25 percent of their leaves.

Figure 85, page 57, shows the percentage of plants with different levels of leaf area with foliar injury symptoms. Of the blackberry plants exhibiting injury, most (24.7 percent) had an average of 7 to 25 percent leaf area affected.

Impacts on ozone-indicator plants on the ANF were small compared to studies in other areas that have documented greater effects. This indicates that ozone damage is not a major concern for the woody vegetation on the ANF.

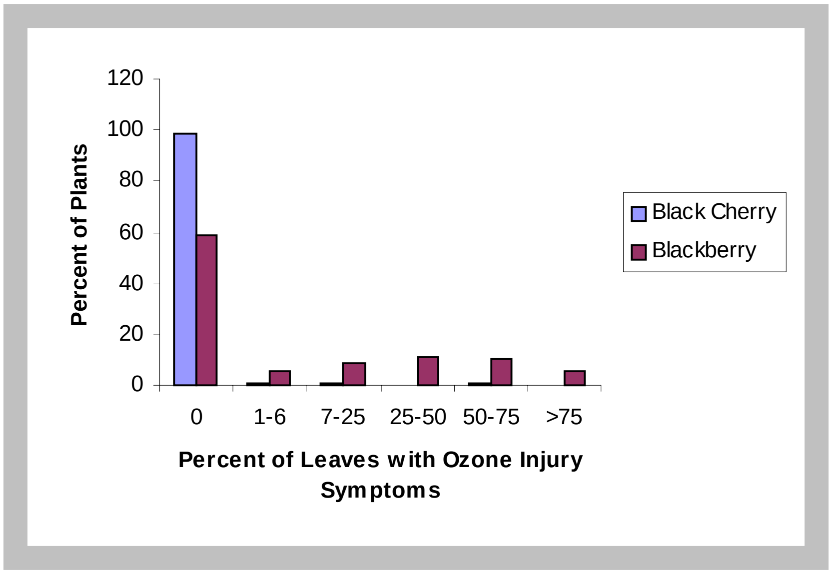

Figure 84. The percent of black cherry and blackberry plants that display varying degrees of foliar ozone injury symptoms (1999 FHM data).

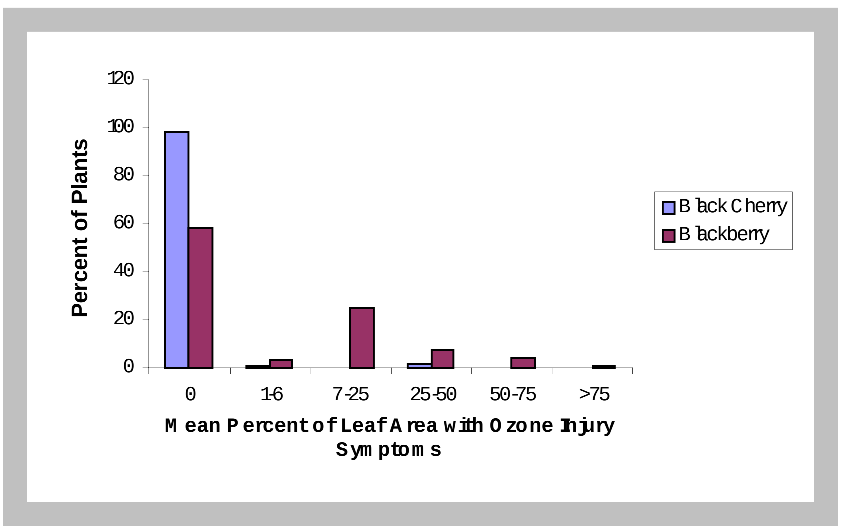

Figure 85. The percent of black cherry and blackberry plants versus the amount of leaf area showing ozone injury symptoms (1999 FHM data).

SUMMARY

The following discussion provides a summary of the information presented in the major subsections of this paper.

