History and Results of the Northern Forest Health Monitoring Program

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Abstract.—The Forest Health Monitoring (FHM) Program was established because of a concern that the forests in the United States were declining. The program was established to monitor the state of and changes in forest conditions across the nation. This report looks at the distributions of trees into various rating categories for three variables collected on the FHM plots from 1991 through 1997. Based on these distributions, some year to year fluctuations are seen in the samples, attributed mostly to changes in the sample composition. Future analyses will need to control these differences in sample composition and will need to look at trends across the same set of trees.

The forests of New England have undergone many changes. At the time of European settlement, the regi was largely forested. The land was cleared for agricu but has been reverting back to forests since the 1800's cities continue to expand, the forests are being divide into smaller acreages among more people. The effect natural stressors (severe weather, insects, and disease) also influencing forest structure, functions, and proce The effects of non-natural stressors (atmospheric dep tion and pollution, and global warming) on the region forests are the most recent phenomena to cause conce about the health of these forests.

To respond to the concerns about the natural environm raised by people in New England and elsewhere, the United States Congress directed the USDA Forest Se to design a program to monitor the status (or "health", o the nation's forests. The Forest Ecosystems and Atmospheric Pollution Act of 1998 (Public Law 100-521) directs the Forest Service to "...conduct such surveys as are necessary to monitor long-term trends in the health and productivity of domestic forest ecosystems."

The Forest Service monitors forest growth and productivity through its periodic forest surveys. To monitor trends in the health of forests, a new system of activities was established. In cooperation with state forestry agencies, and the U.S. Environmental Protection Agency (USEPA), the Forest Service initiated the Forest Health Monitoring (FHM) program in 1990 by establishing a plot network in six New England states (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont).

Since 1990, the national FHM program has grown to include 27 states divided among four regional programs (fig. 1). As of 1998, the Northern FHM program has

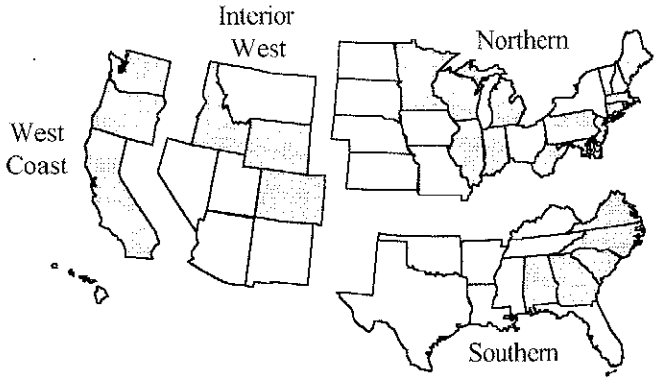

Figure 1.—*The four regional divisions of the national Forest Health Monitoring (FHM) program. States included in the 1998 FHM program are shaded in gray.*

16 states. By the end of 1999, the program will be operating in 18 states (fig. 2). Eventually, the Northern program will collect forest health data in 24 states in the northeastern and north-central United States. All four regional programs coordinate activities with a central, national office to implement the FHM program.

The state agencies and universities that participate in the Northern FHM program are key to its success. They provide the field crews for data collection, both on and off the plots. In addition, they provide input used in the improvement of the program's measurements. Finally, they provide support and direction, particularly through the National Association of State Foresters (NASF), so that the program is able to keep expanding into new states.

The FHM program is designed to be a "...systematic assessment of the state and change in forest health." It is systematic in that the plots are established on a grid with periodic remeasurements. FHM aerial and ground surveys include the plot locations. The program is an assessment of various indicators of forest health. The

