RESEARCH ARTICLE

Composition, Structure, and Tree Reproduction at White Pine Hollow, Iowa, USA: A Remnant Old-Growth Forest

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Natural Areas Journal 23:238–246

ABSTRACT: A relict population of eastern white pine (*Pinus strobus* L.) occurs at White Pine Hollow State Preserve in northeastern Iowa, USA. White pine was not self-replacing in our study plots here, and without disturbances that alter the successional trend the species will eventually disappear from the flat to rolling uplands where most pines currently occur. Some natural pine reproduction occurs on steep slopes. Live tree density was 967 trees ha^{-1}, and mean basal area was 34 m^2 ha^{-1}. Basal area was significantly greater on plots with white pine. Without recruitment of pine into the overstory, these plots will experience declines in basal area. The diameter distribution of all live trees had a negative exponential shape. However, the distributions for white pine, white oak (*Quercus alba* L.), and northern red oak (*Quercus rubra* L.) were unimodal, with no or few trees in the smaller size classes. Compared to a previous study at White Pine Hollow, there has been a dramatic decrease in the density of white pine and white oak trees, and an increase in sugar maple (*Acer saccharum* Marsh.). Mean density of standing dead trees was 95 trees ha^{-1} with basal area 4 m^2 ha^{-1}. Overall, the number of standing dead trees by diameter class was 10% that of live trees, but this relationship did not hold true for individual species. For white pine and the oaks, the ratio of dead to live trees was much greater than the average for all species combined. The mean volume of downed wood was 66 m^3 ha^{-1}.

Composición, Estructura, y Reproducción de Árboles en White Pina Hollow, Iowa, USA: un Remanente de Bosque Maduro

RESUMEN: Una población relictual de pino blanco del este (*Pinus strobus* L.) existe en la Reserva Estadual de White Pine Hollow en el Norte de Iowa, USA. El pino blanco no se está autoreempazando en los plots que estudiamos, y sin disturbios que alteren la tendencia sucesional la especie eventualmente desaparecerá desde el llano a las lomas donde existe la mayoría de los pinos. Cierta reducción natural de pinos ocurre en las pendientes pronunciadas. La densidad de árboles vivos fue de 967 árboles ha^{-1}, y el área basal media fue de 34 m^2 ha^{-1}. El área basal fue significativamente mayor en los plots con pino blanco. Sin el reclutamiento de pinos en el dosel, estos plots experimentarán disminuciones en su área basal. La distribución del diámetro de todos los árboles vivos tuvo una forma exponencial negativa, no obstante las distribuciones para pino blanco, roble blanco (*Quercus alba* L.), y el roble rojo del norte (*Quercus rubra* L.) fueron unimodales sin o con pocos árboles en las clases pequeñas. Comparado con un estudio previo en White Pine Hollow, hubo una disminución dramática en la densidad de pinos blancos y robles blancos, y un aumento del arce dulce (*Acer saccharum* Marsh.). La densidad promedio de los árboles muertos en pie fue de 95 árboles ha^{-1}, con un área basal de 4 m^2 ha^{-1}. En general el número de árboles en pie sin vida por clase de diámetro fue el 10% de los árboles vivos, pero esta relación no se mantuvo cuando el análisis se hizo por especie. Para el pino blanco y los robles, la tasa de árboles muertos sobre los vivos fue mucho mayor que el promedio para todas las especies combinadas. El volumen promedio de madera colectada fue de 66 m^3 ha^{-1}.

Index terms: old-growth forest, *Pinus strobus* L., succession, coarse woody debris, tree cavities

INTRODUCTION

Interest in White Pine Hollow State Preserve, an old-growth forest located in northeastern Iowa, USA (Figure 1), dates back to the 1930s. Naturalists from Dubuque recognized its unique features and it soon became the first forest in the state to be preserved (Cawley 1965). The core of the preserve was acquired from 1935 to 1937, and additional parcels were added in 1942 and 1964. In 1968 the unit was formally dedicated as a state preserve. The total area of the preserve today is 288 ha. In 1989 and 1992 additional land was acquired but is not currently dedicated as a part of the preserve due to past disturbances.

The richness of White Pine Hollow's flora has long been recognized and the area is commonly used as a classroom for university botany courses. Detailed compilations of plant species present in the Hollow were created (Pammel 1923, Conard 1932, Thorne 1964), and many of the species found there were noted as relicts of northern and eastern forests (Thorne 1964).

Today, White Pine Hollow is one of the few remnant old-growth forests in the state. Both its old-growth qualities and its location along the southern extent of eastern white pine's (*Pinus strobus* L.) natural distribution lend themselves to its unique character (Rosendahl 1955). White pine, however, is no longer regenerating in the flat upland and ridgetop habitats where the majority of mature pines presently occur. It appears that over time white pine will be replaced by hardwood species, except on limited areas of steep slopes where some pines have successfully regenerated and escaped deer grazing. This successional trend was previously recognized by Cawley (1965).

