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A Historical Perspective on Pitch Pine–Scrub Oak Communities in the Connecticut Valley of Massachusetts

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Abstract

We present a regional–historical approach to the interpretation, conservation, and management of pitch pine–scrub oak (PPSO) communities in the Connecticut Valley of Massachusetts. Historical studies, aerial photographs, GIS analyses, and extensive field sampling are used to (a) document changes in the historical distribution, composition, and dynamics of these communities, and (b) evaluate the importance of regional–historical approaches to understanding, conserving, and managing uncommon communities. At the time of European settlement, pine plains dominated by both pitch and white pine were widespread, occurring on 9000 ha or more of the extensive (approximately 32,000 ha) xeric outwash deposits in the Connecticut Valley. Pine plains were harvested for diverse forest products from the 17th to the early 19th centuries. After 1830, most sites were cleared and plowed for agriculture and then abandoned in the late 19th and early 20th centuries, resulting in widespread natural reforestation. Modern PPSO communities differ from historical communities with respect to landscape distribution, composition, and structure. Nearly all modern pitch pine stands in the Connecticut Valley became established on former agricultural fields. Current vegetation on these former fields differs substantially from those few sites that were never plowed. In particular, several species (for example, *Gaultheria procumbens, Gaylussacia baccata, Quercus ilicifolia,* and *Q. prinoides*) that are characteristic of unplowed sites have not successfully colonized former fields in the 50 to more than 100 years since agricultural abandonment. Urban, commercial, and residential development have been widespread in the 20th century. By 1985, only 38.6% of the outwash deposits remained forested, and only 1094 ha of pitch pine stands and 74 ha of scrub oak stands occurred, primarily in numerous small patches. Several stands have been destroyed since 1985, and development threatens all remaining sites. The trend towards rapid urban development in the 20th century makes it increasingly urgent that the few, relatively large, undeveloped sites be protected. Our results suggest that (a) land protection efforts should prioritize large, undeveloped sand plains, areas that were not plowed historically, and reestablishment of contiguity between isolated sites to facilitate colonization of former agricultural lands by sand plain species; (b) management of PPSO communities should not be restricted to maintenance of open barrens; "old-growth" pitch and white pine stands occurred historically, and some PPSO communities should be allowed to mature without frequent disturbance; (c) the exclusive use of prescribed fires during the spring months is unlikely to maintain communities similar to modern ones or to restore communities similar to historical ones. Establishment or maintenance of open barrens species and communities may require more varied disturbance regimes, perhaps including mechanical treatment in combination with prescribed fire to simulate severe summer fires; (d) regional–historical perspectives are critical for understanding modern community dynamics and for evaluating conservation objectives and management strategies for uncommon plant communities.

Key words: conservation and management; disturbance; fire; historical ecology; land-use history.

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INTRODUCTION

Understanding the history and influence of disturbance events, such as wind, fire, pathogens, and a variety of human land-use activities, is increasingly recognized as vital to interpreting community patterns and dynamics (Patterson and Backman 1988; Foster 1992; Foster and Boose 1992; Abrams 1996; Motzkin and others 1996; Ostfeld and others 1996). A historical approach is particularly useful in studies of uncommon communities for which information on past distribution, composition, and dynamics may aid in evaluating conservation objectives and management strategies (for example, Jacobson and others 1991; Motzkin and others 1993, 1996; Dieffenbacher-Krall 1996). Most previous studies, however, have been restricted to investigations of individual sites and have not placed local results in a regional context. Such a context is necessary to determine the degree to which local dynamics are characteristic of the community type targeted for conservation and to provide information on changes in disturbance regimes, species distribution patterns, and other processes that influence local community patterns but are dependent in part on the nature of the surrounding landscape (Givnish 1981; Givnish and others 1988; Saunders and others 1991; Aizen and Feinsinger 1994; Boose and others 1994; Matlack 1994).

We investigated changes in the historical distribution, composition, and dynamics of pitch pine–scrub oak (PPSO) communities throughout the Connecticut Valley of Massachusetts, a broad lowland region of approximately 135,270 ha. PPSO communities are priorities for conservation in the northeastern US because they are uncommon, support several rare plant and animal species, and are threatened by industrial, commercial, and residential development. We selected these communities for investigation in part because they were well documented historically, allowing us to evaluate changes in their distribution in a manner that is not possible for many communities. Such a historical approach is particularly useful because PPSO communities occur on xeric sites where opportunities for paleoecological reconstruction are limited.

Our previous study of these communities on a single site in the Connecticut Valley (Motzkin and others 1996) resulted in interpretations that differ from those reported for other northeastern sand plains. Whereas most previous studies identified fire (in combination with timber and fuelwood cutting) as the primary determinant of modern vegetation patterns (Lutz 1934; Buell and Cantlon 1950; Little 1964; Reiners 1965; Little 1979; Forman and Boerner 1981; Givnish and others 1988), Motzkin and others (1996) found that variation in current vegetation is related largely to agricultural history, with differences between formerly plowed vs unplowed sites persisting for 50 to more than 100 years after agricultural abandonment. The current study was undertaken in part to determine whether historical agriculture similarly influenced PPSO communities across a much broader geographic region.

Specific questions addressed in this study include: (a) How have the size, overall extent, and distribution of PPSO communities changed in the Connecticut Valley of Massachusetts within the historical period? (b) How have historical disturbances (for example, fire and land use) influenced the distribution, composition, and dynamics of modern PPSO communities? (c) What conservation and management implications emerge from a regional–historical perspective of PPSO communities?

XERIC OUTWASH, PINE PLAINS, AND PITCH PINE–SCRUB OAK COMMUNITIES

Throughout the northeastern US, several pine–oak associations occur on xeric, nutrient-poor sand and gravel deposits. PPSO communities are characterized by numerous species that are highly flammable and that have strategies for survival or regeneration after fire. Pitch pine (*P. rigida*) is an important overstory species, along with frequent white pine (*P. strobus*) and tree oaks (especially *Quercus coccinea* and *Q. velutina*). PPSO communities often support dense ericaceous understories (especially *Gaylussacia baccata*, *Vaccinium* spp., and *Gaultheria procumbens*) and varying amounts of scrub oak (especially *Quercus ilicifolia*). "Scrub oak stands" are shrublands dominated by *Quercus ilicifolia* and/or *Quercus prinoides*, with little or no tree canopy. "Pine plains" is a term that was used historically to describe areas dominated by pines. Because many historical sources provide little information about the relative importance of pitch vs white pine, or the relative abundance of tree and shrub oaks, caution must be exercised in interpreting specific stand composition and structure from these references.

STUDY AREA

The Connecticut Valley Lowland is a downfaulted Mesozoic basin located between the Central and Western Upland physiographic regions of southern New England. The entire region underwent Wisconsinan glaciation with glacial maximum circa 20,000–25,000 BP and deglaciation approximately 14,000–15,000 years BP (Stone and Borns 1986). A debris dam at Rocky Hill, Connecticut blocked drainage of the Connecticut River and its tributaries, forming Glacial Lake Hitchcock that occupied much of the region for several thousand years after deglaciation. Extensive glaciofluvial sands and gravels were deposited as large deltas into the lake and in numerous kame deposits. Small amounts of silt subsequently were incorporated into the upper horizons of the outwash as a result of eolian deposition after lake drainage, resulting in loamy sand soil textures. Because the surface of many of the outwash deposits are several to more than 20 m above modern groundwater levels, soils are often highly drought prone despite evenly distributed annual precipitation of approximately 110 cm (Mott and Fuller 1967).

The area of investigation for the current study includes the portion of the Connecticut Valley Lowland that occurs in Massachusetts (Figure 1). The boundary of the study area was derived from the bedrock geological map for Massachusetts (Zen 1983), modified in the northeastern section to conform to the distinct topographic break between the lowland and adjacent uplands, thereby including outwash deposits occurring along the boundaries between these regions. Elevations within the study area range from approximately 13 to 100 m, with ridges that rise to approximately 350 m. Climate is continental, with cool winters and warm summers (Mott and Fuller 1967). Soils include sandy loams derived from glacial till on upland hills, coarse silty alluvium along major rivers, fine-textured soils in glaciolacustrine deposits, and loamy sands on glacial outwash deposits.