Current Forest Conditions

<u>Overstory - Live Trees</u>

The current forest of the Allegheny Plateau is dominated by black cherry, red maple, sugar maple, American beech, and hemlock. Associated species include white ash, black and yellow birch, yellow-poplar, and cucumbertree. These same species were present in the pre-European settlement forest, though in different proportions. The pre-settlement forest was comprised mostly of eastern hemlock and American beech (Lutz 1930). Presently, the maple/beech/birch forest-type group is the largest component on the ANF with about 83 percent of the FIA and FHM plots categorized as this group. The two major factors that were most likely causes of this change were widespread cutting and increased levels of deer browsing. The following points highlight specific characteristics of the current forest overstory.

- Black cherry and red maple are the most abundant tree species; together they account for more than one-half of the total tree basal area on the ANF.

- Eastern hemlock has the most uniform diameter distribution, with nearly as much basal area in the 5- to 10-inch class as in the over 20-inch class. Basal area increased with diameter class for all other species.

- Close to 40 percent of the stands in the ANF are 60 to 80 years old, and approximately 27 percent is in the 80 to 100 year age class.

- Forests averaging 11 inches or more in d.b.h., with a basal area between 40 and 240 ft2/acre, occupy about 73 percent of the ANF.

- Close to 75 percent of the ANF forestland stocked with trees averaging larger than 5 inches d.b.h. is classified as fully stocked or overstocked, with approximately one-third of the forestland falling into the overstocked category.

- There is an average of 77.7 live trees per acre $\geq$9” d.b.h. and 7.8 live trees per acre $\geq$20” d.b.h.. It is likely that most of the ANF meets suitable or optimal habitat conditions for the Indiana bat.

- Crown dieback was generally low (<10 percent) for most tree species; white ash had the largest amount of basal area (10.6 percent) with >75 percent dieback.

<u>Understory</u>

Ferns and herbs, together, cover greater than 30 percent of the ground area in all stand types. Studies show that if more than 30 percent of the ground cover is occupied by interfering plants, then adequate regeneration of desirable tree species is unlikely. Thus, competition by ferns and herbs appears to be influencing tree seedling development in many ANF stands.

A factor that can have a substantial effect on changes in forest composition is deer browsing. It has long been known how deer can affect regeneration (Marquis 1978). Most Allegheny hardwood stands do not have the dense understory required for natural regeneration (Marquis 1978). This advance regeneration is the key to success in regenerating the species on the ANF (Bjorkbom 1979; Grisez and Peace 1973). An option for increasing numbers of desirable seedlings is shelterwood cutting.

The future composition of a forest is strongly dependent on advance regeneration present in the understory. The following points summarize seedling and sapling composition in relation to overstory-size class.

- In non-oak sawtimber stands, American beech was the most abundant seedling and sapling; however, black cherry seedlings are a significant component of the understory. In oak sawtimber stands, red maple and American beech dominated both the seedling and sapling categories.

- In poletimber stands, black cherry, striped maple, and American beech were the most abundant seedlings, and black cherry was the most abundant sapling.

- On seedling/sapling plots, black cherry is the most abundant seedling or sapling.

With the advent of beech bark disease, dominance by American beech is likely to decrease. The virtual absence of oak regeneration indicates that oak dominated stands may transition to other species unless management activities are undertaken to enhance oak development. Black cherry tends to dominate younger stands. This underscores the important role deer browsing plays, and the need to continue to develop and implement reforestation practices designed to enhance tree seedling development and diversity, such as herbicide/fencing and release.

Down Woody Debris

Red maple and black cherry constitute the majority of the down woody debris (DWD) on the ANF. The majority of the DWD is in decay class three, in the 6- to 12-inch diameter class, and in stands that are 11- to 50-years old or older than 110 years. The hemlock type has an average of three to four times as much down woody debris as any other forest type.