In 1994 we inventoried the woody vegetation in White Pine Hollow as part of a larger study of old-growth forests in the Midwest (Shifley et al. 1997, Spetich 1995, Spetich et al. 1999). This paper reports findings for White Pine Hollow and compares the composition and structure of the vegetation at White Pine Hollow with values for other old-growth hardwood and hardwood-pine study sites in the Midwest.

STUDY AREA

White Pine Hollow State Preserve lies in the northwestern corner of Dubuque County in Liberty Township (T90N, R2W, parts of Sec. 5, 6, 7, and 8), 3.2 km northwest of Luxembourg, and is a remote management unit of the Yellow River State Forest. Three branches of the Pine Hollow Creek run through the preserve, creating steep slopes and deep ravines. A variety of geological features including cliffs, sinkholes, talus slopes, large slump-blocks, and springs are common (Herzberg and Pearson 2002). It is a unique and ecologically important area lying along the southwestern boundary of white pine's natural distribution (Burns and Honkala 1990). Eastern white pine occurs in two habitats within the preserve. Mature dominant pines are most abundant on the flat to rolling uplands in the southeastern portion of the preserve and probably originated following significant past disturbance(s). Eastern white pine also is found on steep, rocky slopes scattered throughout the preserve; this is more typical for white pine in northeastern Iowa. Yew (*Taxus canadensis* Marsh.) and some uncommon herbaceous species are also are found in the preserve, which has some unique microclimates due to steep topography and narrow ravines (Thorne 1964).

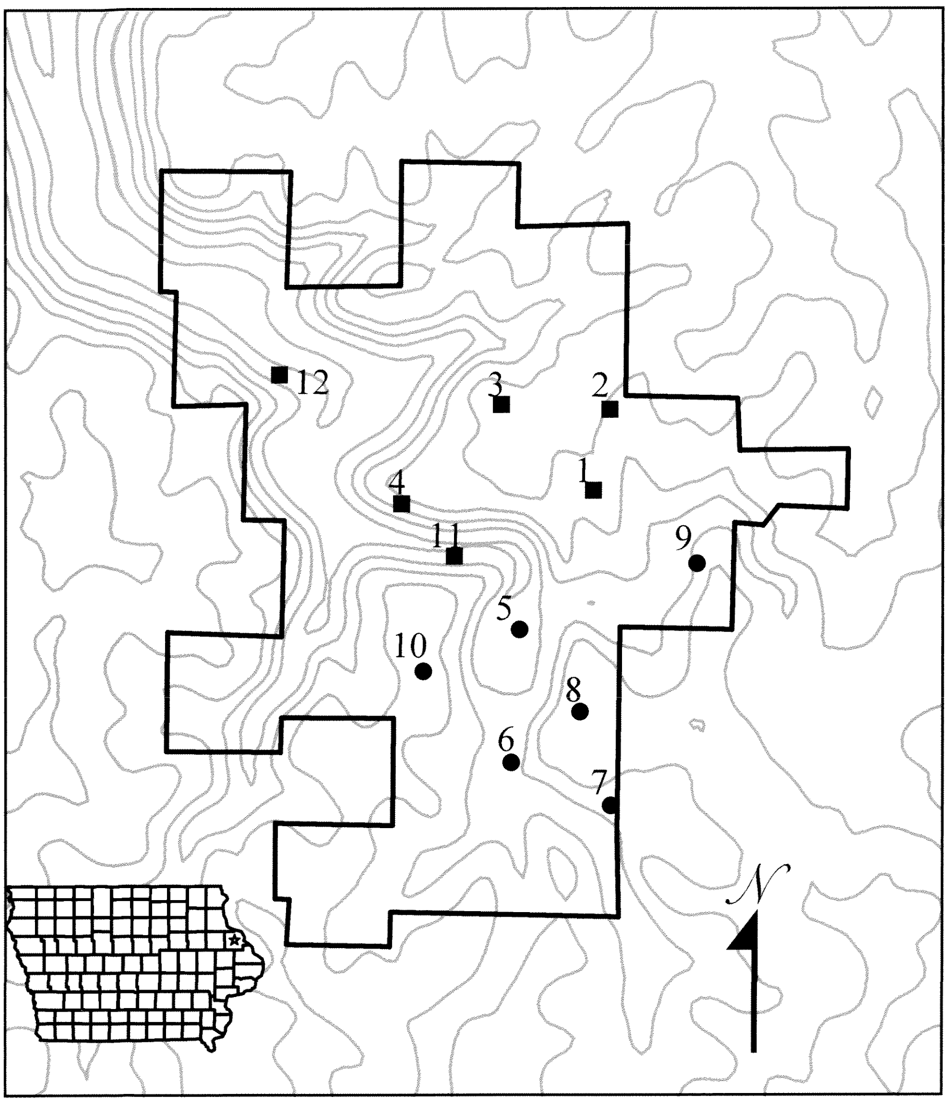

Figure 1. Map of White Pine Hollow, Dubuque County, Iowa, USA. Circular markers indicate plots where white pine trees occurred. Contours are on 50-foot intervals.