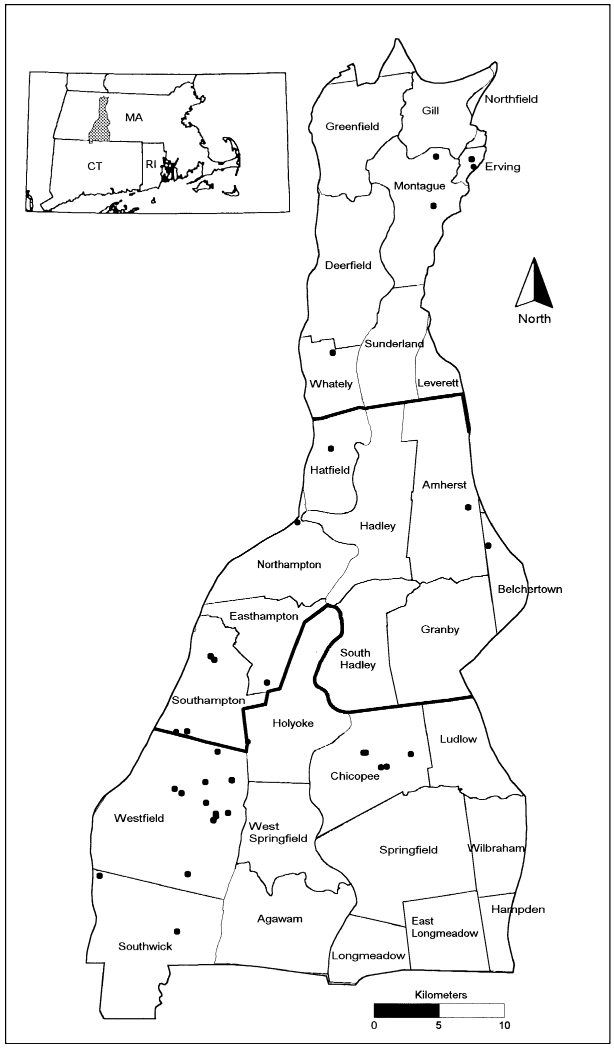

Figure 1. The Connecticut Valley of Massachusetts, indicating towns mentioned in the text and the location of 32 field sites (filled circles). Bold lines are the boundaries, from north to south, of Franklin, Hampshire, and Hampden Counties.

METHODS

Historical Distribution and Land Use of Pine Plains

To document historical changes in the distribution and land use of pine plains, we reviewed a wide range of regional and county histories (for example, Dwight 1823; Sylvester 1879; Garrison 1991), historical maps (Massachusetts Archives 1794, 1830; Wright and DeForest 1911), and ecological and forestry sources (Rane 1908, 1918; Parmenter 1922, 1928a, 1928b; Bromley 1935). In addition, we reviewed town histories for each town in the study area (see Table 1 for full list of references) and conducted interviews with individuals knowledgeable about materials used in historical construction (W. Flint and W. Gass personal communication).

Aerial Photo and GIS Analyses

The distribution of modern PPSO was determined using aerial photographs, ground truthing, and field inventories. Color infrared aerial photographs (1985 leaves-on, 1:25,000 scale) for the entire region were visually scanned using a 4× magnification mirror stereoscope, and all stands with visible pitch pine or scrub oak were delineated. Pitch pine was distinguishable from other conifers on the photos by color and crown structure, and scrub oak stands had smooth signatures that are distinct from other shrublands, young forests, or grasslands. Field checks of numerous stands (more than 80) resulted in the identification of several stands overlooked in the

Table 1. Summary of Historical References[a]

Town	Before 1800	1800–1900	1900–1950	1985 (ha)
Agawam	A, B, 2		F	1
Amherst				2
Belchertown	1, 2			
Chicopee	A, B, C	E		22
Deerfield	A, 1			
Easthampton				27
E. Longmeadow	C	E		
Erving				33
Gill				
Granby	1, 2			
Greenfield	A	E		
Hadley	A, B, 1, 2			
Hampden				
Hatfield	C, 1	D, E		7
Holyoke				14
Leverett				
Longmeadow	C, 2	B, E		2
Ludlow	1	D	F	4
Montague	A, C	A, D, E	F	550
Northampton	1, 2			
Northfield	A, 1, 2			
South Hadley		D		
Southampton	A, B			57
Southwick			F	44
Springfield	A, B, C, 1, 2	D, E	A	
Sunderland				
Westfield	A, B, 1		A, F	299
W. Springfield	A			4
Whately	2	D, E		28
Wilbraham	A		F	
Total				1094

[a]References to pine plains (A–F), tar and turpentine production (1), and gathering of candlewood (2) in towns in the Connecticut Valley of Massachusetts are shown. Where specific location was identified, historical references are listed according to modern town boundaries. A, town and regional histories; B, Sylvester (1879); C, Massachusetts Archives (1794); D, Dwight (1823); E, Massachusetts Archives (1830); F, forestry references [Parmenter (1928a, 1928b); Rane (1908, 1918)]. References from Dwight (1823) are recorded as 1800–1900 although some were based on observations in the 1790s. Estimates for 1985 are derived from aerial photo survey.

All historical data are permanently stored in Harvard Forest Archives Research File HF 1996-22. Town and regional histories reviewed include Burt (1898); Crafts (1899); Czelusniak and others (1975); D'Amato (1985); Dickinson (1968); Garrison (1991); Green (1876); Historical Records Survey (1939); Judd (1905); LaFrancis (1980); Lockwood (1922); Massachusetts Historical Commission (1984); Merrick and Foster (1964); Noon (1912); Pressey (1910); Rodger and Rogeness (1983); Shaw (1968); Swift (1969); Szetela (1962); Temple (1872); Temple and Sheldon (1875); Thompson (1904); Trumbull (1898); Wells and Wells (1910); Wright (1936); Wright and DeForest (1911).

initial photo survey. The minimum consistent mapping unit was 0.5 ha, with smaller stands included where identified.

Historical sources indicated that PPSO communities were restricted largely to xeric outwash. To determine the maximum potential historical distribution of these communities and to evaluate the relationship between substrate type and modern PPSO distribution, a map of soils was developed based on existing surveys (Mott and Fuller 1967; Mott and Swenson 1978; Swenson 1981). We combined all excessively drained outwash series (that is, Hinckley, Windsor, and Carver) into a single "xeric outwash" type. All other soil series were grouped as "other" soils, with the exception of areas mapped as "urban land–Hinckley–Windsor association," which were considered to be xeric outwash. Mapping was much less detailed in urban associations than elsewhere and may include some areas of other soils. In the southern portion of the study region (for example, Hampden County) where large areas were mapped as "urban land," xeric outwash soils may be widespread; however, without soil data, these areas were not considered xeric outwash. Our maps are therefore conservative.

Detailed land-use data for the study region were available for 1971 and 1985 from MassGIS (1991; MacConnell and others 1991). We reclassified the original data into several broad land-use/land-cover types: (a) "urban," including all lands that are developed for commercial, industrial, residential, recreational, or transportation purposes; (b) "forest," including forests, orchards, and nurseries; (c) "agriculture," including active agricultural lands as well as powerlines, abandoned fields, and areas of no vegetation; and (d) "water," including all ponds, streams, and nonforested wetlands.

To determine cover types for xeric outwash deposits that were forested in 1985 but that did not support pitch pine stands, we used land-cover data layers developed as part of the national Gap Analysis Project (GAP; Slaymaker and others 1996). We reclassified GAP data into two broad categories: "conifer," including all polygons supporting greater than or equal to 60% conifers, and "other," including hardwood, mixed (that is, less than 60% conifers), open canopy (40%–60% cover), and other GAP classes.

Stand and xeric outwash maps were georeferenced to 1:25,000 scale U.S. Geological Survey topographic maps by using a zoom transfer scope and then digitized in a vector format by using ROOTS (stand maps; Corson-Rickert 1992) or ARCINFO (soil map; ARCINFO 1992). Area and cross-tabulation analyses were performed in raster format in IDRISI (Eastman 1992) with a pixel resolution of 30×30 m (100×100 ft). In determining the percentage of modern pitch pine and scrub oak stands on xeric outwash vs other soils, we performed a buffering analysis (to 30 m) to evaluate the likely contribution of mapping errors to our results.

Modern Vegetation and Disturbance History

Field sampling was conducted at 32 sites identified in the aerial photo survey in which *Pinus rigida* occurs in the overstory (Figure 1). Sites were distributed throughout the Connecticut Valley and were selected to include a range of stand sizes from the largest contiguous pitch pine stands to small, isolated stands. At each field site, one to four 100-m^2 releves were sampled in representative areas after initial stand reconnaissance. In each releve, cover–abundance estimates were recorded for each vascular species within height strata according to Braun-Blanquet classes (Mueller-Dombois and Ellenberg 1974).

We recorded evidence of disturbance, including windthrow mounds, timber cutting, fire scars (basal and branch), stem charring, and soil charcoal in each releve. Soils were examined for presence–absence and depth of a plowed surface (Ap) horizon and artifacts of human activity (for example, barbed wire, plow mounds, and cut stumps; Motzkin and others 1996) were noted.

Species cover–abundance data were ordinated using detrended correspondence analysis (DCA; Hill 1979), and a vegetation classification was developed using cluster analysis (Orloci 1967). Cover–abundance estimates were used to calculate importance values for these analyses as follows. For each species in each releve, Braun-Blanquet cover–abundance values were summed for all strata in which the species occurred. The number of strata in which the species occurred was then subtracted from this summation, with the value "1" added to the total. This procedure results in a minimum value of 1 assigned to a species that occurs in only one stratum with a cover value of 1 (single occurrence, minimal cover). Because of the nonlinear nature of the Braun-Blanquet cover class values, this method (a) emphasizes the occurrence of species within strata more than their cover, (b) increases the importance of species that occur in multiple strata relative to those that occur in a single stratum, and (c) upweights rare or uncommon species because the minimum importance value represents a greater percentage of the maximum value than would occur if one were to use actual cover values (Clark and Patterson 1985; Motzkin and others 1993). Using importance values in this way allowed us to emphasize, for this analysis, both the species that are of particular successional importance in the stands that we sampled and species that, although uncommon at many sites, are characteristic of PPSO communities.

