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SURVEY OF OLD-GROWTH FOREST IN MASSACHUSETTS

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ABSTRACT. We surveyed forests in Massachusetts to identify any remaining old-growth stands. We located twenty-eight tracts in western Massachusetts that met our criteria, with one additional site east of the Connecticut River. Hemlock and northern hardwoods in excess of 150–200 years dominate most sites, which range in area from 3–28 ha. Most stands occur on steep slopes and may have escaped cutting due to their inaccessibility. Several potential sites remain to be investigated, but we do not expect that the total area of old-growth forests in Massachusetts will greatly exceed 260 ha. However, less stringent definitions of old growth may include additional sites and greater acreages.

Data collected from 26 permanent vegetation monitoring plots provide comparisons with other forests. Basal areas in the old-growth stands are similar to other old-growth forests in New England, from 34–42.8 m^2/ha; values are only slightly higher than basal areas from nearby second growth forests of the same type. Densities of stems >10 cm dbh in the old-growth plots are 347–480 trees/ha, 25–40% lower than in second growth forests. No vascular plant species were encountered that were unique to the old-growth stands.

Key Words: old-growth, northern hardwood forests, eastern hemlock, Massachusetts

Old-growth forests in the eastern United States have attracted considerable attention in the last decade, and increasingly are threatened in much of North America (Davis 1996). Such forests are important because they may contain unique assemblages of species, offer significant dendrochronological information on past tree growth, and provide valuable baseline information on forest composition and dynamics for comparison with other areas (Whitney 1987). Definitions vary among researchers, but forests that frequently are referred to as old growth are generally regarded to have had continuous forest growth over a long period with little human disturbance (Leverett 1996; Whitney 1987). Examples have been reported in several New England states (Dunwiddie et al. 1996), including Maine (Maine Critical Areas Program 1983), Vermont (Bormann and Buell 1964), New Hampshire (Cline and Spurr 1942; Carbonneau 1986; Leak 1987), and New York (Leopold et al. 1988; Woods and Cogbill 1994). In Massachusetts, however, Egler (1940) reported finding no "pre-colonial" forests in his study of the vegetation in the Berkshires. One unpublished reference (Hosier 1969) presents data from a purported virgin stand in northwestern Massachusetts, but no evidence is provided to support the claim that the stand is, indeed, old growth. Thus, a primary purpose of our study was to determine whether any old-growth forest remains in Massachusetts.

Once we determined that old-growth forests existed in the state, three specific objectives were defined: (1) to identify and map existing old-growth forests in Massachusetts, (2) to compile a descriptive summary of the location, physical characteristics, flora, and structure of these sites, and (3) to determine how the Massachusetts old-growth stands compare with data from other forests in the northeastern United States. Detailed reports documenting features of the individual stands have been submitted to the Massachusetts Natural Heritage and Endangered Species Program (Dunwiddie 1991; Dunwiddie 1993). In this paper we provide an overview of all the known old-growth sites in Massachusetts, summarize some of the tree and understory data collected in this study, and compare results with other old-growth sites in New England.

The first step in identifying old-growth forests was to develop criteria that distinguish such stands from regrowth forests. We modified criteria used elsewhere in the Northeast (Maine Critical Areas Program 1983) to identify stands that would be considered by most researchers to be old growth. Using less conservative criteria, others might add to the acreage of old-growth forest in Massachusetts. However, our intention was to provide an inventory of fairly unequivocal sites that could be useful as a starting point for other investigations.

To qualify as old-growth forest, a stand must (1) be a relatively homogeneous area of at least 3 ha, (2) exhibit minimal evidence of human influence or other catastrophic disturbance of the stand, (3) show evidence of tree regeneration, especially of late-successional species, resulting in a relatively stable forest composition, and (4) include dominant canopy trees of an age >50% of the maximum age for those species (Fowells 1965).

These criteria eliminated small or fragmented sites with little undisturbed forest interior, as well as stands dominated by early-successional species such as *Betula papyrifera* Marsh. (paper birch) and *Acer rubrum* L. (red maple). The second and fourth criteria eliminated areas where widespread blowdowns, landslips, and other disturbances removed old trees from dominance in stands. The determination of a minimum age for trees to be considered old growth is arbitrary, but application of the last criterion included stands dominated by *Tsuga canadensis* (L.) Carr. (eastern hemlock) >200–225 years old, and hardwoods such as *Acer saccharum* Marsh. (sugar maple) and *Fagus grandifolia* Ehrh. (American beech) >175–200 years old.

MATERIALS AND METHODS

Forests considered to be probable old growth were identified by extensive field searching, as well as by information provided by the Massachusetts Natural Heritage and Endangered Species Program, foresters, and other individuals. Although we considered potential sites throughout the state, our work fairly quickly became focused in western Massachusetts. Numerous sites were rejected due to small size, evident disturbance, or lack of old trees. Areas that appeared to meet our criteria were selected for more detailed study. Beginning in 1991, assessments were made of composition, signs of disturbance, area, and likelihood of sufficient age; selected increment cores were gathered from dominant trees to more accurately determine the age of the older individuals. General information was recorded on the species, slope, aspect, and elevation of each stand. A compass and altimeter were used to map the perimeter of old-growth stands on enlarged U.S. Geological Survey topographic maps. Stand acreage was calculated from these maps.