Average precipitation at the nearest weather station (Guttenberg L & D 10) is 81 cm annually. July is normally the wettest month, with an average of 11 cm of rainfall. The coldest and warmest months are typically January and July, with average low temperatures in January of -14 °C and average highs in July of 29 °C. The great majority of land area at White Pine Hollow lies on gently sloping to very steep (≥ 60%), well drained, silty soils that formed in loess or silty surficial sediment with an underlying residuum of limestone. The northwestern reaches of the state park is characterized by moderately sloping to steep topography with well drained and moderately well drained, silty soils that formed in loess over an underlying residuum of shale (U.S. Soil Conservation Service 1985). Elevations range from 260 to 360 m above sea level.

Some trees in White Pine Hollow exceed 300 years in age. In the past, some of the largest trees in the preserve were subjectively selected for coring and aging. In the 1980s, 18 oak trees were found to have years of origin varying from 1560 to 1830 (D. Duvick, unpubl. data). In the early 1990s, 15 white oaks (*Quercus alba* L.) originating between 1700 and 1867, and approximately 50 white pines dating back to the 1860s, were cored (J. Pleasants, unpubl. data). In another study, the oldest tree cored was a white oak that dated back to 1631, and the oldest white pine cored originated in 1829. At least 13 white oaks originated around 1800, and at least 16 white oaks and 18 white pines originated prior to 1900 (Landers and Duvick, n.d.).

METHODS

In the spring of 1994, we sampled 12 50-m by 20-m (0.1-ha) rectangular plots in White Pine Hollow State Preserve. Plot corners had been previously established by Dr. John Pleasants from Iowa State University. Slope, aspect, and topographic position were recorded at each plot. Plots were primarily on rolling uplands and moderate slopes; slopes on inventory plots ranged from 4% to 65%, with three-fourths of plots less than 25% slope. Plot aspects were nearly equally distributed among protected (north and east) and exposed (south and west).

Information for trees ≥5 cm dbh (diameter at breast height, 1.3 m above ground level) was gathered on the 0.1-ha main plots, and trees ≥2 cm and <5 cm dbh were sampled on 0.01-ha subplots. For plots 1 and 2, the 0.01-ha subplot was located in a 20-m by 5-m strip at the end of the main plot. For all other plots, the subplot was circular and located in the center of the main plot. We recorded species and dbh for all trees. For live trees ≥5 cm, we also recorded crown class (dominant, codominant, intermediate, or suppressed) and decay stage (healthy live, declining, or standing dead in various stages of decomposition). Total height was measured for a subset of 159 trees that encompassed a range of diameter classes. For dead trees, we recorded species (if known), decay stage, and height. All trees were examined for cavities, and the number, size, and type of cavities were noted. Each tree was permanently numbered for future repeat inventory.

We tallied woody stems ≥1 m tall and < 2 cm dbh by species on four 2.5-m^2 subplots per main plot. We visually estimated percent herbaceous vegetation cover (< 1 m tall) on these subplots. Additionally, we estimated and recorded the percent ground cover of tree boles, dead leaves and foliage, down wood, exposed rock, bare ground, or other material on these 2.5-m^2 subplots.

Downed wood ≥10 cm diameter was inventoried on the 0.1-ha main plots. For each piece of wood, we recorded the length, midpoint diameter, and decomposition class. The five decomposition classes followed Maser et al. (1979) and ranged from recently fallen (class 1) to almost fully decayed (class 5).

Individual species' importance values (IV) were calculated as [relative density + relative basal area] / 2. For most other analyses, individual species were grouped (Table 1). Species nomenclature follows Little (1979). Stocking percents were calculated using tree area equations in Gingrich (1967) and Stout et al. (1987), and derived

Table 1. Species groups used for analysis at White Pine Hollow, Dubuque County, Iowa.

Species Group	Included Species [a]
Ash	white ash, green ash, black ash
Elm	American elm, slippery elm
Hickory	bitternut hickory, shagbark hickory
Maple	sugar maple
Pine	white pine
Red oak	northern red oak
White oak	chinkapin oak, white oak
Other	American basswood, bigtooth aspen, black cherry, black walnut
Understory	musclewood, ironwood
Lianas	grape, poison ivy

[a] Scientific names of all woody species are listed in Table 3

Table 2. Mean, standard deviation, and range for characteristics of live and dead trees and down wood for all plots combined at White Pine Hollow, Iowa.