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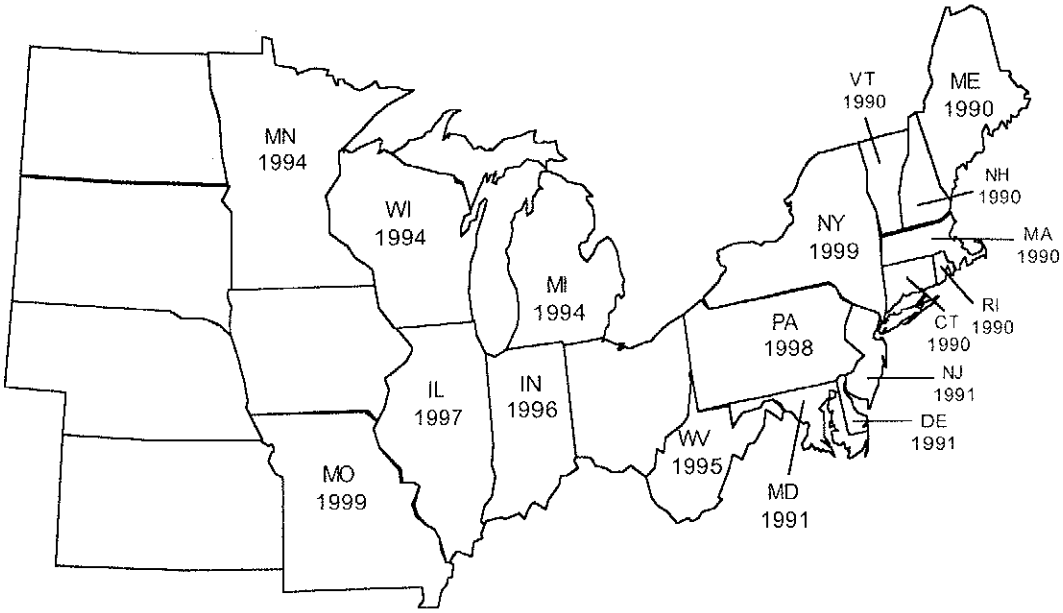

Figure 2.—*The states included, or to be included, in the Northern Forest Health Monitoring program and the year of entry into the program.*

results of these assessments are reported annually. The program reports on the state and change of forest health, looking at current conditions and changes in those conditions over time. Finally, forest health is assessed with measurements in various indicator sets, including: growth and yield, visual crown symptoms, species diversity and composition, insect and disease status, ozone bioindicator plants, and biogeochemistry.

As can be seen, the FHM program collects a large amount of information on forest health. This paper presents a summary of differences between years in the state of three crown condition variables (crown dieback, foliage transparency, and crown density) collected on overstory trees on the Northern FHM plots.

METHODS

The FHM data were collected according to national FHM data collection standards (USDA Forest Service 1998). Even though the FHM program was begun in 1990, significant changes were made to some of the protocols in 1991. Since 1991, the methods for the collection of the crown condition data have remained consistent. Table 1 shows the number of live trees greater than 5.0 inches diameter at breast height (dbh) on which data were collected for the years 1991 through 1997. The data for Pennsylvania are from plots established in 1995 as part of a separate regional study. These plots were approximately one-fourth of the total number of plots established in 1998, when Pennsylvania officially joined the program.

Table 1.—*Number of live trees, 5.0 inches dbh and greater, by year and species group*

Year	Hardwoods	Softwoods
	Number	*Number*
New England		
1991	2,602	1,754
1992	2,535	1,684
1993	3,230	2,618
1994	3,171	2,526
1995	3,375	2,645
1996	1,197	847
1997	1,006	992
Mid-Atlantic		
1991	351	126
1992	334	117
1993	553	166
1994	541	158
1995	2,257	203
1996	1,293	103
1997	1,435	112
Lake States		
1991	—	—
1992	—	—
1993	—	—
1994	5,719	2,640
1995	4,970	2,560
1996	3,140	1,312
1997	2,519	1,183

It should be noted here that the numbers of plots and trees measured in each state vary from year to year. For the years 1991 through 1995, all trees on all forested plots were evaluated every year. Beginning in 1996, the FHM program began measuring plots on a 4-year cycle, with approximately one-third of the total number of plots evaluated each year. (Each year's sample of plots is made up of one-fourth of the total plots plus an overlap set of plots measured to estimate year to year variability.) The numbers of trees change from year to year due to tree mortality or removal, ingrowth, changes in the use of the land containing an FHM plot, different plots being measured each year, or crews not being able to evaluate the trees because of conditions on the plot.