Even with well-defined criteria for identifying old-growth stands, mapping boundaries and determining acreages is still subject to considerable interpretation. The density of older trees necessary to qualify a stand as old growth is ultimately a subjective decision, and different perspectives adopted by other researchers could significantly change acreage estimates of old-growth forest in the state. Because of our desire to identify reasonably unequivocal sites, we only considered stands that included at least three older trees per hectare throughout the stand. In the field, this necessitated identifying probable old trees, and estimating their density on a site. Where old individuals were common and readily recognizable, decisions on the boundaries of old-growth stands were clear. However, where densities of old trees were low, or where trees lacked characteristics often associated with great age, such as deeply fissured bark, snag tops, or heavy limbs, mapping decisions were more difficult.

Detailed quantitative data on the canopy and understory vegetation were collected from within the twelve stands that had been identified by 1992. A standardized methodology developed for sampling old-growth forests was adapted from Shifley et al. (1991). Permanent 0.1 ha fixed-radius plots were located within each stand to collect tree data, with several nested plots for sampling other vegetation strata. Time constraints precluded installing the large number of randomly placed plots (often >30 for many parameters recommended by Shifley et al. 1991) to derive statistically valid descriptive samples of the entire stands. Instead, from one to four plots were established in locations that included several trees that were typical of the older trees in the stand. Where several different forest types were represented within a single stand, attempts were made to place plots to capture this variability in composition.

The plot layout follows Shifley et al. (1991) and consists of a 0.1 ha circular plot for trees, a 0.01 ha circular subplot for saplings, and four 2.5 m^2 subplots for ground vegetation. All living and dead trees >10 cm diameter at breast height (dbh) were recorded in the large plot, and saplings from 2–10 cm dbh were sampled in the 0.01 ha subplot. Each plot center was marked with a 2.5 cm plastic pipe. Data collected for each tree included azimuth and distance from the plot center, species, dbh, crown class and ratio, and decay stage.

At least two trees, estimated to be among the oldest trees in the plot based on size, bark, and crown characteristics, were cored. These cores were glued into mounts and sanded, and growth rings were counted to provide minimum ages. Actual ages were estimated by determining growth rates for the innermost several centimeters of the cores, calculating the distance to the center based on diameter measurements, and adding the appropriate number of years based on the extrapolated growth. At several sites, heights were measured for individual trees using a tape measure and inclinometer.

Understory vegetation was sampled in four square subplots 3 m from the center of the main plot. Woody stems at least 1 m tall and less than 2 cm dbh were counted by species, and the abundance of each species in the subplots was recorded on a three-point scale. A species list also was compiled for each 0.1 ha plot and for each site as a whole.

In this paper, we present summaries of physical site characteristics, basal area and density data from living and dead trees in the different forest types, and understory compositional data. Vascular plant names follow Gleason and Cronquist (1991); bryophytes follow Conard and Redfearn (1979).

RESULTS

Twenty-eight old-growth stands in western Massachusetts were identified and described in this study (Tables 1 and 2). One additional site, Wachusett Mountain, was identified in central Massachusetts. Collectively, they include a total area of 255.2 ha. In addition, we identified ten other small stands of old growth in western Massachusetts, but did not include them here because the individual stands are less than 3 ha. We have yet to confirm whether Chesterfield Gorge, a 7 ha hemlock stand belonging to The Trustees of Reservations, is an old-growth forest that meets our criteria.

Quantitative data were gathered from 26 plots in 13 of the stands (Table 1). Most of the stands are small, generally less than 12 ha, and occur on steep slopes (av.=35°). Many stands are on northwest- to northeast-facing slopes and, with the exception of the Mt. Greylock sites, most occur at elevations from 300–500 m. Canopy trees ranged from about 24 m to 36 m tall.

The data on the total area of old-growth forest from the Mt. Greylock stands represent minimum estimates, and are likely to understate the true amount. The stands all are scattered within the area known as the Hopper, within which exists a complex disturbance matrix resulting from fire, landslides, blowdowns, and land use. The interspersion of old trees through much of the Hopper, individually and in larger stands, makes it difficult to delineate precise boundaries of areas that meet all the criteria of old growth defined in this study.

Table 1. Characteristics of old-growth stands with permanent vegetation monitoring plots in Massachusetts. Different stands within each site are distinguished by letters or local names. H = Hemlock, NHW = Northern hardwoods. All sites are owned by the Massachusetts Department of Environmental Management with the exception of Bash Bish A, which is private.

Stand			
Site Name	Size (ha)	Lat. (N)	Long. (W)
Bash Bish			
A-Grinder	6.9	42°6′	73°29′
B-Falls	5.6	42°7′	73°30′
Cold River			
A	7.6	42°38′	72°58′
B-Black Bk.	4.5	42°37′30″	72°58′30″
C	16.6	42°38′	72°58′30″
D	28.2	42°38′	72°59′
E-Manning Bk.	5.3	42°38′30″	72°59′30″
Dunbar Bk.	13.1	42°42′	72°58′
Parsonage	4.2	42°43′	72°59′
Fife Bk.	9.5	42°41′30″	72°59′
Mt. Greylock			
Deer Hill	11.6	42°38′	73°11′
Money Bk.	9	42°39′30″	73°10′30″
Mt. Everett	9.8	42°7′	73°25′30″
Tower Bk.	11.3	42°44′	72°56′

In 1995, we confirmed the presence of a large old-growth forest on Wachusett Mountain (Dunwiddie 1995; Cogbill 1996). This stand is surprising for its size, as well as for its previously overlooked location in the east-central part of the state. While detailed

Table 1. Extended.