RESULTS

Historical Distribution of Pine Plains

One of the earliest references to pine plains in the Connecticut Valley occurs on a 1642 map of the Massachusetts Bay Patent, which indicates two pine plains in the southeastern portion of the study area (Wright and DeForest 1911). Numerous subsequent references suggest that pine plains were widespread throughout the study area at the time of European settlement (Table 1 and Figure 2), which ranged from the mid-17th century in the southern and central towns to the early 18th century in the northern section. In the 17th and early 18th centuries, the largest pine plains occurred on extensive xeric outwash deposits in Springfield/Chicopee, Montague, Longmeadow, and Westfield. The Springfield/Chicopee pine plains, which were apparently the largest in the Massachusetts portion of the Connecticut Valley, are indicated on maps from 1642, 1794, 1830, and 1935 (Figure 3; Massachusetts Archives 1794, 1830; Wright and DeForest 1911; Bromley 1935) and are referred to in historical deeds, legislation, travel accounts, and town and regional histories from the 17th to 20th centuries (for example, Dwight 1823; Green 1876; Sylvester 1879; Burt 1898; Wright 1936; Massachusetts Historical Commission 1984). Maps of Springfield/Chicopee in 1794 and 1830 indicate several thousand hectares of pine plains (Figure 3), and Cryan (1985) estimated that the original extent was greater than 6000 ha. Extensive "barren pine plains" in the town of Montague are indicated on a 1714 map, before settlement of the town, and again on maps from 1794 and 1830 (Figure 4; Massachusetts Archives 1794, 1830; Pressey 1910). Although we did not find any early maps of pine plains in the town of Westfield, several early deeds or acts of legislation refer to them (Sylvester 1879) and provide the basis for later maps that depict 17th century pine plains in Westfield [for example, "Map of Indian Lands at Woronoco" by H. A. Wright and "Historical Map of the Original Settlement" by L. M. Dewey in Lockwood (1922)].

The primary sources of information about the distribution of pine plains in the 19th century are the observations of Dwight (1823) and a series of maps from 1830 that indicate forest cover for each town in Massachusetts (Massachusetts Archives 1830; Table 1). In several instances, Dwight specifically noted extensive "yellow pine plains" (for example, Ludlow, Montague, and Whately), confirming the importance of *Pinus rigida* on at least these sites.

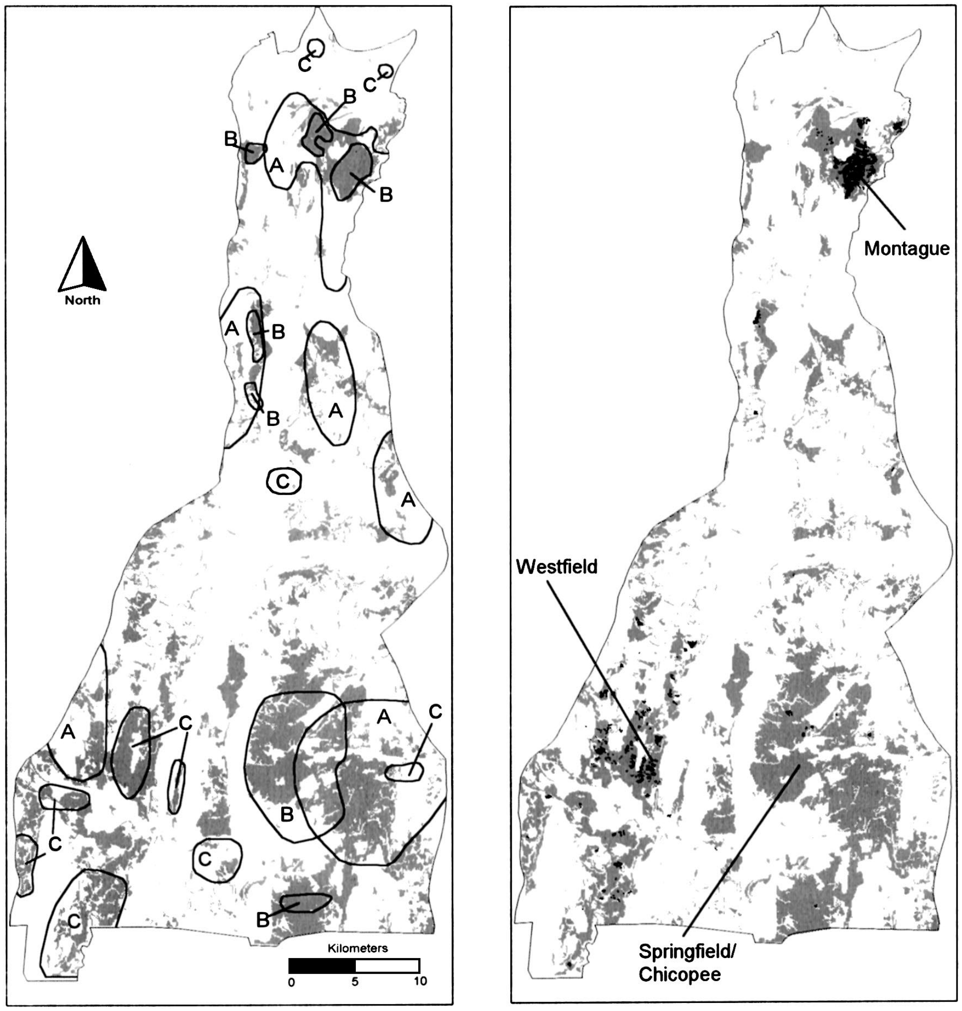

Figure 2. Left Generalized location map for historically documented pine plains in the Connecticut Valley of Massachusetts with xeric outwash soils (gray) as background. Historical sources are as follows: A, Bromley 1935; B, Massachusetts Archives 1794, 1830; C, other (Temple and Sheldon 1875; Sylvester 1879; Thompson 1904; Judd 1905; Lockwood 1922; Parmenter 1928a; Merrick and Foster 1964; Swift 1969; and LaFrancis 1980). Additional historical references listed in Table 1 are excluded because no specific information is available on location within towns. Right Xeric outwash soils (gray) and 1985 pitch pine stands (black) in the Connecticut Valley of Massachusetts. Approximately 91% of modern pitch pine stands occur on areas mapped as xeric outwash.

Information on the distribution of pine plains in the early 20th century is limited primarily to forest inventories that provide acreage estimates for several towns in Hampden County (Table 2). Around 1920, Parmenter (1928a) estimated 498 ha of pitch pine stands in several towns that are partially in the study area. Parmenter (1928a) did not indicate extensive pitch pine stands in Springfield or Chicopee in the early decades of this century, the period during which tract house development occurred (Massachusetts Historical Commission 1984). Aerial photographs show almost no closed canopy pitch pine stands on Montague Plain in 1939, although extensive open canopy stands and old fields with young pitch pine occurred (Motzkin and others 1996).

Scrub oak stands were not described in the study area until the late 19th century (Pressey 1910), although references to such stands in eastern Massachusetts occur from the 17th to the mid-19th centuries (Freeman 1802; Banks 1911; Torrey and Allen 1962), and Dwight (1823) suggested that on sand plains in New Haven, Connecticut, “the surface was (formerly) covered with shrub oaks.” Around 1920, Parmenter (1928a) estimated 1018 ha of scrub oak in several towns in Hampden County, in addition to stands on Westfield Plain (Rane 1918; Parmenter 1928a). Scrub oak stands