Overstory - Dead Trees

The Allegheny National Forest has experienced considerable tree mortality over the past two decades due to several natural and exotic disturbance agents. Outbreaks of cherry scallopshell moth, elm spanworm, forest tent caterpillar, oak leaftier, gypsy moth, and beech bark disease have all occurred on the ANF. There also have been four severe droughts. Disturbances such as defoliation episodes, particularly when concurrent with droughts, may cause mortality that otherwise would not be expected, or they may simply compress natural “background” levels of mortality into a short event. According to the 1998 and 1999 FHM data, dead trees ranged from 1.2 percent of total basal area for red oak to 25.8 percent for bigtooth aspen. Among the five most abundant tree species on the ANF, dead trees are proportionally greatest for sugar maple. This may be due to a general decline in sugar maple health on the Allegheny Plateau (Horsley and others 2000).

Distribution of standing dead basal area showed some variability by species and d.b.h. class.

- The percent of total standing basal area that was dead varied substantially by tree species, with sugar maple (18.2 percent), birch (11.4 percent), white oak (17.4 percent), and aspen (25.8 percent) having the most. Though total standing dead basal area for American beech was only 7.3 percent, nearly half of the basal area in the >20" d.b.h. size class was dead.

- In the 5- to 10-inch d.b.h. class, nearly one-third of the total black cherry basal area, 12 percent of the oak, and 14 percent of the red maple was dead. In the other d.b.h. classes, standing dead basal area for these species was less than 8 percent.

- Close to 15 percent of the eastern hemlock basal area in the 15- to 20-inch d.b.h. class was dead. Standing dead basal area is less than 3 percent in the other d.b.h. classes

- For sugar maple, the greatest proportion (almost 25 percent) of standing dead basal area was in the 5- to 10-inch d.b.h. class. In the 10- to 20-inch d.b.h. classes, standing dead basal area exceeded 16 percent.

From the 1989 FIA survey, the greatest proportion of standing dead basal area was located on the western half of the ANF, while the 1998/1999 FHM survey indicates the highest proportion of standing dead is now on the southeastern two-thirds of the ANF. The likelihood of meeting suitable dead tree habitat conditions for Indiana bat is very high. It is quite possible that optimal habitat conditions are met as well.

Disturbance Processes

Gypsy Moth — Periodic outbreaks of gypsy moth will probably continue to cause some mortality in oak stands. There was evidence of a significant linear trend between years of gypsy moth defoliation and the percentage of live oak basal area before the outbreak. The effect of these defoliation episodes on the future species composition of the ANF will only accelerate the replacement of oak by other species.

Cherry scallopshell moth — There was evidence of a significant linear trend between years of cherry scallopshell moth defoliation and percent black cherry basal area. Even though these outbreaks will probably occur intermittently and cause some mortality, the effect on the relative abundance of black cherry should be minimal since it is such a dominant species in the overstory and understory.

Elm spanworm — Elm spanworm defoliated over 300,000 acres in 1993. The preferred species for elm spanworm during this outbreak were American beech, black cherry, red maple, and sugar maple. The only significant linear trend between percent basal area of a species and years of elm spanworm defoliation was for black cherry. This analysis also found evidence for a significant relationship between years of elm spanworm defoliation and percent standing dead red maple. There was evidence of a significant linear trend (increasing dieback) between years of elm spanworm defoliation and red maple crown dieback.

Combination of cherry scallopshell moth and elm spanworm — The condition of black cherry may be most clearly understood by looking at the combined impacts from both cherry scallopshell moth and elm spanworm. There was evidence of a significant linear trend between years of defoliation by these species and percent black cherry basal area and standing dead black cherry basal area.

Beech bark disease complex — As the beech bark disease complex moves south across the ANF the relative abundance of American beech in the overstory is likely to continue to decline. According to the 1998 and 1999 FHM data, the percent of the American beech basal area that was standing dead was 9.7 percent within the killing front and only 0.9 percent outside of the killing front. As beech bark disease spreads through the rest of the ANF, we can expect similar declines in beech dominance to continue even though beech seedlings/saplings may be quite abundant.