Plot				
No.	Elev. (m)	Aspect (deg.)	Slope (deg.)	Forest Type
1	421	70	45	H-NHW
2	442	35	40	H
1	367	10	45	H
1	308	360	32	NHW
2	413	30	45	H-NHW
3	457	320	42	H-NHW
4	396	310	40	NHW
1	384	310	43	H-NHW
2	390	310	38	H-NHW
3	396	320	40	H-NHW
1	372	90	39	NHW
1	381	320	37	H
2	381	40	35	H-NHW
1	440	90	16	H-NHW
2	430	100	15	NHW
1	392	58	28	NHW
2	468	46	26	H-NHW
1	494	290	25	H
1	500	190	17	NHW
2	497	190	10	NHW
3	369	200	38	H-NHW
4	378	210	35	H-NHW
1	611	360	26	H
2	611	340	45	NHW
3	659	360	45	H-NHW
1	502	28	30	H
0	400–488	90–120	25–30	H-NHW

data on the stand have not been collected yet, our initial surveys suggest that it extends from about 420–600 m elevation on the north and east sides of the mountain, with an area of about 28 ha. The site is dominated by several forest types, including hem-

Table 2. Characteristics of old-growth stands in Massachusetts in which permanent plots have not been established. Different stands within each site are distinguished by local names. Areas are approximate. H = Hemlock, NHW = Northern hardwoods, BB = Black Birch, RO = Red Oak, RP = Red Pine, WP = White Pine, RS = Red Spruce. DEM = Mass. Department of Environmental Management, TTOR = The Trustees of Reservations, AMC = Appalachian Mountain Club.

Site Name	Size (ha)	Lat. (N)	Long. (W)
Negus	3	42°39′	72°57′
Cold River			
Todd-Clark	24	42°38′45″	72°57′30″
Wheeler Bk.	3	42°38′	72°58′45″
Upper Cold R.	3	42°38′	73°5′
Trout Bk.	3	42°37′	73°12′
Bryant Estate	3	42°30″	72°57′
Dunbar Brook			
Bear Swamp	10	42°42′	72°57′40″
Upper Dunbar	6	42°42′	72°58′45″
Ice Glen	4	42°16′20″	72°18′45″
Sages Ravine	6	42°31′	72°27′15″
Mt. Greylock			
Paris Bk./Mt. Fitch	4	42°39′	73°10′
Money Bk. tribut.	6	42°38′	73°10′
Roaring Bk.	6	42°37′	73°12′
Spruce Mtn.	4	42°42′	72°59′15″
Windsor Jams	3	42°32′	73°59′
Wachusett Mtn.	28	42°30′30″	71°53′30″
Total (Tables 1 & 2)	259.2		

lock, *Betula alleghaniensis* Britton (yellow birch), beech, other hardwoods, and *Picea rubens* Sarg. (red spruce). Ages of some of the trees have been documented in excess of 300 years (Dunwiddie 1995).

Forest composition and structure. The old-growth stands found in this study represent a spectrum of hemlock and northern hardwood forest types common in the Berkshires. These include stands dominated almost entirely by hemlock, such as Bash Bish and Mt. Greylock-Deer Hill, forests with a mixture of hemlock and northern hardwoods including yellow birch, beech, and sugar maple, and forests consisting primarily of northern hardwoods. The plot data were grouped within these three forest types for most analyses. Several sites that were documented after 1992, and

Table 2. Extended.

Elev. (m)	Aspect	Forest Type	Owner
300–500	South	NHW-RO	NE Power
240–520	Varied	H-NHW, H-BB-RO	DEM
300–390	Varied	H-NHW	DEM
360–450	Varied	H-NHW-RS	DEM
330–480	East	H-NHW	DEM
400–450	Varied	H-NHW	TTOR
330–540	Varied	NHW-RO-H	DEM
420–510	Varied	NHW, H-NHW	DEM
220–330	Varied	H-WP-RP-NHW	Laurel Hill Assoc.
330–470	North	H	DEM-AMC
450–750	Varied	H-NHW-RS	DEM
450–850	West	H-NHW-RS	DEM
480–670	Varied	H-NHW-RS	DEM
600–730	Varied	RS-NHW	DEM
425–450	Varied	H-RS	DEM
420–600	N-E	NHW-H-RO	DEM

in which no plot data were gathered, presented an unusual mixture of hemlock, *Betula lenta* L. (black birch), and *Quercus rubra* L. (northern red oak) that might be considered another forest type.

Seven plots fell within hemlock-dominated stands (Tables 3 and 4). Hemlock comprises an average of 75% of the basal area (65–90%) and 71% of the stem density. Red spruce and yellow birch are frequent but minor associates in the canopy, and *Acer pensylvanicum* L. (striped maple) is common in the subcanopy. These plots contain the highest average basal area of living trees of any of the three old-growth forest types examined in this study (42.75 m^2/ha), with a maximum value of 52.22 m^2/ha recorded at one site. Average live stem densities are also higher in the hemlock stands than in the other two forest types (480 trees/ha). The species richness of understory vascular plants is the lowest

Table 3. Average basal area and density of living and standing dead trees >10 cm dbh in seven plots in Berkshire old-growth hemlock forests.