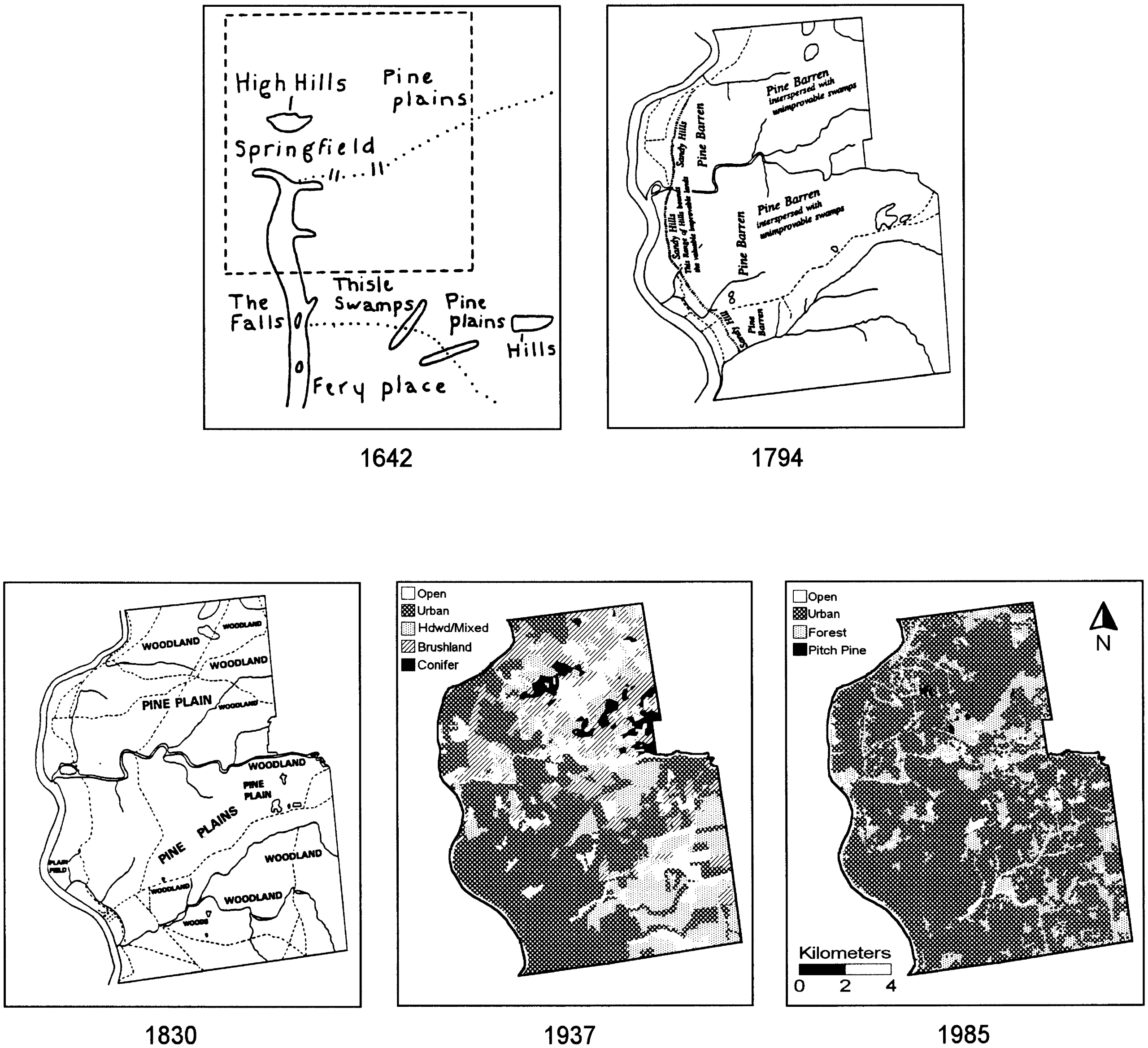

Figure 3. Historical maps of Springfield/Chicopee, Massachusetts, indicating the conversion of several thousand hectares of pine plains that existed prior to the 20th century to urban uses. The dashed box in 1642 represents the approximate area detailed in the later maps. 1642, 1794, and 1830 maps are redrafted for clarity, but labeling is indicated as in originals. For 1937, Hdwd/Mixed may include some conifer stands in the southern area (Springfield), where forest type was not identified. Map sources are as follows: 1642 (Wright and DeForest 1911); 1794 (Massachusetts Archives 1794); 1830 (Massachusetts Archives 1830); 1937 (W.P.A. 1937); 1985 (MassGIS 1991, modified to include pitch pine stands identified in the current study). See Figure 2 for general location.

also occurred on Montague Plain in the early 20th century (Rane 1918); in 1939 they covered approximately 113 ha (Motzkin and others 1996).

Land-Use History of Connecticut Valley Pine Plains

Little is known about the prehistoric human use of pine plains in the Connecticut Valley, although Indian trails crossed several sites and Woodland Period (3000–500 years BP) archaeological remains occur on or adjacent to some historical pine plains (Pressey 1910; Thomas 1975; Anonymous 1982; Massachusetts Historical Commission 1984). Large settlements were located within a few kilometers of several pine plains, suggesting that these sites were probably used for hunting and gathering of wild foods. However, it is unlikely that xeric outwash deposits were used extensively for prehistoric Indian agriculture (M. Mulholland personal communication).

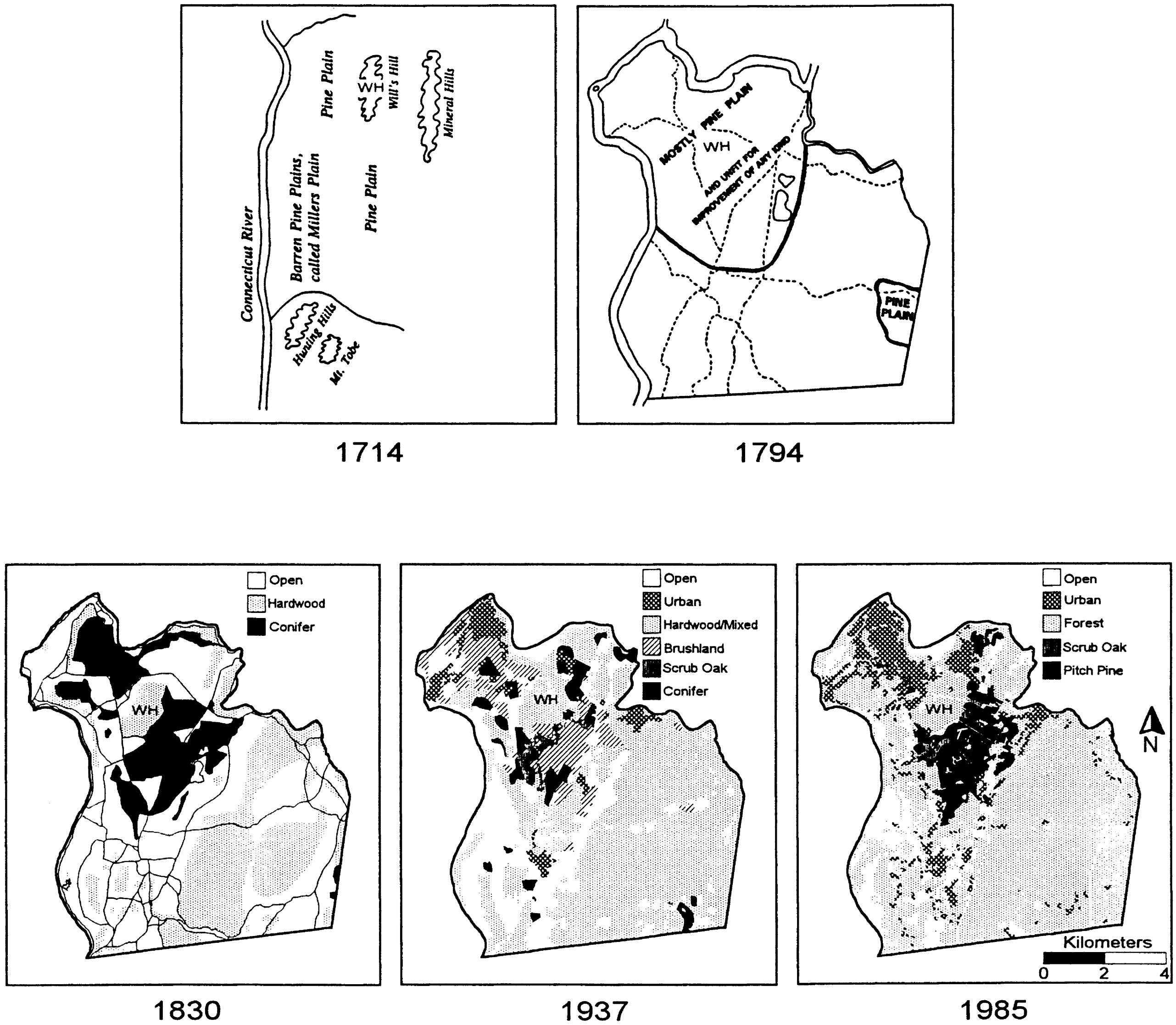

Figure 4. Historical maps of Montague, Massachusetts indicating changes in the historical distribution of pine plains. Note that extensive pine plains indicated west and northwest of Will's Hill (WH) in 1714, 1794, and 1830 were nearly eliminated completely by urban development by 1985. 1714 and 1794 maps are redrafted for clarity, but labeling is indicated as in originals. Map sources are as follows: 1714 (Pressey 1910); 1794 (Massachusetts Archives 1794); 1830 (Massachusetts Archives 1830); 1937 (W.P.A. 1937, modified to indicate scrub oak stands according to Motzkin and others 1996); 1985 (MassGIS 1991, modified to include pitch pine and scrub oak stands identified in the current study). See Figure 2 for general location.

From the earliest decades of European settlement, the pine plains of the Connecticut Valley were highly valued for diverse forest products. In 1662 Governor Winthrop described the making of tar and charcoal from pines on extensive pine plains in the Connecticut portion of the Valley, and 17th century regulations limited the gathering of "candlewood" (that is, pieces of resinous pine burned as a source of light) and the production of naval stores in several Connecticut Valley towns in Massachusetts (Table 1; Winthrop 1662). Pine plains also were highly valued as sources of timber. Hard (pitch) pine and chestnut (*Castanea dentata*) were the most common materials used for structural timbers in the Massachusetts portion of the Connecticut Valley until the early 19th century, and pitch pine was perhaps the most common wood used for floorboards, some of which were up to 15 inches wide. White pine was used less frequently for flooring, but white pine boards up to 2 feet wide were commonly used for paneling (B. Flint and W. Gass, personal communication). Pitch pine was also an important fuel for

Table 2. Change in Areal Extent (ha) of Pitch Pine and Scrub Oak Stands in Hampden County Towns for Which Early 20th Century Estimates Are Available

	Pitch Pine			Scrub Oak	
Town	1907	1920	1985	1920	1985
Agawam		47	1	—	
Hampden		—	—	124	—
Longmeadow		—	2	769	—
Ludlow		16	4	—	—
Southwick	492	176	44	—	—
Westfield		259	299	*	4
Wilbraham		*	—	125	—
Total		>498	350	>1018	4

*Data for 1985 are from aerial photo survey; historical data are from Parmenter (1928a), except for Southwick in 1907 (Rane 1908). *, noted by Parmenter (1928a) but no acreage estimate available. Note the substantial decline in pitch pine and the near elimination of formerly extensive scrub oak stands.*

homes and by the mid-19th century was used extensively as fuel for locomotives (Bromley 1935). In the early 20th century, pitch and white pine were used commonly in box manufacturing (Harshberger 1916).