Characteristics		Mean	SD	Range
Density (trees ha^{-1})	Live trees ≥2 cm dbh	967	175	750–1300
	Live trees ≥10 cm dbh	399	93	290–580
	Dead trees ≥2 cm dbh	95	46	30–190
	Dead trees ≥10 cm dbh	47	23	20–80
Basal Area (m^2 ha^{-1})	Live trees ≥2 cm dbh	34.0	9.0	19.5–49.8
	Live trees ≥10 cm dbh	32.4	9.0	16.8–48.1
	Dead trees ≥2 cm dbh	4.1	2.7	0.7–10.8
	Dead trees ≥10 cm dbh	4.0	2.8	0.5–10.8
Stocking (%)	Live trees ≥2 cm dbh	109.7	20.1	73.4–139.5
	Live trees ≥10 cm dbh	101.2	20.6	59.0–130.4
	Dead trees ≥2 cm dbh	12.66	7.9	2.9–31.1
	Dead trees ≥10 cm dbh	12.0	8.2	1.9–31.1
Down wood (m^3 ha^{-1})	Logs >10 cm diameter	66.3	40.3	20.9–144.1

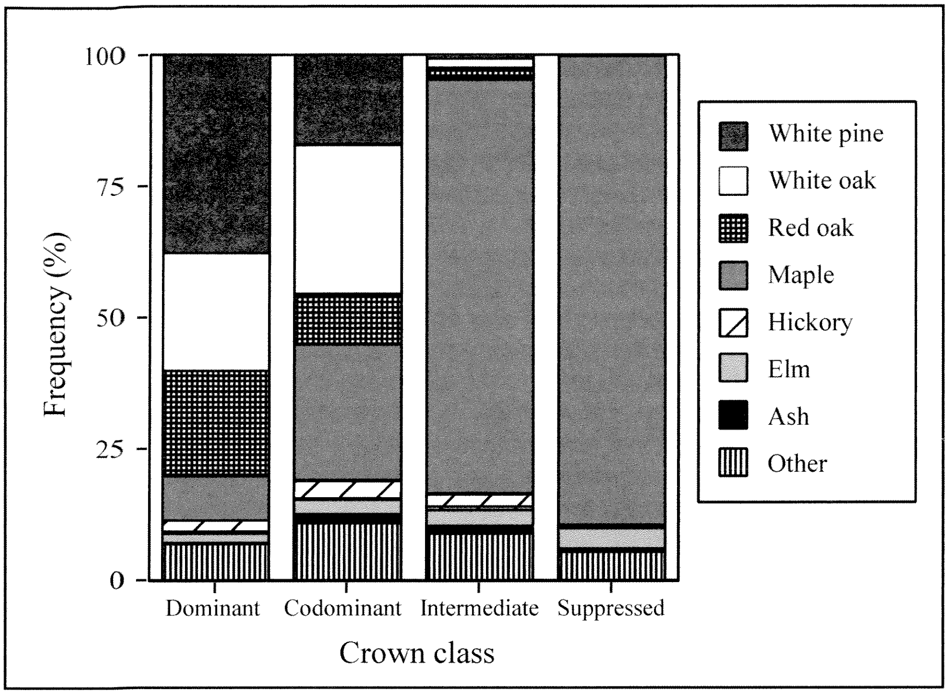

Figure 2. Relative distributions of species groups within four crown classes at White Pine Hollow, Iowa. Species groups are defined in Table 1.

from Philbrook et al. (1973).

RESULTS

Species Composition and Importance Values

White Pine Hollow had a mean density of 967 live trees ha^{-1} ($\geq$2 cm dbh), but values ranged from 750 to 1300 trees ha^{-1} among the 12 plots sampled (Table 2). The basal area of live trees ranged from 20 to 50 m^2 ha^{-1} with a mean of 34 m^2 ha^{-1}. Eighty-nine percent of all live trees were classified as healthy, while 11% were declining. For all species combined, approximately 5% of trees were in a dominant canopy position, 20% were codominant, 30% were intermediate, and 45% were overtopped. Figure 2 shows the relative distribution of species groups within these canopy positions.

Twenty-one woody species were found on the study plots (Table 3). Sugar maple (*Acer saccharum* Marsh.) had the highest importance value, the highest relative density, and a high basal area. Eastern white pine was second in importance. Although it had a much lower relative density than sugar maple, the pine had the highest relative basal area of any species. White oak and northern red oak (*Quercus rubra* L.), third and fourth in importance value, were similar, with large relative basal areas. Ironwood (*Ostrya virginiana* [Mill] K. Koch), an understory species, was fifth in importance due to a large number of small trees. Only seven woody species at least 1 m tall and less than 2 cm dbh were recorded (Table 4). None were white pine, white oak, or northern red oak, which dominated the overstory.