	Live		Dead	
	BA (m^2/ha)	Density (trees/ha)	BA (m^2/ha)	Density (trees/ha)
Acer pensylvanicum	0.6	28.6	0.3	10.0
Acer rubrum	0.02	4.3		
Acer saccharum	0.1	1.4		
Betula alleghaniensis	1.9	30.0	0.2	5.7
Betula lenta	1.5	27.1		
Fagus grandifolia	0.7	11.4	0.3	4.3
Picea rubens	4.0	22.9	0.7	10.0
Pinus strobus	1.5	10.0	0.5	4.3
Quercus rubra	0.3	1.4		
Tsuga canadensis	32.1	342.9	1.4	31.4
Unknown			0.5	1.4
Total	42.8	480.0	3.9	67.1

in this forest type, with an average of 10.6 species in the 0.1 ha plots. Besides seedlings of hemlock and yellow birch, the only commonly occurring understory species is *Dryopteris carthusiana* (Vill.) H. P. Fuchs, found in 50% of the subplots.

Seven old-growth plots were placed in northern hardwood forests (Tables 5 and 6). Sugar maple is the primary species in these stands, with beech as a secondary dominant. The lowest average basal areas and stem densities occur in this forest type, but the understory species richness is high (25.3 spp./0.1 ha). The most common understory taxa include *Dryopteris carthusiana* (68%), *Arisaema triphyllum* (L.) Schott (64%), and seedlings of striped maple (54%) and beech (54%).

Twelve plots were established in hemlock-northern hardwood forests (Tables 7 and 8). This forest type is intermediate in most measures between the hemlock and northern hardwood stands; both the basal area and stem density values fall between the other two forest types. Hemlock has the highest basal area and stem densities, but beech, sugar maple, and yellow birch also are prominent in the canopy. Understory species richness averaged 15.5 spp./0.1 ha. Taxa frequently encountered in the subplots include *Dryopteris carthusiana* (79%), *Viburnum alnifolium* Marsh. (60%), *Lycopodium lucidulum* Michx. (35%), and *Oxalis acetosella* L. (33%).

Table 4. Percent frequency of understory species in old-growth hemlock forest.

	Bash Bish A2	Bash Bish B1	Cold River A4	Cold River D1	Parson-age	Grey-lock	Ever-ett
Acer pensylvanicum			25			100	
Acer rubrum					50	25	
Acer spicatum			25			25	
Acer sp.			75				
Betula alleghaniensis	100	50	25		25	25	
Betula lenta				75		25	
Dryopteris marginalis		50	50				
Dryopteris carthusiana	25	25	75		50	100	75
Fagus grandifolia			50			25	
Lycopodium lucidulum			25		50		
Mitchella repens			50				
Oxalis acetosella						100	
Picea rubens				75			
Polypodium vulgare		100			25		
Polystichum acrostichoides			50				
Prunus serotina					25		
Tsuga canadensis	100	75	25	100	75	25	100
Viburnum alnifolium			75				
No. of Vascular Species	8	10	14	7	10	16	6
Bazzania trilobata	100	25		75	50		50
Dicranum sp.	50	50			50		
Hypnum sp.	75	25			25		100
Leucobryum cf. *albidum*	25						
Leucobryum glaucum	100	75		75	25		25
Lichens		50		25			
Nowellia sp.	25						
Odontoschisma denudatum	25						
Polytrichum sp.		25		25			25
Scapania nemorosa		25					
Tetraphis pellucida		50			25		
Unidentified bryophytes	50	100	100	100	100	25	
No. of Bryophytes and Lichens	8	9	1	5	6	1	8

In all three forest types, about 50% of the trees >10 cm dbh were recorded in the canopy, with the other half classified as either overtopped or midstory. The density and basal areas of standing dead trees varied widely among all the plots. However, both the average stem density and basal area values are close to

Table 5. Average basal area and density of living and standing dead trees in northern hardwood forests. All data are from old-growth forest sites with the exception of the 22 Berkshire Continuous Forest Inventory plots (CFI); Berk = Berkshires, MA (this study; n = 7); Adir = Adirondacks, NY (Leopold et al. 1988); Bowl = The Bowl, NH; Mt. Pd = Mountain Pond, NH; Wms = Williams, NH (Leak 1987).

	Live					
	BA (m^2/ha)					
	Berk >10 cm	Adir >5 cm	CFI >13 cm	Bowl >5 cm	Mt. Pd >5 cm	Wms >5 cm
Acer pensylvanicum	0.1	0	0	1.4	0.8	0.5
Acer rubrum	0.8	0	3.4	0	0	0
Acer saccharum	21.4	30.0	6.1	10.6	15.8	6.5
Betula alleghaniensis	1.4	2.2	3.6	7.7	2.3	3.4
Betula lenta	0.2	0	0	0	0	0
Fagus grandifolia	6.8	2.0	5.1	10.3	8.4	5.8
Fraxinus americana	2.5	0	1.1	0	1.2	0.8
Ostrya virginiana	0.1	0.6	0	0	0	0
Picea rubens	0	0	0	0.4	0.3	0
Pinus strobus	0	0	0	0	0	0
Quercus rubra	0	0	1.3	0	0	0
Tsuga canadensis	0.7	2.8	1.7	0.1	0	0.9
Other	0.1	0	5.3	0.1	1.7	7.5
Total	34.1	37.6	27.7	30.6	30.6	25.3

10% of the total (living and dead) in all three forest types (Tables 3, 5, and 7).