Widespread agricultural clearance probably did not occur on pine plains until the mid-19th century (Table 1; Massachusetts Archives 1830). Most (more than 80%) undeveloped sand plains were then plowed and used for crops or pasture for several decades and subsequently abandoned in the late 19th and early 20th centuries. Maps from 1937 (W.P.A. 1937) indicate agricultural fields and extensive brushland on many xeric outwash plains, including sites that subsequently were developed into urban land (Figure 3).

Corn frequently was grown on sand plains, as well as hay, rye, wheat, strawberries, and blueberries. Corn and hay are still grown on some xeric outwash plains in the study area. Some sites (for example, Montague Plain) initially were divided into small (2–4 ha), long, narrow lots, suggesting that they were intended for cultivation rather than grazing (Olmsted 1937; Motzkin and others 1996). However, pasturing may have been common after subsequent aggregation into larger ownerships or as a part of the "common field system" in which animals were allowed to graze in cultivated fields after harvesting of crops (Garrison 1991). We observed old barbed wire at several sites, and 1937 land-use maps (W.P.A. 1937) indicate small open or wooded pastures. Determining the land-use history of unplowed portions of the xeric outwash plains is problematic because of lack of historical references;

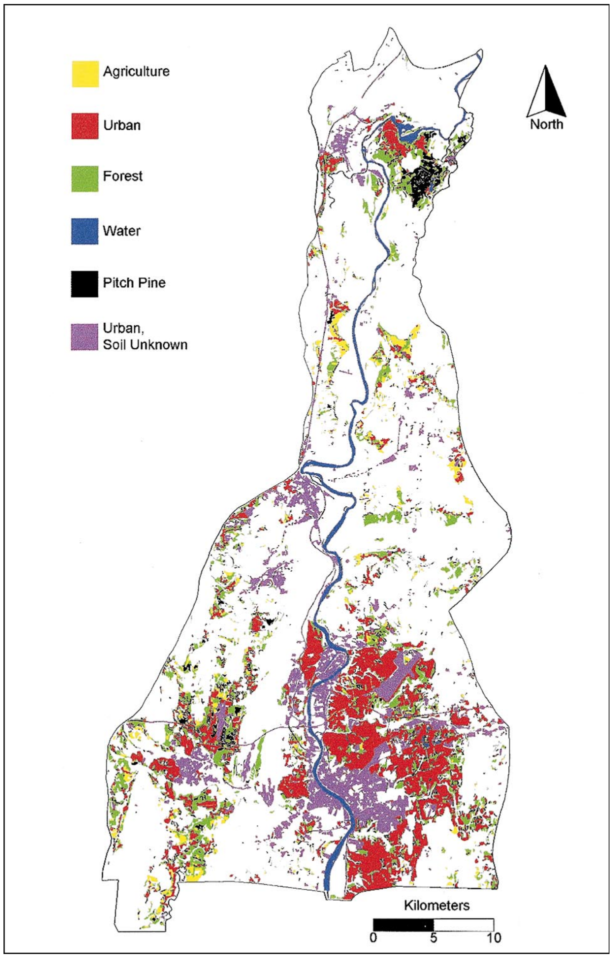

Figure 5. 1985 land use on xeric outwash soils in the Connecticut Valley of Massachusetts. Urban areas with unknown soils are indicated in purple, although some urban lands probably occur on xeric outwash. Land-use data from MassGIS (1991).

these areas were probably used as woodlots or unimproved pastures (Motzkin and others 1996).

In the 20th century most agricultural lands were abandoned, and each of the major historical pine plains was impacted by urban and suburban development. The Springfield/Chicopee and Longmeadow Plains are developed nearly completely for urban uses (Figures 3 and 5), and airports and industry have been constructed on the Westfield and Montague Plains. Large portions of the remaining pine plains are zoned for future industrial development.

Modern Distribution of Pitch Pine–Scrub Oak Communities

In the Massachusetts portion of the Connecticut Valley, pitch pine occurred in the overstory on 1094 ha (approximately 0.8% of the study area) in 1985 (Table 1 and Figure 2). Pitch pine is most abundant

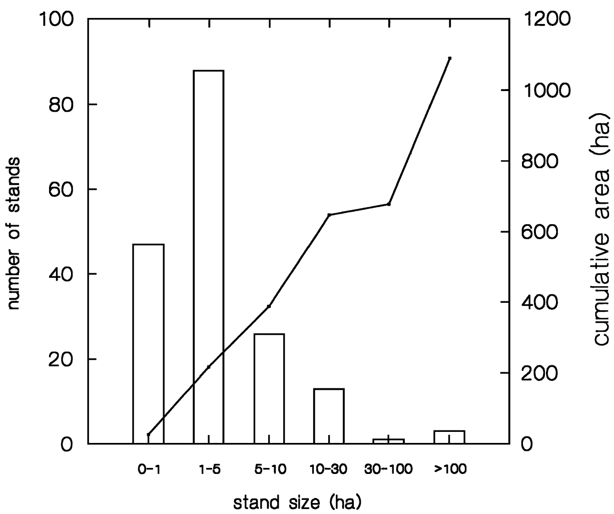

Figure 6. Frequency distribution (bars) and cumulative area (solid line) of pitch pine stands of different sizes in the Connecticut Valley of Massachusetts. Stands less than 5 ha in size comprise only approximately 20% of the pitch pine acreage in the study area, whereas three stands, each greater than 100 ha, account for more than 30% of the total acreage.

on Montague Plain and in the town of Westfield, together supporting approximately 78% of the total pitch pine acreage. Pitch pine occurs in numerous small stands, with only 17 out of 191 stands larger than 10 ha (Figure 6). Since 1985 several stands have been eliminated through development or cutting, with few areas of recent pitch pine regeneration. Although we know of several small stands or areas of sparse pitch pine cover that were not included in the aerial photo survey, it is unlikely that large stands were overlooked, and extensive fieldwork throughout the study area suggests that our estimates are probably accurate to within approximately 10%.

In 1985 only 74 ha of scrub oak stands occurred in the Connecticut Valley, of which 69 ha (93%) were on Montague Plain, with the remaining acreage in several small stands on Westfield Plain. A 4-ha stand on the northern portion of Montague Plain recently was bulldozed to create a baseball field. This stand occurred on a site that had never been plowed.

Distribution and Land-Use of Xeric Outwash Plains in the Connecticut Valley

Soil surveys (Mott and Fuller 1967; Mott and Swenson 1978; Swenson 1981) identify nearly 32,000 ha of xeric outwash soils in the study area (Figure 2). This represents approximately 24% of the region, and 35%, 18%, and 14% of the portions of Hampden, Franklin, and Hampshire Counties, respectively, that occur within the Connecticut Valley. Xeric outwash deposits occupy from less than 3% (for example, Gill) to more than 62% (for example, Chicopee and Longmeadow) of the portions of individual towns that occur within the study area.

In 1971 14.1% of the xeric outwash plains were in agriculture, 43.3% were forested, and 41.6% were developed lands. By 1985 the percentage of xeric outwash soils in agriculture was 12.7% whereas forests declined to 38.6%. Urban lands increased to 47.6% in this 14-year period, representing a 5.6% increase or 0.43% per year increase in developed land. Particularly striking is the nearly complete urbanization of the extensive outwash plains in the southeastern portion of the study area. These areas now support only small, isolated patches of forest (Figure 3 and 5).

Relationship of Pitch Pine–Scrub Oak Distribution to Xeric Outwash

Numerous sources suggest that historical pine plains in the Connecticut Valley were restricted largely to dry, “barren” soils. In 1985, 91% of pitch pine stands and 100% of scrub oak stands occurred on xeric outwash deposits (Figure 2). Approximately 2.3% of pitch pine stands did not occur on mapped xeric outwash but occurred within 30 m of xeric outwash. The remaining 7% of pitch pine stands are more than 30 m from mapped xeric outwash, including a few isolated stands on soils that are not excessively drained, as well as a few stands that are contiguous with those on xeric outwash.

By 1985 only approximately 12,350 ha (38.6%) of the xeric outwash deposits remained forested. The 990 ha of pitch pine stands identified on xeric outwash represents approximately 8% of these forested areas. According to the GAP classification, the remaining forested areas include more than 4000 ha (approximately 34%) of other (that is, non-pitch pine) conifer stands, primarily old-field white pine stands, conifer plantations, and a few hemlock stands (Slaymaker and others 1996; G. Motzkin personal observation). The remaining approximately 7000 ha (approximately 58%) support “other” forest types, especially hardwood, mixed, and open canopy stands.

Modern Vegetation, Disturbance History, and Environmental Variability

Stands sampled include nearly pure *P. rigida* stands as well as *P. strobus*–dominated stands with varying amounts of *P. rigida* and hardwoods in the overstory. *P. rigida* is limited to the overstory in 52 out of 58 releves, whereas *P. strobus* occurs in two or three height strata in 92% (48) of the 52 releves in which it occurs (Figure 7).