Diameter Distributions and Tree Height

For all species combined, the diameter distribution for live trees $\geq$2 cm dbh had a negative exponential form (Figure 3). When plotted separately, sugar maple followed this shape very closely, while other species groups did not. The pine, white oak, and red oak groups had unimodal diameter distributions. No pines <18 cm dbh were present on the study plots, and the smallest white oak was 16 cm dbh.

The two largest trees we sampled were a 111-cm-dbh northern red oak and an 82-cm white pine. An average of 53 trees ha^{-1} were $\geq$ 50 cm dbh, and 21 trees ha^{-1} were $\geq$ 60 cm dbh. Trees $\geq$ 60 cm dbh accounted for only 2% of the total density but 24% of the total basal area. Sixty percent of these large trees were white pine, and 36% were oaks.

A 38-m white pine was the tallest tree sampled on the site (Table 5). Forty percent of all trees in the dominant crown class were white pine, although pines occurred on only half of the 12 sample plots (Figure 2). Where white pines occurred, they tended to be taller than other trees of similar diameter. For woody stems $\geq$1 m tall and < 2 cm dbh, the mean density was 2917 stems ha^{-1} (Table 4), but density varied considerably among plots.

Snags

The mean density of snags (i.e., standing dead trees) $\geq$ 2 cm dbh was 95 trees ha^{-1}, and the mean basal area of these trees was 4 m^2 ha^{-1} (Table 2). Almost 60% of dead stems were in decay classes 3 and 4 (main bole intact, with the majority of the bole covered by tight or loose bark). White pine and white oak accounted for approximately 12% and 25% of the number of snags, respectively, compared to about 5% and 6% of the number of live trees. In contrast, sugar maple accounted for over 60% of the live stems, but 28% of the dead stems. The diameter distribution for dead trees followed a negative exponential form, and the relative frequency of dead trees by dbh class was similar to the relative frequency of live trees (Figure 4). The largest dead tree was a 70-cm-dbh white oak. The average height of all dead trees was 8 m; many dead trees were in intermediate and suppressed crown classes and/or had broken tops.

Cavities

Four percent of live trees and 28% of dead trees had at least one natural or excavated cavity with minimum height and width $\geq$ 2 cm. Live trees 30 to 50 cm dbh and dead trees >30 cm dbh were most likely to have cavities (Figure 5). Live trees were most

Table 3. Dbh distribution, density, basal area, and importance value for woody species ≥2 cm dbh at White Pine Hollow, Iowa.