Age estimates for selected older trees were obtained from ring counts on increment cores collected at many of the sites. These figures may underestimate the true ages by up to 50 years or so for many of the trees due to heart rot or cores not reaching the center. Some of the hemlock cores contained over 300 rings, and a few of these trees may have attained ages of 400 years or more. Fewer hardwoods were cored, but sugar maples of 200–250 years were encountered in several plots. All the plots contain trees in excess of 200–225 years, confirming the assessment that the stands were of an age to be considered old growth. A graph of the estimated ages of all the cored trees in the study plots shows a modal age of 220–240 years (Figure 1).

The size of old trees in Massachusetts old-growth stands varies greatly with the growing conditions. In many sites studied here,

Table 5. Extended.

Live			Dead			
Density (Tr/ha)			BA (m^2/ha)		Density (Tr/ha)	
Berk >10 cm	Adir >5 cm	CFI >13 cm	Berk >10 cm	Adir >5 cm	Berk >10 cm	Adir >5 cm
11.4	0	0	0	0	0	0
0	0	53.7	0	0	0	0
184.3	180	0	1.9	0.5	11.5	50
8.6	10	0	0.5	0	2.8	0
1.4	0	0	0	0	0	0
110	110	97.9	0.8	0	8.7	0
12.9	0	0	0	0	0	0
1.4	60	0	0	0	0	0
0	0	0	0	0.2	0	20
0	0	0	0	0	0	0
0	0	10.7	0	0	0	0
7.1	70	30.4	0	0	0	0
10	0	276.8	0.02	0	2.8	0
347.1	430	469.3	3.2	0.8	25.7	70

old trees were neither particularly tall nor of exceptional girth due to rigorous growing conditions, a factor which may have contributed to these stands not being cut for lumber. However, since maximum dimensions of trees frequently are of interest in comparing growth in different regions, data are included summarizing the upper size limits measured for twelve species in Massachusetts old-growth sites in the most favorable growing conditions (Table 9).

DISCUSSION

The stands identified as old growth in this study consist of later-successional species that have been undisturbed for over 200 years. If limited disturbances, such as selective cutting, occurred centuries ago, they might be difficult to detect. However, we consider any such activity at these sites unlikely to have been sig-

Table 6. Percent frequency of understory species in old-growth northern hardwood forests.

	Cold River A1	Cold River C1	Cold River E2	Dunbar 1	Fife Bk. 1	Fife Bk. 2	Greylock 2
Acer pensylvanicum	25	25	50	50	100	100	25
Acer rubrum							25
Acer saccharum	50	25	25	50	75	100	
Acer spicatum	50			25			25
Acer sp.		25	75	50			
Actaea pachypoda				25		25	
Allium tricoccum			100			100	
Arisaema triphyllum			100	50	100	100	100
Aster acuminatus							75
Aster divaricatus							50
Aster sp.			50			25	
Athyrium filix-femina				50	25		
Betula lenta							25
Botrychium virginianum						25	
Carex sp.			25			25	
Caulophyllum thalictroides			100			50	
Claytonia virginica						50	
Dicentra canadensis					25	100	
Dryopteris marginalis	25		25				25
Dryopteris carthusiana	100	100	75	100			100
Erythronium americanum		25	75		100	75	
Fagus grandifolia	75	25	50	25	100	100	
Fraxinus americana			25	25	25		25
Galium triflorum						75	
Impatiens capensis						100	25
Laportea canadensis						25	
Lonicera canadensis	25						
Lycopodium lucidulum	50						100
Osmorhiza claytonii						50	
Oxalis acetosella			50				25
Panax trifolius						25	
Polygonatum pubescens		25					
Polystichum acrostichoides	50	75	75	75			
Prunus serotina			25		25		
Ranunculus sp.						25	
Ribes sp.				25			
Rubus sp.					25		
Streptopus roseus			50				
Thelypteris noveborascensis							25
Tiarella cordifolia	25			25			25
Trillium cernuum				25			
Trillium erectum	25	25	75		25	25	

Table 6. Continued.

	Cold River A1	Cold River C1	Cold River E2	Dun-bar 1	Fife Bk. 1	Fife Bk. 2	Grey-lock 2
Tsuga canadensis			25				
Viburnum acerifolium					25		
Viburnum alnifolium	75	75		50			100
Viola canadensis						100	
Viola rotundifolia	50	25			50	25	25
Viola sp.				25	25	75	25
No. of Vascular Species	16	18	29	20	30	38	26
Bazzania trilobata	25						
Dicranum sp.	25		25				
Unidentified bryophytes	25	50	50	75	25	75	100
No. of Bryophytes	3	1	2	1	1	1	1

nificant. Although settlements existed in Berkshire County in the mid-1700s, forest cutting at that time would have focused on clearing the better agricultural land and on harvesting high quality timber, especially spruce and pine, in accessible locations. While factors such as steep slopes, remoteness from logging roads, and lesser quality wood combined to favor the survival of these remnants of old growth, chance no doubt contributed as well.

This survey of old-growth forest in Massachusetts emphasizes its extreme rarity in the state. After more than 300 years of intensive land clearance, agriculture, forestry, and development, only about thirty documented sites remain. Furthermore, these scattered remnants are small patches in a matrix of regrowth forest. The largest old-growth site is only about 28 ha, considerably smaller than the stands of several thousand hectares in the Adirondacks of New York (Leopold et al. 1988) and the White Mountains of New Hampshire (Leak 1987).