Nutrient deficiency — The effect of nutrient deficiency on the mortality of sugar maple has been documented by Horsley and others (2000). The patterns of sugar maple mortality observed in this study were consistent with these previous studies. The FHM data for the ANF were used to compare live and dead sugar maple basal area to the terrain position of the trees and whether they had been defoliated by elm spanworm. The most standing dead sugar maple was located on the ridge tops regardless of whether the areas were defoliated or not. This suggests that the less nutrient rich upper slopes are less suitable for sugar maple growth. In addition, sugar maple mortality was greatest in defoliated areas.

Ozone injury — Black cherry and blackberry were used as bioindicators of ground level ozone damage. Only a very small portion of black cherry trees showed any signs of foliar injury while over 40 percent of blackberry plants suffered some amount of foliar injury. However, most of the blackberry injury noted affected only 7 percent to 25 percent of the leaf area of each plant. Taken together, these results suggest that ozone pollution is not having substantial effects on the forest of the Allegheny Plateau.

Conclusions

The results of this analysis serve to illustrate how aerial survey data can be combined with forest health monitoring plot data to quantify the effects of insect outbreaks on tree vigor and mortality. While there have been many previous studies quantifying the effects of defoliation on forest conditions, these studies have generally used measurements of both defoliation and forest conditions on specific plots. The advantage of using FHM and FIA plot data is these data were collected with a sampling system that was designed to quantify conditions over entire regions. Though there has been some interest in inferring regional conditions from impact studies conducted at certain study locations, this has not always been reliable because of the non-random nature of study-site locations. In contrast, FHM and FIA data represent random samples of land area, and data can be more reliably used to infer conditions across an entire region. While the intensity of FHM sampling in the ANF has been much greater than most regions, this type of analysis could be applied to assess forest changes and defoliation impacts across larger geographical regions. Though the spatial resolution of aerial survey data is limited, this study illustrates that these data can be used to detect meaningful measures of defoliation impact.

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APPENDIX A

Tree Species	Latin Names
American basswood	*Tilia americana*
American beech	*Fagus grandifolia*
American chestnut	*Castanea dentata*
American elm	*Ulmus americana*
American hornbeam	*Carpinus caroliniana*
apple spp.	*Malus* sp.
ash spp.	*Fraxinus* sp.
bigtooth aspen	*Populus grandidentata*
birch spp.	*Betula* sp.
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 spp.	*Crataegus* sp.
mountain maple	*Acer spicatum*
northern red oak	*Quercus rubra*
oak spp.	*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* sp.
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*

APPENDIX B

Associates of Forest Health Monitoring Forest Cover Types (USDA For. Serv. 1998).

Black cherry —	sugar maple, northern red oak, red maple, white ash, basswood, sweet birch, butternut, American elm, and hemlock.
Red maple/central hardwoods —	upland oak, hickory, yellow-poplar, black locust, sassafras, Virginia pine, and shortleaf pine.
Red maple/northern hardwoods —	sugar maple, beech, birch, aspen, white pine, red pine, and hemlock.
Hemlock —	beech, sugar maple, yellow birch, basswood, red maple, black cherry, white ash, white pine, paper birch, sweet birch, northern red oak, and white oak.
Mixed northern hardwoods —	wide variety of upland hardwoods typical of northern hardwood or cove hardwood types where the sugar maple/beech/yellow birch combination or black cherry alone do not comprise a plurality of stocking.
White oak/red oak/hickory —	scarlet oak, bur oak, pin oak, white ash, sugar maple, red maple, walnut, basswood, locust, beech, sweetgum, blackgum, yellow-poplar, and dogwood.
Sugar maple/beech/yellow birch —	basswood, red maple, hemlock, northern red oak, white ash, white pine, black cherry, sweet birch, American elm, rock elm, and eastern hophornbeam.
Nonstocked —	qualifies as forest but is presently stocked with too few trees to assign a forest type.