Scientific Name	Common Name	Density (trees ha^{-1}) by dbh class (cm) 2–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–120	Density (trees/ha^{-1})	Basal Area (m^2/ha^{-1})	Relative Density (%)	Relative Basal Area (%)	Importance Value[a]
Acer saccharum Marsh.	Sugar maple	390.00	150.83	21.67	13.33	3.33	2.50	—	—	—	—	581.67	6.54	60.17	19.24	39.70
Pinus strobus L.	Eastern white pine	—	0.83	1.67	9.17	8.33	11.67	9.17	2.50	0.83	—	44.17	9.72	4.57	28.61	16.59
Quercus alba L.	White oak	—	4.17	5.83	16.67	17.50	10.00	3.33	—	—	—	57.50	8.03	5.95	23.62	14.79
Quercus rubra L.	Northern red oak	0.83	2.50	3.33	5.83	5.83	5.00	2.50	0.83	—	0.83	27.50	4.96	2.84	14.60	8.72
Ostrya virginiana (Mill.) K. Koch	Ironwood	95.83	14.17	—	—	—	—	—	—	—	—	110.00	0.45	11.38	1.34	6.36
Tilia americana L.	American basswood	24.17	15.83	8.33	3.33	3.33	0.83	—	—	—	—	55.83	1.77	5.78	5.21	5.49
Ulmus americana L.	American elm	9.17	6.67	2.50	—	0.83	—	—	—	—	—	19.17	0.37	1.98	1.10	1.54
Carya ovata (Mill.) K. Koch	Shagbark hickory	1.67	0.83	3.33	4.17	—	—	—	—	—	—	10.00	0.61	1.03	1.79	1.41
Carpinus caroliniana Walt.	Musclewood	21.67	—	—	—	—	—	—	—	—	—	21.67	0.09	2.24	0.26	1.25
Juglans nigra L.	Black walnut	—	—	0.83	—	—	0.83	—	0.83	—	—	2.50	0.56	0.26	1.65	0.96
Ulmus rubra Mühl.	Slippery elm	5.83	3.33	—	0.83	—	—	—	—	—	—	10.00	0.17	1.03	0.50	0.77
Vitis spp.	Grape	9.17	—	—	—	—	—	—	—	—	—	9.17	0.02	0.95	0.04	0.50
Populus grandidentata Michx.	Bigtooth aspen	—	—	—	0.83	0.83	—	—	—	—	—	1.67	0.24	0.17	0.70	0.44
Prunus serotina Ehrh.	Black cherry	—	—	0.83	—	—	0.83	—	—	—	—	1.67	0.22	0.17	0.66	0.41
Carya cordiformis (Wangenh.) K. Koch	Bitternut hickory	3.33	—	0.83	—	—	—	—	—	—	—	4.17	0.05	0.43	0.15	0.29
Fraxinus americana L.	White ash	—	—	0.83	0.83	—	—	—	—	—	—	1.67	0.11	0.17	0.33	0.25
Fraxinus nigra Marsh.	Black ash	3.33	0.83	—	—	—	—	—	—	—	—	4.17	0.02	0.43	0.07	0.25
Celtis occidentalis L.	Hackberry	0.83	0.83	—	—	—	—	—	—	—	—	1.67	0.01	0.17	0.03	0.10
Quercus muehlenbergii Engelm.	Chinkapin oak	—	—	0.83	—	—	—	—	—	—	—	0.83	0.03	0.09	0.08	0.08
Rhus radicans L.	Poison ivy	0.83	—	—	—	—	—	—	—	—	—	0.83	0.00	0.09	0.01	0.05
Fraxinus pennsylvanica Marsh.	Green ash	0.83	—	—	—	—	—	—	—	—	—	0.83	0.00	0.09	0.01	0.05
TOTAL		567.49	200.82	49.98	54.99	39.98	31.66	15.00	4.16	0.83	0.83	966.67	34.00	100.00	100.00	100.00

[a] Importance value calculated as (relative density + relative basal area) / 2.

likely to have just one cavity per tree for all dbh classes. For all but the smallest diameter class, a greater percentage of dead trees than live had multiple cavities per tree. For both live and dead trees, the number of mid-sized cavities (5.0 to 9.9 cm opening) per ha was greater than the number of smaller or larger cavities per ha. In most cases this relationship held true even when trees were grouped by dbh class.

Table 4. Density of woody stems < 2 cm dbh and ≥1 m tall.

Species	Stems ha^{-1}
Musclewood	1500
Sugar maple	667
American elm	334
Basswood	167
Bitternut hickory	83
Hackberry	83
Ironwood	83
TOTAL	2917

Ground Cover and Coarse Woody Debris

On average, live herbaceous material was found over approximately one-quarter of the ground surface area. Nearly 3% of the ground surface was covered by downed wood (Table 6) with a mean volume of 66 m^3 ha^{-1} (Table 2). The diameter distribution of pieces of downed wood had a negative exponential form. Nearly 90% of the pieces of down wood were in decay states 3 and 4 (i.e., absent bark and twigs; in contact with the ground; round to oval in shape; and either broken large hard pieces or decomposed into small, soft, blocky pieces).