The variables analyzed for differences are crown dieback, foliage transparency, and crown density. Measurements for each variable are made for each tree. The measurements are estimated into five percent rating classes ranging from 0 to 100 percent. These ratings are based on the estimated percentage of the tree's crown that meets the definition of the variable. The variables are defined as follows:

Crown Dieback—Recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds toward the trunk. The lower the rating, the lower the mortality and presumably the healthier the tree.

Foliage Transparency—The amount of background (skylight, foliage of other trees) visible through the live, normally foliated portion of the crown or branch. The lower the rating, the thicker the foliage and presumably the healthier the tree.

Crown Density—The amount of crown branches, foliage, and reproductive structures that blocks light visibility through the crown. The higher the rating, the denser, and presumably healthier, the tree.

The states in the Northern FHM program are grouped into three subregional sets, as defined below.

New England	Connecticut, Maine, Massachu setts, New Hampshire, Rhode Island, Vermont;
Mid-Atlantic	Delaware, Maryland, New Jersey, Pennsylvania, West Virginia;
Lake States	Illinois, Indiana, Michigan, Minnesota, Wisconsin.

The years for which data were available and used in these analyses for each state are as follows:

1991-1997:	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, Delaware, Maryland, New Jersey
1994-1997:	Michigan, Minnesota, Wisconsin
1995-1997:	West Virginia
1996-1997:	Indiana
1995 only:	Pennsylvania
1997 only:	Illinois

The data were summarized by species group (hardwoods and softwoods) within each subregion. The results are presented in tables 2-4.

RESULTS AND DISCUSSION

Crown Dieback

For reporting the distribution of the dieback ratings, ratings are grouped into one of four categories. None contains those trees with dieback ratings of 0 to 5 percent; Light includes ratings from 6 to 20 percent; Moderate includes ratings from 21 to 50 percent; and Severe includes any ratings over 50 percent.

More than 95 percent of all trees in the samples in all subregions had no more than 20 percent crown dieback. The samples in the mid-Atlantic states showed a shift between 1995 and 1996. In the 1996 sample, the percentage of trees in the None category (0 to 5 percent dieback) decreased for both hardwoods and softwoods. There was a corresponding increase in the percentage of trees in the Light category. This shift is probably a result of Pennsylvania plots not being included in the 1996 sample, which allowed the West Virginia trees to have a greater influence on the sample for the Mid-Atlantic subregions. In 1996, there were reports of the effects of the beech bark disease complex on American beech (*Fagus grandifolia*, Ehrh.). For softwoods, there were increases in all three of the Light, Moderate, and Severe categories. The increase in the percentage of trees in the Light category absorbed most of the decrease in percentages in the None category.

In the Lake States subregion, the percentage of hardwoods and softwoods in the None category has decreased in each sample since 1994. This has been associated with a generally corresponding increase in the percentage of trees in the Light category. However, the combined total of percentages in the Moderate and Severe categories has remained relatively consistent, fluctuating between 2 and 3.5 percent for hardwoods and remaining at around 2.5

Table 2.—*Percentage distribution of live trees, 5.0 inches dbh and greater into four crown dieback classes by year and species group*

	Hardwoods				Softwoods			
Year	None (0-5%)	Light (6-20%)	Moderate (21-50%)	Severe (51+%)	None (0-5%)	Light (6-20%)	Moderate (21-50%)	Severe (51+%)
	- - - - - - Percent - - - - - -				- - - - - - Percent - - - - - -			
New England								
1991	78.4	17.3	2.9	1.4	93.3	5.5	0.6	0.6
1992	77.8	18.5	2.6	1.1	93.8	5.0	0.9	0.3
1993	69.7	26.2	3.1	1.0	88.5	8.8	1.3	1.4
1994	75.7	19.3	3.6	1.4	89.2	9.1	1.2	0.5
1995	76.4	19.4	2.9	1.3	89.1	9.1	1.3	0.5
1996	74.5	22.1	2.6	0.8	88.7	9.6	1.3	0.5
1997	77.8	19.1	2.4	0.7	92.3	6.3	1.1	0.3
Mid-Atlantic								
1991	70.1	29.3	0.6	0.0	78.6	20.6	0.8	0.0
1992	83.5	14.7	1.5	0.3	96.6	3.4	0.0	0.0
1993	91.1	8.0	0.7	0.2	95.8	3.6	0.6	0.0
1994	92.6	6.3	0.9	0.2	97.5	2.5	0.0	0.0
1995	91.8	6.3	1.1	0.9	97.0	3.0	0.0	0.0
1996	88.8	9.5	1.2	0.5	77.7	19.4	1.9	1.0
1997	91.6	7.5	0.5	0.4	84.8	15.2	0.0	0.0
Lake States								
1991	—	—	—	—	—	—	—	—
1992	—	—	—	—	—	—	—	—
1993	—	—	—	—	—	—	—	—
1994	88.9	8.3	1.3	1.6	89.9	7.8	1.6	0.8
1995	86.3	10.3	1.7	1.7	89.8	8.3	1.2	0.7
1996	84.6	13.2	0.9	1.3	86.6	11.1	1.7	0.7
1997	82.6	15.0	1.7	0.7	84.3	13.2	1.8	0.8