Data from some other New England old-growth forests are presented in Tables 5 and 7 for comparison. In addition, data are included from selected Continuous Forest Inventory (CFI) sites in Massachusetts (W. Rivers, Massachusetts Department of Environmental Management, pers. comm.). These variable-radius tree plots are located every half mile on most state lands in the Berkshires. Data included in the tables come from all the CFI plots in the vicinity of the old-growth stands (generally sites with-

Table 7. Average basal area and density of living and standing dead trees in hemlock-northern hardwood forests. All data are from old-growth forest sites with the exception of the 22 Berkshire Continuous Forest Inventory plots (CFI); Berk = Berkshires, MA (this study; n = 12); Adir = Adirondacks, NY (Leopold et al. 1988).

	Live		
	BA (m^2/ha)		
	Berk >10 cm	Adir >5 cm	CFI >13 cm
Acer pensylvanicum	0.2	0.5	0.0
Acer rubrum	0.0	0.0	7.1
Acer saccharum	4.6	3.2	0.2
Betula alleghaniensis	3.6	0.0	4.4
Betula lenta	0.3	0.0	0.0
Fagus grandifolia	5.8	5.5	2.2
Fraxinus americana	0.2	0.0	0.0
Ostrya virginiana	0.01	0.0	0.0
Picea rubens	0.3	2.2	0.0
Pinus strobus	0.0	0.0	1.8
Quercus rubra	1.6	0.0	0.7
Tsuga canadensis	20.5	30.9	14.1
Other	0.3	0.0	4.6
Total	37.4	42.3	35.2

in the same valley) that were from the same forest types. These figures provide comparative data for second growth hemlock-northern hardwood and northern hardwood forest types; no CFI data were available for the hemlock forest type. It is important to note, however, that due to the small sample sizes and non-random placement of plots in the Berkshire old-growth stands, differences between these data sets should be considered only as general trends. In addition, different authors used different minimum diameters, which also limits data comparability.

The hemlock old-growth stands in the Berkshires (Table 3) had a similar total basal area (42.8 m^2/ha) to that reported by G. Whitney from Heart's Content, Pennsylvania (42.4 m^2/ha), and an old-growth hemlock-yellow birch forest in New Hampshire (Tritton and Siccama 1990). Heart's Content had a lower stem density (366 stems/ha) than the average from the Berkshire sites (480 stems/ha). Standing dead stems in the Berkshire old-growth hemlock forests represented 8% of the total basal area, and 12% of

Table 7. Extended.

Live			Dead			
Density (Tr/ha)			BA (m^2/ha)		Density (Tr/ha)	
Berk >10 cm	Adir >5 cm	CFI >13 cm	Berk >10 cm	Adir >5 cm	Berk >10 cm	Adir >5 cm
10.8	93.0	0.0	0.1	0.1	6.7	18.0
0.0	0.0	119.7	0.0	0.0	0.0	0.0
61.7	25.0	0.0	0.4	0.3	5.8	3.0
46.7	0.0	0.0	0.0	3.2	0.0	15.0
10.8	0.0	0.0	0.1	0.0	1.7	0.0
109.2	238.0	41.2	1.2	1.4	15.8	23.0
1.7	0.0	0.0	0.03	0.0	0.8	0.0
0.8	0.0	0.0	0.0	0.0	0.0	0.0
1.7	28.0	0.0	0.0	0.9	0.0	15.0
0.0	0.0	12.3	0.0	0.0	0.0	0.0
4.2	0.0	14.5	0.0	0.0	0.0	0.0
163.3	240.0	328.3	2.6	4.2	11.7	25.0
5.0	0.0	204.2	0.04	0.2	1.7	3.0
415.8	622.0	720.2	4.5	10.4	44.7	102.0

the density. These values closely match those reported by Tritton and Siccama (1990) for this forest type (8 and 9%, respectively).

Data from northern hardwood forests in New England are compared in Table 5. Basal areas of old growth in Massachusetts are similar to values from the Adirondacks and New Hampshire, but averaged about 23% higher than in the CFI second growth plots. Although somewhat different minimum stem diameters were used in different studies, stem densities were higher in the Adirondacks and in the CFI plots than in the Berkshire old growth; this pattern also was observed in the hemlock-northern hardwood types (Table 7). Standing dead stems in the Berkshire old-growth northern hardwood forests represented 8% of the total basal area, and 7% of the stem density, less than the average of figures reported by Tritton and Siccama (1990) for this forest type in New Hampshire and Vermont (12% of the total basal area, 13% of the total stem density).

Average live basal areas in the twelve hemlock-northern hard-

Table 8. Percent frequency of understory species in hemlock-northern hardwood old-growth.

	Bash Bish	Cold River	
	A1	A2	A3
Acer pensylvanicum		25	
Acer saccharum			25
Acer spicatum		50	
Acer sp.			25
Aralia nudicaulis	25	25	
Arisaema triphyllum			
Aster sp.			
Betula alleghaniensis	50		
Betula lenta	25		
Carex sp.			
Clintonia borealis		25	
Dryopteris marginalis			
Dryopteris carthusiana	100	100	
Erythronium americanum			
Fagus grandifolia		75	
Fraxinus americana			
Gymnocarpium dryopteris			
Kalmia latifolia			25
Lycopodium lucidulum	25	75	
Maianthemum canadense			
Mitchella repens		25	
Oxalis acetosella	100	25	
Picea rubens			
Polypodium vulgare		25	
Polystichum acrostichoides		25	
Prunus serotina			
Rubus sp.			
Sambucus sp.			
Streptopus roseus			
Taxus canadensis			
Trientalis borealis			
Tsuga canadensis	50	25	
Viburnum acerifolium			
Viburnum alnifolium	50	100	
No. of Vascular Species	8	21	6
Atrichum undulatum			
Bazzania trilobata	25		
Dicranum sp.			
Hypnum sp.	100		
Tetraphis pellucida	25		
Thuidium delicatulum			
Unidentified bryophytes	100	50	100
No. of Bryophytes	5	1	1

Table 8. Extended.