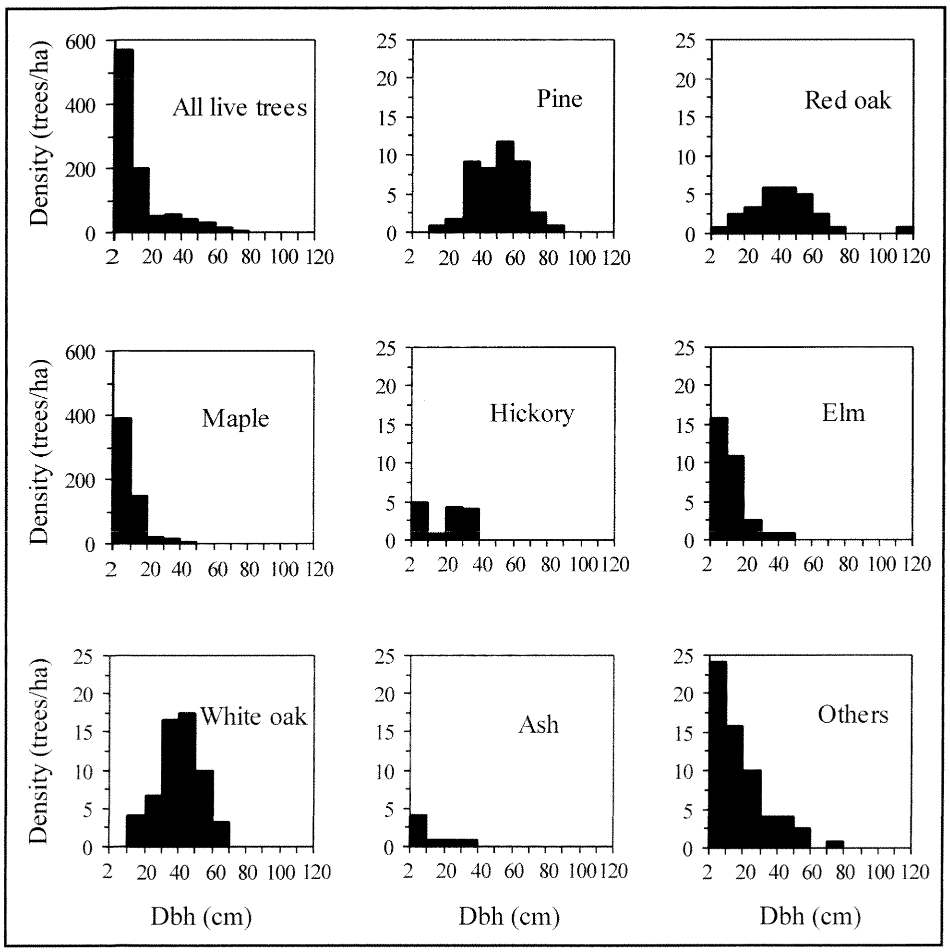

Figure 3. Frequency distribution for number of live trees in 10-cm dbh classes for all species combined and for individual species groups at White Pine Hollow, Iowa. Species groups are defined in Table 1.

DISCUSSION

Cawley (1965) concluded that sugar maple and ironwood were replacing white pine and white oak in the understory of White Pine Hollow. Two of our study plots in the rolling uplands were in close proximity to the two plots sampled in that study, and we were able to make some comparisons. Between 1965 and 1994 there was a dramatic decrease in the density of white pine trees and saplings, and an increase in sugar maples in both the tree and sapling size classes (Table 7). White oaks showed a similar decline in abundance. A reduction in the total number of large oaks and pines is the inevitable consequence of self-thinning in a maturing forest, but the lack of these species in the reproduction layer signals an impending shift in the species composition.

In nearby southwestern Wisconsin, white pine has been found to be regenerating on steep slopes at a number of sites, but was highly variable depending on local disturbance factors (Ziegler 1995). The current woody vegetation structure on the study plots at White Pine Hollow strongly supports Cawley's (1965) contention that the dominance of white pine, white oak, and northern red oak in the upper canopy strata (Figure 2) and in the larger diameter classes (Figure 3) will not continue. The current dominance of maple in the lower canopy strata indicates that, barring the large and repeated disturbances needed for the oaks and pine to regenerate, sugar maple will continue to increase at the expense of white pine and white oak. The sites we sampled were fully stocked with trees, and tree recruitment will be limited to species that are tolerant of shade and of deer browsing. There will be a gradual shift in the tree size distribution as the large trees of low or intermediate shade tolerance (e.g., oaks and white pine) are replaced by numerous smaller maples. White pine reproduction was observed only on steep slopes (outside the sampled plots) where overstory competition and deer browse appeared to be substantially less than on the upland flats and ridges.

In a regional analysis of midwestern U.S. old-growth forests (Spetich 1995), seven-

Species	No. Obs.	Max. Height (m)	Mean Height[a] (m)
White pine	31	38	30
White oak	22	32	23
N. red oak	13	31	23
Sugar maple	70	28	14
Black walnut	3	28	—
Bigtooth aspen	1	28	—
American elm	2	24	—
American basswood	5	22	—
Shagbark hickory	3	21	—
Ironwood	8	18	—
White ash	1	14	—

Table 5. Maximum height and mean height of live trees across a range of diameters.

[a] Computed only for species with sample size greater than 10.

teen other old-growth stands in the central hardwoods of Missouri, Illinois, and Indiana were sampled following the methods used in this study. Compared to those hardwood forests, live tree density at White Pine Hollow was low but basal area and dead tree density were higher. Remnant old-growth white pine stands frequently have basal areas in excess of 55 m^2 ha^{-1} (Philbrook et al. 1973, Tyrrell et al. 1998). In contrast, the basal area of old-growth hardwood forests in the Midwest rarely exceeds 35 m^2 ha^{-1} (e.g., Parker 1989, Shifley 1994, Spetich 1995). At White Pine Hollow the mean number of trees per hectare did not differ significantly between plots with and without white pine (one-way ANOVA comparison of means, P=0.2), but the total basal area was significantly greater on the plots with pine (Figure 6). Mean basal area for these plots was 41 m^2 ha^{-1}, compared to 30 m^2 ha^{-1} for plots without pine (P = 0.0007). Mean basal area on areas with white pine will undoubtedly decline as pines are replaced by hardwoods. This process will also result in a substantial accumulation of downed wood on the forest floor.