percent for softwoods. These differences are likely the result of changing sample constituents. The 1994 sample consisted only of trees in Michigan, Minnesota, and Wisconsin. In 1995, a reduced sample was taken in Michigan and Wisconsin, and an intensified sample was measured in Minnesota. Trees from Indiana were added in 1996 and trees from Illinois were added in 1997. The sample that will be measured in 1998 in Michigan, Minnesota, and Wisconsin will be the first remeasurements of a sample. This will begin to provide the change and trend information for that part of the subregion.

Foliage Transparency

For reporting the distribution of the transparency ratings, ratings are grouped into one of three categories. Normal contains those trees with dieback ratings of 0 to 30 percent; Moderate includes ratings from 31 to 50 percent; and Severe includes any ratings over 50 percent.

In New England, the percentage of trees with ratings in the Normal category has remained at about 98 percent, after a 1991 low of 93 percent for hardwoods and 95 percent for softwoods. Since the 1991 sample, the percentage of both hardwood and softwood trees in the Severe category has been less than 1 percent.

In the Mid-Atlantic states, the percentage of hardwood and softwood trees in the Normal category decreased with corresponding increases in the Moderate and Severe categories. The 1997 sample of trees in this subregion showed a return to previous percentage distributions. These differences occurred mainly as different states were included in the sample.

Table 3.—*Percentage distribution of live trees, 5.0 inches dbh and greater into three foliage transparency classes by year and species group*

Year	Hardwoods Normal (0-30%)	Hardwoods Moderate (31-50%)	Hardwoods Severe (51+%)	Softwoods Normal (0-30%)	Softwoods Moderate (31-50%)	Softwoods Severe (51+%)
	- - - - Percent - - - -			- - - - Percent - - - -		
New England						
1991	93.3	4.0	2.7	94.6	4.8	0.6
1992	97.2	2.0	0.8	97.8	1.4	0.8
1993	98.9	0.9	0.2	98.4	0.8	0.8
1994	98.7	1.0	0.3	99.2	0.7	<0.1
1995	98.9	0.6	0.5	99.0	0.9	0.1
1996	98.3	1.1	0.6	98.7	1.2	0.1
1997	98.3	1.7	0.0	98.9	1.1	0.0
Mid-Atlantic						
1991	99.7	0.3	0.0	95.2	2.4	2.4
1992	99.4	0.6	0.0	99.2	0.8	0.0
1993	98.0	1.6	0.4	98.2	1.2	0.6
1994	96.9	1.8	1.3	98.8	1.2	0.0
1995	92.5	5.8	1.7	90.6	8.4	1.0
1996	94.0	5.2	0.8	85.4	12.6	1.9
1997	98.3	1.4	0.4	95.5	3.6	0.9
Lake States						
1991	—	—	—	—	—	—
1992	—	—	—	—	—	—
1993	—	—	—	—	—	—
1994	97.7	1.1	1.2	98.0	1.8	0.2
1995	96.4	2.4	1.2	97.9	2.1	<0.1
1996	97.0	2.3	0.6	97.8	2.2	0.0
1997	94.4	5.0	0.6	95.0	4.8	0.2

In the Lake States, the percentage of hardwood and softwood trees in the Normal categories in the 1997 sample decreased with corresponding increases in the percentage of trees in the Moderate category, compared with previous samples. This is consistent with the differences in crown dieback for the same subregion.