Cluster analysis of species importance values based on absolute (Euclidian) distance identified two pri-

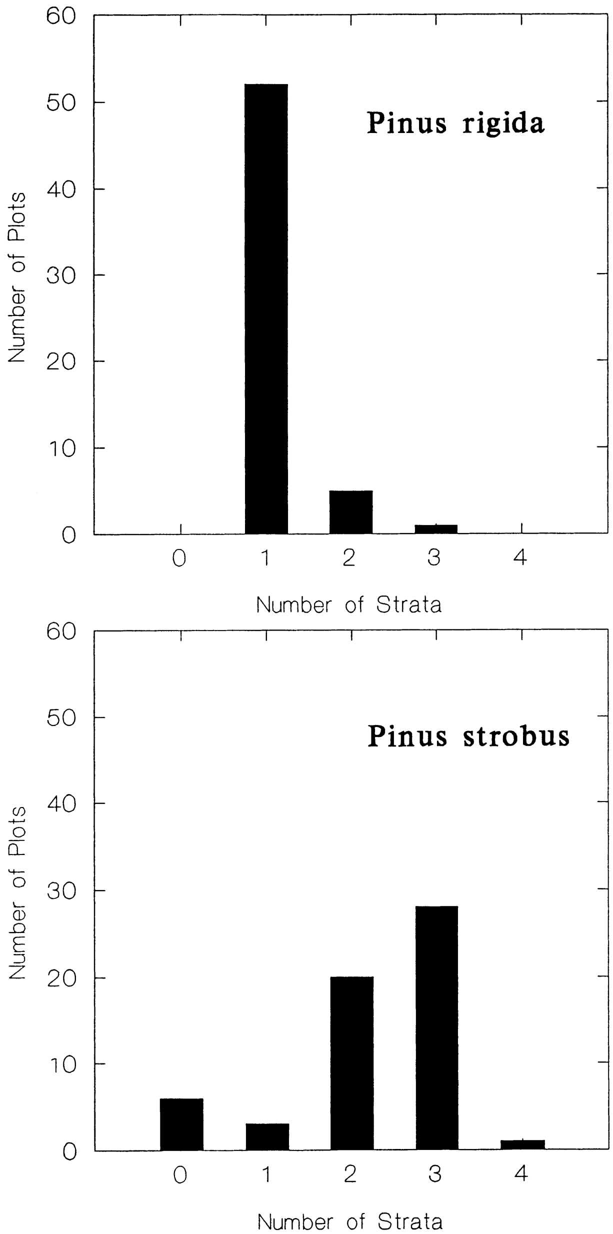

Figure 7. The number of height strata in which pitch pine (top) and white pine (bottom) occur in 58 releves in Connecticut Valley pitch pine stands.

mary groups that are distinguished on the basis of species composition and abundance (Table 3). Group I is characterized by the frequent occurrence of *Betula populifolia*, *B. lenta*, *Chimaphila maculata*, and *Polytrichum* spp., none of which occurs in group II releves. *Pinus strobus* is more abundant and *Acer rubrum* less abundant in group I than in group II, although they each have high frequencies in both groups. The five releves in group II have higher frequency and importance values for *Gaultheria procumbens*, *Gaylussacia baccata*, *Pteridium aquilinum*, *Quercus ilicifolia*, *Q. prinoides*, *Vaccinium vacillans*,

Table 3. Frequency of Occurrence and Mean Importance Value of Species in Cluster Analysis Groups

	Frequency (%)			Importance Value ($\overline{x}$)	
Species	All	I	II	I	II
Number of releves	58	53	5	53	5
Quercus velutina	81	85	40	5.3	1.4
Quercus alba	66	68	40	2.4	1.4
Betula populifolia	38	42	0	1.4	0.0
Chimaphila maculata	41	45	0	0.7	0.0
Polytrichum spp.	36	40	0	1.0	0.0
Vaccinium corymbosum	24	26	0	0.6	0.0
Betula lenta	22	25	0	0.8	0.0
Betula papyrifera	17	17	0	0.6	0.0
Kalmia latifolia	12	13	0	0.6	0.0
Tsuga canadensis	12	13	0	0.5	0.0
Fagus grandifolia	10	11	0	0.4	0.0
Osmunda cinnamomea	10	11	0	0.3	0.0
Lycopodium spp.	7	8	0	0.2	0.0
Gramineae spp.	7	8	0	0.1	0.0
Prunus pensylvanica	7	8	0	0.1	0.0
Dennstaedtia punctilobula	5	6	0	0.2	0.0
Rubus flagellaris	5	6	0	0.1	0.0
Rubus hispidus	5	6	0	0.1	0.0
Populus grandidentata	5	4	0	0.2	0.0
Rhododendron roseum	3	4	0	0.3	0.0
Nyssa sylvatica	3	4	0	0.2	0.0
Spiraea latifolia	3	4	0	0.1	0.0
Populus tremuloides	3	4	0	0.1	0.0
Mitchella repens	3	4	0	0.1	0.0
Pinus strobus	90	91	80	5.5	1.8
Maianthemum canadense	22	23	20	0.5	0.4
Prunus serotina	62	62	60	1.1	1.2
Cypripedium acaule	40	40	40	0.6	0.6
Pinus rigida	100	100	100	4.7	5.4
Viburnum cassinoides	9	8	20	0.2	0.2
Castanea dentata	12	9	20	0.3	0.6
Comptonia peregrina	7	6	20	0.1	0.2
Quercus rubra	24	23	40	1.1	1.2
Kalmia angustifolia	22	21	40	0.5	0.8
Corylus americana	14	11	40	0.2	0.8
Quercus spp.	10	8	40	0.2	1.0
Lycopodium obscurum	17	13	60	0.3	1.4
Carex pensylvanica	26	23	60	0.4	1.4
Quercus coccinea	48	45	80	2.5	5.4
Acer rubrum	72	70	100	2.3	8.0
Vaccinium angustifolium	62	58	100	1.4	3.8
Vaccinium vacillans	48	43	100	1.2	3.2
Quercus ilicifolia	33	26	100	0.8	4.8
Amelanchier spp.	31	25	100	0.5	3.0
Gaultheria procumbens	14	8	80	0.2	2.2
Gaylussacia baccata	24	17	100	0.6	6.2
Pteridium aquilinum	24	17	100	0.6	2.6
Quercus prinoides	17	9	100	0.3	3.8

Importance values indicated in boldface are significantly different (Student's t test; $P < 0.05$) from their group pair.

V. angustifolium, and *Amelanchier* spp. *Pinus rigida* occurs with nearly equal frequency and abundance in the two groups. Average species richness is 13.9 species for the 58 releves. Group I releves average 13.5 species, whereas group II averages 18.0 species.

Fifty-one of the 58 releves (88%) at 30 of the 32 sites investigated (94%) occurred on formerly plowed sites, as evidenced by distinct plow (Ap) horizons approximately 15–30 cm in depth. Unplowed A horizons were typically less than 10 cm in depth and black, with gradual boundaries in contrast to the deeper Ap horizons that are dull brown or gray with smooth and abrupt boundaries. A single releve had a shallow (approximately 10 cm) "scratch" plow layer with an irregular lower boundary suggesting that the site was minimally cultivated and abandoned long ago. Seven releves on unplowed sites average 20.4 species per 100 m^2, significantly more (*t* test, $P < 0.001$) than the average of 13.0 species per 100 m^2 found on formerly plowed sites. All releves in group II occurred on sites that were never plowed, with the exception of the one releve on the scratch plowed site. In contrast, 94% of group I releves had distinct plow horizons. All of the sites investigated show evidence of past fires (that is, soil charcoal, stem charring, or fire scars), but only two stands appeared to have burned since the early 1970s.

All releves that were never plowed have high DCA Axis 1 values (Figure 8). Species characteristic of mesic or wet sites (for example, *Tsuga canadensis, Fagus grandifolia, Nyssa sylvatica, Osmunda cinnamomea*, and *O. regalis*) have low Axis 2 scores, as do species such as *Gaylussacia baccata* and *Kalmia angustifolia* that are found on xeric as well as mesic sites (Figure 8). Other xeric-site species have moderate-to-high Axis 2 scores.