Cold River					Dunbar	Fife Bk.		Grey-lock
B1	B2	B3	D2	E1	2	3	4	3
	25	75		25		75	50	50
		25		25		75	25	
			25	25				25
			100	100		25	50	
							100	
		25	25	100				
						25	25	
		25				50		
							75	
						25		
25								
75	100	100	100	100	100	50	25	100
				100				
	50	25		50		25	50	25
				75				
			50					
	75	25	25		100			100
				25				
		25	75	100				75
								25
	25	50	25		25	25		
				25				
				25		25		
				25		25		
			25					
	25							
							50	
					50		25	
						50	50	
50	75	100	75	75	100		25	75
10	9	15	13	32	11	23	17	21
		25	50			25		
							25	
				25		25		
75	75		75	75	50	100	100	75
1	1	1	5	3	1	4	2	1

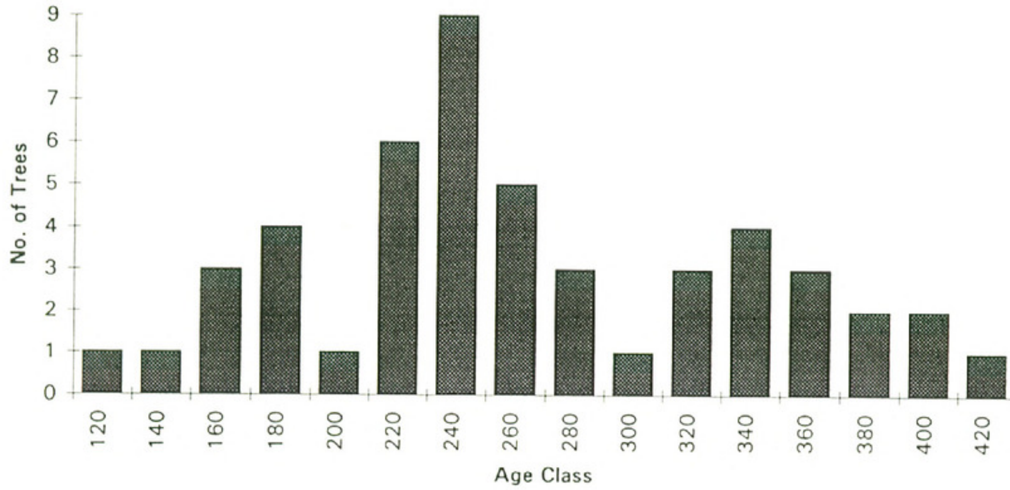

Figure 1. Distribution of ages of old trees in the study plots, determined by ring counts on increment cores and estimates of additional rings to tree center.

wood plots sampled within old-growth forests in the Berkshires are about 10% lower than in the Adirondack sites (Table 7), many of which appear to be in richer soils and on more level ground (pers. obs.). The CFI plot live basal areas are very similar to the nearby old-growth stands. However, live stem densities are nearly twice as high in the CFI sites. Stem densities are also 50% higher

Table 9. Maximum tree sizes in old-growth stands. Absolute maxima represent the greatest values found over all sites. The maximum diameters and heights for a species seldom apply to the same tree. The average maxima apply to sites exhibiting favorable growing conditions. All units are in meters.

Species	Absolute Maximum Diameter	Absolute Maximum Height	Average Maximum Diameter	Average Maximum Height
Acer saccharum	1.26	41.0	0.97	33.5
Acer rubrum	0.99	32.9	0.77	28.1
Acer pensylvanicum	0.34	18.0	0.19	11.6
Betula alleghaniensis	1.24	29.9	1.02	27.1
Betula lenta	1.00	33.2	0.74	26.2
Fagus grandifolia	0.98	35.7	0.81	31.4
Fraxinus americana	1.35	39.3	1.01	35.1
Picea rubens	0.78	39.0	0.60	31.7
Pinus strobus	1.24	46.5	0.95	38.7
Prunus serotina	0.90	34.2	0.70	29.5
Tilia americana	0.85	35.1	0.68	30.1
Tsuga canadensis	1.30	41.2	1.04	34.2

Table 10. Average basal area and density of large trees (>35 cm dbh) in Berkshire old-growth forests.

	BA (m^2/ha)	% of Total BA	Density (Trees/ha)	% of Total Density
Hemlock	30.9	72	159	33
Hemlock-Northern Hardwood	27.8	74	114	27
Northern Hardwood	26.6	78	99	29

in the Adirondack old-growth sites than in the Berkshires. The composition of all these sites is similar, with the exception of red maple instead of sugar maple in the second growth CFI plots. The basal area and density of standing dead trees in this forest type were similar to both the hemlock and northern hardwood types (10–11% of the total), but considerably less than values reported from the Adirondacks by Leopold et al. (1988). Understory species composition was similar in old-growth hemlock-northern hardwood stands from both the Berkshires and Adirondacks, with *Dryopteris carthusiana* a common dominant herb. Species richness was also similar to the Adirondacks (15.8 vs. 17.3 spp./0.1 ha).