Crown Density

For reporting the distribution of the density ratings, ratings are grouped into one of three categories. Poor contains those trees with density ratings of 0 to 20 percent; Average includes ratings from 21 to 50 percent; and Good includes any ratings over 50 percent.

In New England, the percentage of trees with ratings in the Good or Average categories remained at 96 percent or better. There was a trend in the samples to show a shift in the ratings from Good to Average until 1997 when the percentage of trees in the Good category rose slightly.

In the Mid-Atlantic states, the percentage of hardwood trees with ratings in the Good category decreased from 1991 to 1994. The percentage of hardwoods in the Good category increased in 1995 and 1996 but decreased again in 1997. The percentage of trees in the Poor category was never more than 3 percent. The percentage of softwood trees in the Good category decreased from 1991 to 1997. This decrease was accompanied by a corresponding increase in the percentage of trees in the Average category. As in the dieback and transparency results, differences in the distributions of the trees in the samples coincided with changes in the states included in the sample.

In the Lake States, the percentage of hardwood and softwood trees has fluctuated between the Good and

Table 4.—*Percentage distribution of live trees, 5.0 inches dbh and greater into three crown density classes by year and species group*

Year	Hardwoods Poor (0-20%)	Hardwoods Average (21-50%)	Hardwoods Good (51+%)	Softwoods Poor (0-20%)	Softwoods Average (21-50%)	Softwoods Good (51+%)
	- - - - *Percent* - - - -			- - - - *Percent* - - - -		
New England						
1991	3.4	41.7	54.8	1.8	38.3	59.9
1992	1.6	48.2	50.2	0.6	38.4	61.0
1993	2.2	53.7	44.1	1.9	51.4	46.7
1994	2.6	60.7	36.7	2.7	61.8	35.6
1995	2.7	58.5	38.8	2.3	64.3	33.4
1996	3.1	58.1	38.9	1.3	58.9	39.8
1997	3.1	52.6	44.3	3.6	54.1	42.2
Mid-Atlantic						
1991	1.1	30.2	68.7	0.0	16.7	83.3
1992	2.7	42.2	55.1	1.7	36.8	61.5
1993	1.6	43.1	55.3	2.4	63.3	34.3
1994	2.4	52.5	45.1	2.5	62.5	35.0
1995	2.5	37.3	60.2	1.5	63.1	35.5
1996	1.2	30.6	68.2	3.9	66.0	30.1
1997	1.3	47.9	50.8	3.6	66.1	30.4
Lake States						
1991	—	—	—	—	—	—
1992	—	—	—	—	—	—
1993	—	—	—	—	—	—
1994	2.9	52.9	44.2	1.5	47.2	51.3
1995	2.7	38.5	58.8	1.2	40.3	58.6
1996	2.1	41.3	56.6	1.5	48.6	50.0
1997	2.6	53.0	44.4	1.5	62.2	36.3

Average categories. For hardwoods, the percentage of trees in the Poor category ranged from 2 to 3 percent. For softwoods, the percentage of trees in the Poor category stayed constant at around 1.5 percent for all samples. As in the Mid-Atlantic subregion, fluctuations in the distributions coincided with the addition of new states to the sample in 1996 and 1997.

CONCLUSION

From this analysis of differences in the distributions of trees into various categories for the three crown variables—crown dieback, foliage transparency and crown density—the following conclusions can be drawn:

1. There are no large differences in the distributions among samples.
2. Yearly fluctuations are confounded by changing sample size and composition.
3. A fraction of the trees on the FHM plots are in severe condition, as measured by the three variables reported here.
4. Future analyses will need to control the sample to include only those plots that were present in all years up to 1995 when the reduction in number of plots measured each year occurred.
5. Now that the trees are being measured on a 4-year rotating basis, and data have been collected on most trees more than once, analyses will be able to assess trends in the same data sets, instead of trying to compare different yearly data sets.

LITERATURE CITED

USDA Forest Service. 1998. Forest health monitoring 1998 field methods guide. Triangle Park, NC: U.S. Department of Agriculture, Forest Service, National Forest Health Monitoring Program, Research.