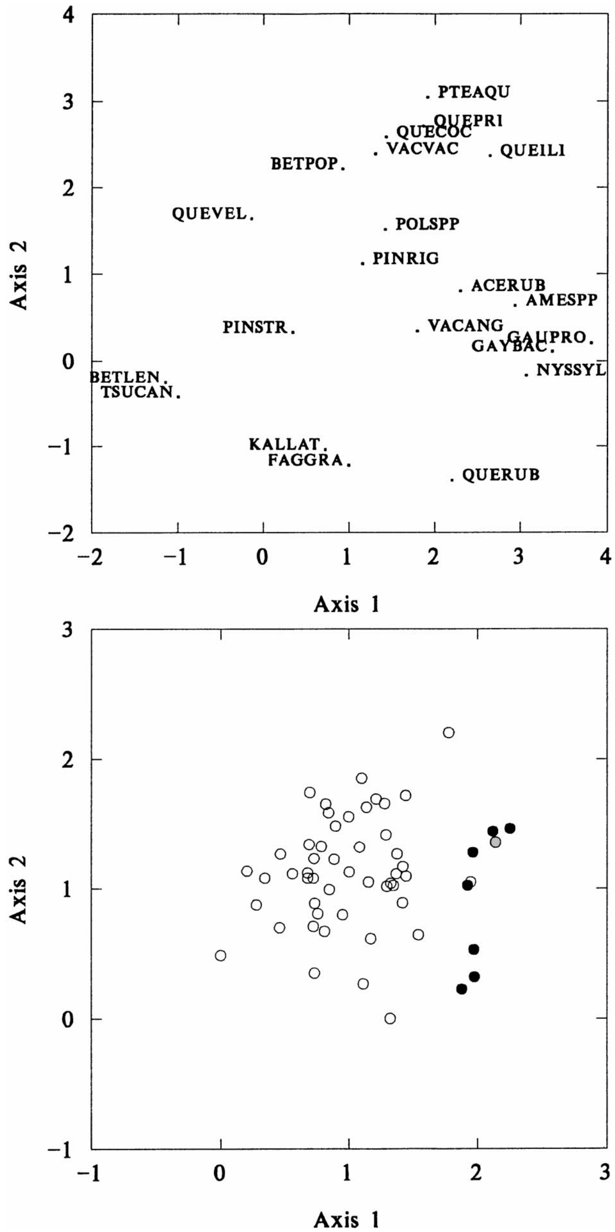

Figure 8. Species (top) and releve (bottom) DCA ordinations of vegetation data from 58 releves in Connecticut Valley pitch pine stands. Filled circles are releves that were never plowed; open circles were plowed historically. Gray shading indicates a single releve on shallow plowed soils. Six-letter acronyms are the first three letters of both the genus and species combined (see Table 3 for complete species names).

Discussion

Historical Changes in the Extent and Distribution of Pine Plains

The total area and distribution of pine plains in the Massachusetts portion of the Connecticut Valley have changed dramatically over the past 350 years. Although the historical record is not sufficiently detailed to allow us to determine the exact area occupied by these communities at the time of European settlement, it does enable us to gain some insight into the magnitude of change that has occurred. Historical references suggesting that early pine plains were largely restricted to areas of "barren" soils are consistent with our results indicating that 91% of modern pitch pine and 100% of scrub oak stands occur on xeric outwash (Bromley 1935; Brierly 1938). We suggest therefore that the 32,000 ha of xeric outwash that occurs in the Connecticut Valley (in addition to unmapped xeric outwash beneath urban areas) represents a rough approximation of the maximum area that could have supported PPSO or related communities in the past. In fact, historical sources confirm that most large and many small xeric outwash deposits supported pine plains at various times during the historical period (Figure 2 and Table 1). For instance, the Springfield/ Chicopee Plain apparently supported several thousand hectares of pine plains (Figure 3), and the towns of Montague, Westfield, and Longmeadow/ East Longmeadow probably each supported 500 to more than 1000 ha (Massachusetts Archives 1794, 1830; Pressey 1910; Lockwood 1922). Historical records document numerous smaller pine plains throughout the study area (Table 1), perhaps representing an additional one to several thousand hectares. For a few towns (for example, Southwick and Holyoke) where we found no references to pine plains before the 20th century, the occurrence of modern stands on extensive xeric outwash deposits leads us to suspect that pine plains may have occurred historically. Based on the historical record alone, we estimate that at the time of European settlement there were 9000 ha or more of "pine plains," occupying approximately one-third or more of the xeric outwash deposits. Because pine stands probably occurred on some outwash deposits for which we failed to find historical references, the actual extent may have been greater than our estimate.

By 1985 approximately 60% of the xeric outwash plains were in urban (47.6%) or agricultural uses (12.7%), and only approximately 39% remained forested. We documented only 1094 ha of pitch pine stands, 78% of which occur in just two towns, and 74 ha of scrub oak stands, 93% of which occur at one site. Since 1985 several stands have been eliminated, and a few remaining ones occur on mesic sites that we suspect did not previously support extensive pine stands. Thus, modern PPSO communities probably represent less than or equal to 10% of the area that supported pine plains in the early historical period, and several of the largest historical stands have been nearly eliminated completely.

Land-Use History

The 17th to early 19th century history of forest product extraction in the Connecticut Valley is similar to the early use of sand plains throughout the northeastern US (Dwight 1823; Wacker 1979; Milne 1985; Copenheaver 1996). Regulations restricting the use of pines at this time may, in some instances, have resulted from concern over the destruction of limited resources (Hawes 1923). However, such regulations also may have stemmed from attempts to secure financial gain for the towns (for example, Burt 1898). The history of naval stores production in the region is poorly documented because such activity was most important in the 17th and early 18th centuries before the recording of agricultural and industrial census data. By the second half of the 18th and early 19th centuries, when such data were recorded, naval stores production was concentrated in the southeastern US (Malone 1964; Williams 1989).

The timing and extent of agricultural use of sand plains varied considerably across the Northeast. Sand plains in North Haven and Windsor-Suffield, Connecticut were cleared for agriculture in the 18th century and, in North Haven, were abandoned in the first half of the 19th century (Dwight 1823; Olmsted 1937). Although some Massachusetts pine plains probably were used for agriculture in the 18th century, historical maps indicate many forested sites in 1830 (Massachusetts Archives 1830), suggesting that widespread clearance did not occur until after that time. This corresponds with the period of maximum agricultural clearance in central New England, and a shortage of good agricultural land at this time may explain the increased use of droughty sites. Although portions of most northeastern sand plains were used for agriculture in the 19th and early 20th centuries (Collins 1909; Howe 1910; Harshberger 1916; Illick and Aughanbaugh 1930; Olmsted 1937; Wacker 1979; Olsvig 1980; Patterson and others 1984; Milne 1985; Backman and Patterson 1988; Seischab and Bernard 1991, 1996; Motzkin and others 1996), the extent of cultivation varied from more than 80% throughout most of the Connecticut Valley, to approximately one-third of the remaining portions of the Albany Pine Bush (W. Patterson personal observation), to relatively minor areas of sand plains in southwestern Maine (Copenheaver 1996; W. Patterson personal observation). Land use on areas that were not cultivated also varied and included sand extraction (for example, Albany Pine Bush and Montague Plain; Rittner 1976), charcoal and berry production (for example, New Jersey Pine Barrens and Waterboro Barrens, Maine; Wacker 1979; Copenheaver 1996), grazing (for example, coastal New England and elsewhere; Dunwiddie 1992), and repeated harvesting of a variety of forest products (for example, New Jersey Pine Barrens and several northern New England sites; Wacker 1979; Copenheaver 1996; W. Patterson personal observation).

In the Connecticut Valley 19th century land clearance eliminated many pine plains but widespread abandonment of agricultural fields in the late 19th and early 20th centuries created conditions that were favorable for pitch and white pine regeneration. The establishment of white pine on old fields throughout central New England has been well documented (Spring 1905). Our results indicate that on xeric outwash plains and a few mesic sites, pitch pine also became widely established on old fields. These results are consistent with the observations of H. D. Thoreau and others from the mid-19th to early 20th centuries who describe pitch pine as a common old-field species (Collins 1909; Illick and Aughanbaugh 1930; Thoreau 1993). Thus, while agricultural clearance destroyed some historical pine plains, agricultural abandonment encouraged both pitch and white pine to regenerate.

Despite the occurrence of modern pine stands on sites that supported pine historically, vegetation composition and structure within these stands apparently differ substantially from the early historical period. The abundance of large white and pitch pine timber used for construction suggests that old-growth stands of these species were formerly common; such stands do not occur on the modern landscape, and current conservation efforts are focused on the use of prescribed fire to create or maintain open barrens vegetation rather than allow mature stands to develop. Within modern pitch pine stands, vegetation composition varies according to land-use history. The few stands that were never plowed support several species that may have been widespread on the pine plains before agricultural clearance (for example, *Gaylussacia baccata, Gaultheria procumbens, Quercus prinoides,* and *Q. ilicifolia;* Table 3, group II), but that have not widely reestablished on former agricultural sites in the 50 to more than 100 years since agricultural abandonment. These results are consistent with those of Motzkin and others (1996) from Montague Plain where most of the same species also are largely restricted to sites that were never plowed. However, in a few instances, our results differ. For instance, in pitch pine stands throughout the Connecticut Valley, we found *Quercus ilicifolia* to be both less frequent and less abundant on plowed vs unplowed sites. In contrast, on Montague Plain, *Q. ilicifolia* occurs with nearly equal frequency on plowed vs unplowed sites, although it is more abundant on unplowed sites (Motzkin and others 1996). These differences may result from dispersal limitations in a highly fragmented landscape. In contrast, large, contiguous sites, such as Montague Plain, include unplowed areas as a local source of propagules for colonization (Matlack 1994).

Although harvesting and agricultural practices strongly influenced the distribution and composition of sand plains through much of the historical period, present and future distribution is controlled largely by patterns of urban and suburban development. Urbanization has resulted in a dramatic decline in the total extent of PPSO communities, particularly through the elimination of extensive pine plains in the southeastern portion of the study area (Figures 3 and 5). In fact, of the sites that historically supported pine plains, only Montague Plain currently supports extensive PPSO communities. The impacts of urbanization are clearly displayed through a comparison of the histories of the Springfield/Chicopee and Montague Plains. Each area supported extensive pine plains until the mid-19th century (Figures 3 and 4). During the mid-19th to early 20th centuries, Montague Plain was largely cleared for agriculture (Motzkin and others 1996), as were portions of the Springfield/Chicopee Plains. In the 20th century, the Springfield/Chicopee Plain has been nearly eliminated completely by urban development (Figure 3), as have the northwestern portions of the sand plains in Montague (Figure 4). On portions of Montague Plain that have not been developed, extensive PPSO communities have become established that, though they undoubtedly differ from historical pine plains in composition and structure, are of great conservation significance because they are the largest examples of these community types in the Connecticut Valley (Figure 2) and because they support several rare species (Schweitzer and Rawinski 1988; Wheeler 1991). However, plans for industrial development continue to threaten this site as well as Westfield Plain and numerous smaller sites throughout the region.