The density of old trees in Massachusetts old-growth forests varies widely both within and between sites. Individuals are often highly clumped, and large areas may have few old trees. Data on the denser, more clumped areas of this old tree distribution can be extracted from the study plots, which were chosen to characterize areas with higher densities of large and generally old trees. Large trees, arbitrarily defined here to include individuals >35 cm dbh, have an average density of 120 trees/ha in the 26 old-growth plots (Table 10). The lowest density occurs in northern hardwood stands (99 trees/ha); hemlock stands have the highest (159 trees/ha). These trees comprise an average of about one-third of the stems, but three-fourths of the basal area. In the western Adirondacks, similar statistics are available in historical reports from uncut hardwood forests (cited in Leopold et al. 1988). Average densities of "sound" canopy trees (>25.4 cm dbh) were reported at 195 (Graves 1899) and 211 stems/ha (McCarthy and Belyea 1920). Values from the Berkshire plots using this lower minimum size cutoff are 186 stems/ha for the plots in hemlock-northern hardwood forest types, and 147 stems/ha for northern hardwoods.

Comparisons of these data suggest that the Massachusetts old-growth forests may have lower average densities of large trees than what was typical in similar forest types in the Adirondacks. These lower values in the Berkshires may result from a number of causes, including (1) slower growth rates, (2) a larger average size for the big trees, which generally is correlated with a lower average density, (3) higher probability of tree fall or other mortality in large trees, or (4) differences in sampling methods. The first and third explanations appear to be most likely, but future research should be directed towards this question for two reasons. First, the delineations of old-growth forests could be quite different, depending on what minimum density of old trees is included. Thus, determinations of the area of old growth in the state could vary considerably on this basis alone. Second, the nature of disturbances and gaps in these forests is not well understood. Viable old-growth ecosystems must include areas big enough to accommodate the scale of disturbances characteristic of these stands. It is not yet clear how large these disturbances typically are in the Massachusetts forests.

The data presented here help identify old-growth forest types that appear to be absent from the state today, but which may have occurred in the past. Notably, *Pinus strobus* L. (white pine) is missing from nearly all the old-growth stands. This species was prized by early loggers, and most stands that included significant numbers of large trees almost certainly would have been cut quickly (Pike 1967). White pine also tends to be an early-successional species and is more prone to wind damage than hemlock; thus it is less likely to persist in great numbers in many later-successional forests. Old northern hardwood stands also are relatively uncommon. These were cut for fuel, potash, and lumber (Pike 1967), and, like the white pines, the hardwoods tend to be more prone to breakage and windthrow than the hemlocks. Thus, the probability of a stand of hardwoods reaching 250–300 years with most of its canopy trees intact approaches zero in this area. Old-growth stands of any type on level ground also are scarce. Such sites generally would have been quite accessible, and hence were likely to have been cut.

No vascular plant taxa were found that were unique to the old-growth sites. The only taxon included in the list of rare species tracked by the Massachusetts Natural Heritage and Endangered Species Program that was seen occasionally was *Ribes lacustre* (Pers.) Poiret (Special Concern). This species also was observed in forests that were not old growth. However, other groups of organisms that were not examined extensively, including fungi, lichens, bryophytes, and invertebrates that inhabit the canopy, bark, rotted wood, and soil, may have taxa that are found primarily in old-growth habitats. For example, recent studies by Cooper-Ellis (1994), in several of the Massachusetts sites identified in this study, noted 24 bryophyte species that occurred exclusively in old-growth forests. Various characteristics of the forest floor, including accumulations of rotted wood, microtopography such as tip-up mounds and pits, and the development of soil horizons, may also reveal some unique qualities in the old-growth sites. Whitbeck (1995) reported significantly higher amounts of woody debris in the Massachusetts old-growth hardwood stands he studied than in second growth forests. Future research should focus on these poorly understood aspects of old-growth forests.

The criteria we used to identify old-growth forests were adequate for providing a first approximation of the minimum extent and distribution of old-growth forest in Massachusetts. However, these criteria clearly excluded areas within old-growth ecosystems where widespread blowdowns and other disturbance processes eliminated most of the old trees. Since disturbance is certainly a component of healthy old-growth ecosystems, future work is needed to develop criteria that more adequately incorporate disturbance processes in definitions of these forests types, and to quantify the range of densities of old trees characteristic of different old-growth forest types.

The methods we employed to quantify most parameters were insufficient to provide statistically valid descriptions of each stand. A much larger number of randomly placed plots would be needed to adequately characterize most of the sites we visited. An expanded array of plots would not only provide a more accurate description of the various components of the stands, but also would serve as an excellent basis for evaluating future changes in these forests.

Only about 30 old-growth stands are known in Massachusetts, with a total area of approximately 257 ha. The extremely small size of these stands, together with their small number, emphasizes the importance in preserving these few fragments that remain of the original forest that once covered much of the state. Efforts can be made to ensure that these stands are not lost to human activities in the future; however, these stands can, and will, eventually fall to storms and other natural disturbances. The loss of large areas of several old-growth stands within the last few decades in the Northeast due to windthrow testifies to the ephemeral nature of this resource. Clearly, if forests that capture many of the attributes and characteristics of old-growth stands are to be conserved into the future, protection efforts must include more than the small fragments that remain. Preservation of old-growth forest in Massachusetts will require the establishment of reserves of sufficient size to accommodate natural processes of disturbance and regeneration.

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