Fire History

The long-term influence of fire on the distribution, structure, composition, and dynamics of pine plains in the Connecticut Valley is largely unknown. However, some insight into fire history may be derived from historical data in combination with information about fire behavior and species autecology. In the approximately 2000 years before European settlement, fires were apparently common on Montague Plain, resulting in charcoal-to-pollen ratios that were consistently higher than in most upland areas in New England and comparable to or slightly lower than sites in coastal New England (Patterson and Sassaman 1988; Motzkin and others 1996; Fuller and others 1998). Because pitch pine is shade intolerant and does not establish on thick litter (Fowells 1965; Little and Garrett 1990), it is likely that occasional fires were sufficiently severe to consume the organic layer, open the canopy, and allow pitch pine regeneration. However, frequent or severe fires probably would have injured existing pitch pines, resulting in scarring that would have prevented the development of old-growth stands of high quality timber, such as those that were harvested in the 17th and 18th centuries. Thus, while it is not possible to determine definitively the pre-European fire regime of Connecticut Valley pine plains, we suspect that fires were occasionally severe enough to consume the soil organic layer (Little and Moore 1949; Forman and Boerner 1981).

The documented decline in fire occurrence throughout the region in the second half of the 20th century (Cook 1921; Averill and Frost 1933; Motzkin and others 1996) is confirmed for Montague Plain by decreased charcoal-to-pollen ratios (Fuller and others 1998) and is consistent with our observations throughout the Connecticut Valley where we found evidence of fire after agricultural abandonment but where fires within the past few decades have been uncommon. The reduced incidence of catastrophic, large fires in pine barrens throughout New England since World War II resulted from improved fire detection and suppression (Fahey and Reiners 1981; Forman and Boerner 1981; Pyne 1982). Reduced importance of fire in recent decades has allowed white pine, which is more fire intolerant when young and more shade tolerant than pitch pine, to become established in the understories of most stands sampled (Figure 7). In addition, shade tolerant hardwoods have established in most stands, suggesting that in the absence of future disturbances, white pine and hardwoods may become dominant (Little 1979).

Although fires have become less frequent in recent decades, occasional fires do occur, largely as a result of human ignitions. Most fires today occur during late winter or early spring (Motzkin and others 1996) when soil moisture is high. These fires are often intense but of low severity in terms of soil organic matter consumption (W. Patterson personal observation). Severe summer burns, such as those that might encourage pitch pine regeneration, typically spread slowly through the organic layer, and modern fire suppression practices greatly limit the number and extent of such fires.

Of particular importance to understanding changes in fire dynamics through the historical period is the changing landscape context that we have documented. Both the nature and frequency of fire are influenced by the surrounding landscape (Givnish 1981). In the pre-European period, extensive xeric outwash plains were dominated by highly flammable vegetation. Fires in such a landscape had a high probability of spreading, and it is likely that they would occasionally impact large areas. In contrast, modern PPSO and other flammable communities are typically small and relatively isolated, occurring in a matrix of developed land or less flammable vegetation. Even in the absence of fire suppression, modern fires would have a lower likelihood of spreading to large areas in this highly dissected landscape. Fire behavior also differs in dissected vs contiguous landscapes. The catastrophic, high intensity fires characteristic of PPSO barrens in the early and middle decades of the 20th century developed over areas of several thousand hectares or more (R. Winston unpublished manuscript). Many of the pine barrens fragments remaining in the Connecticut Valley today are less than 10 ha in size and could not support fires that would grow to the intensity of historical fires. Instead, fire incidence as well as intensity are likely to be far lower in modern pitch pine stands.

Conservation and Management Implications

Our results document the significant impact of historical agriculture and 20th century urbanization on xeric outwash deposits of the Connecticut Valley of Massachusetts. The development of outwash plains for urban and agricultural uses has substantially altered the distribution of natural communities occupying these sites, influencing ecological processes, such as disturbance regimes and species dispersal patterns, that are dependent in part on these landscape patterns. Most undeveloped outwash plains were cleared and plowed for agriculture, and several species, including *Gaultheria procumbens* and *Gaylussacia baccata,* that we suspect were formerly widespread on xeric outwash have not colonized many of these old fields in the 50 to more than 100 years since agricultural abandonment. Paleoecological analyses from Montague Plain (Fuller and others 1998) and anecdotal evidence from throughout the Connecticut Valley suggest that the structure of modern stands also differs from early historical pine plains. For instance, old-growth pitch and white pine, which were apparently widespread in the early historical period, have been completely eliminated by historical cutting and land clearing. We conclude therefore that modern PPSO communities differ substantially from those that occurred at the time of European settlement with respect to landscape distribution, vegetation composition, structure, and disturbance dynamics.

Although distinct from historical communities, modern PPSO communities are unusual and important components of the landscape, supporting species assemblages and ecological processes that differ from those that occur on the more widespread mesic uplands. Clearing for agriculture, forest cutting, and fire history were the primary historical disturbances impacting these communities prior to the 20th century. Urban development in the 20th century continues to threaten all remaining xeric outwash plains, making it increasingly urgent that the few relatively large and undeveloped sites, notably Montague Plain and portions of Westfield Plain, be protected. In addition, our results highlight the conservation importance of those few sites that were never plowed, as components of landscape diversity and as important sources for colonization of former agricultural sites.

Of particular conservation interest is the fact that PPSO communities support several rare species and, in particular, distinctive insect assemblages that include species that require pitch pine or scrub oak for portions of their life cycles (Schweitzer and Rawinski 1988; Wheeler 1991; Mello 1992). Some characteristic pine barren species (for example, *Hemileuca maia* and *Lycaeides melissa samuelis*) have experienced dramatic population declines in recent decades, giving rise to concerns about their long-term viability (Cryan 1985; Givnish and others 1988). Based on the autecology of several species, a number of hypotheses have been proposed about long-term landscape patterns, vegetation change, and disturbance histories of PPSO communities. Givnish and others (1988) base their interpretation of long-term vegetation patterns and fire frequencies in scrub oak stands in part on observations of the species biology of the Inland Barrens buck moth (*Hemileuca maia*), a species that is characteristic of open scrub oak stands with little forest cover. We found no references to scrub oak stands in the study area prior to the late 19th century. Our results, as well as those of Backman and Patterson (1988), indicate that in some instances the community composition and structure that currently support rare species may be quite different from that which occurred historically, suggesting the need for great caution in using modern conditions to interpret historical habitats and population levels for both rare and common species.

Prescribed fire is increasingly used to manage pine barrens, in part because of the perception that modern PPSO communities differ from those that occurred prior to European settlement primarily as a result of fire suppression. However, as a result of modern fire management practices and the composition, structure, and landscape context of PPSO communities, it is likely that modern fires have differing impacts on the vegetation than historical or prehistorical fires. In particular, all prescribed fires to date have been conducted in the spring, because "open burning" regulations limit the application of fires during dry summer months. Although spring burns temporarily reduce fire hazard, they appear to have little effect on the root systems of hardwood and shrub species that compete with pitch pine. If pine barrens are to continue to have a substantial component of pitch pine, it may be necessary to manage them with treatments including growing season cutting of hardwoods and soil scarification to promote pitch pine regeneration as well as different prescribed burning regimes to facilitate the establishment and maintenance of barrens vegetation (Little and Moore 1949; Matlack and others 1993).

Based on our results, we offer the following specific conservation and management recommendations: (a) land protection efforts should prioritize large, undeveloped sandplains, areas that were not plowed historically, and reestablishment of contiguity between isolated sites to facilitate colonization of former agricultural lands by barrens species; (b) management of PPSO communities should not be restricted to maintenance of open barrens; some PPSO communities should be allowed to mature without frequent severe disturbance; (c) establishment or maintenance of open barrens species and communities may require varied disturbance regimes, perhaps including mechanical treatment in combination with prescribed fire to simulate severe summer fires. In addition, our results suggest that regional–historical perspectives are critical for understanding modern community dynamics and for evaluating conservation objectives and management strategies for uncommon plant communities. Species assemblages, disturbance dynamics, and landscape setting of modern PPSO communities in the Connecticut Valley of Massachusetts are substantially different from those that occurred throughout the past several centuries as a result of species response to local historical land-use practices and changing fire regimes, as well as changes in disturbance dynamics and population processes that are sensitive to the broader landscape setting. This is undoubtedly true of many modern community types, although lack of historical information often limits our ability to document historical and landscape changes. In fact, we know very little about the composition and dynamics of past landscapes, but it is inappropriate to assume that they closely resembled modern ones. Management for unique values associated with modern communities must therefore be based on an understanding of both modern ecosystem dynamics and the processes that have changed these communities from their prehistoric "analogues."

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