The relationship between the number of live trees and standing dead trees by diameter class found here is a pattern that has been observed for numerous remnant old-growth hardwood forests in the Midwest (Spetich et al. 1999). There is no a priori reason to expect similarity of form between the diameter distribution of live and standing dead trees, particularly given the many factors that potentially affect the relationship (e.g., growth, survival, and decomposition rates; snag windthrow frequency). The similarity in the relative abundance of live and dead trees by diameter class does not hold for individual species. For white pine, northern red oak, and white oak, the ratio of dead to live trees was 25%, far greater than the average for all species combined. These three species were among the largest trees on the site, and this high ratio of dead to live trees may result simply from the ability of large snags to remain standing for many years and thus accumulate in the larger size classes.

The unique contribution of eastern white pine to the species diversity and scenic beauty of White Pine Hollow will gradually diminish as the species disappears from the upland areas of the preserve. The trend is readily apparent, evidenced by the high density and basal area of dead white pines, the low density but high basal area of live white pines, and the lack of white pine regeneration except on the steepest bluff sites. The management dilemma is how to maintain the unique old-growth character

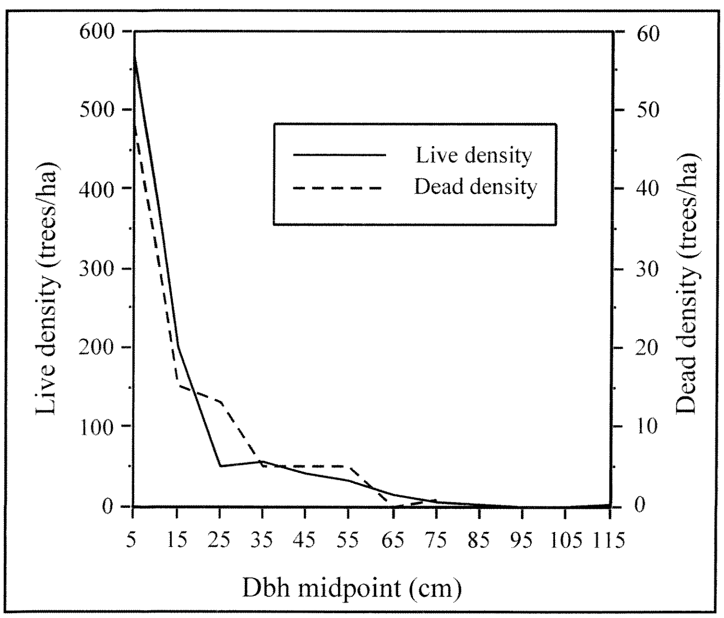

Figure 4. Frequency distributions for live and dead-standing trees in 10-cm dbh classes at White Pine Hollow, Iowa. Note that the two curves have scales that differ by a factor of ten.

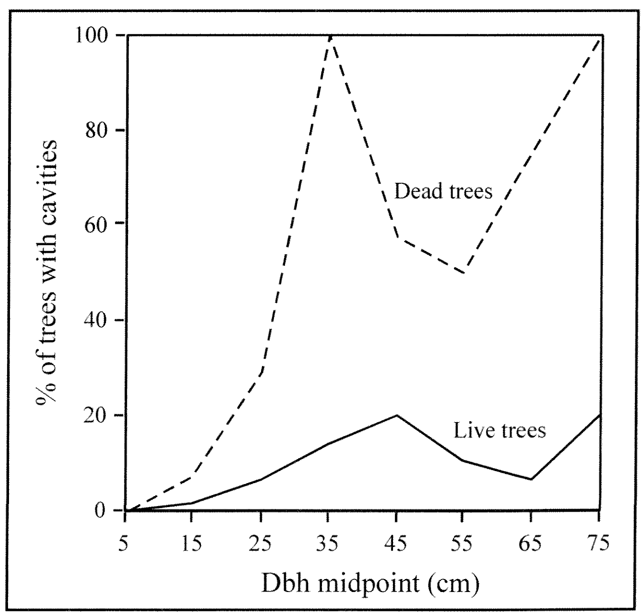

Figure 5. Frequency by diameter class of live trees and snags for trees with at least one cavity, White Pine Hollow, Iowa.

Table 6. Mean percent of ground surface covered by various materials, exclusive of live vegetation.

Material	% Coverage
Dead leaves	85.6
Bare ground	8.5
Downed wood	2.9
Tree boles	1.3
Moss	0.2
Exposed rock	1.5

of the site while encouraging pine and oak reproduction, which generally benefit from multiple, appropriately timed disturbances (natural or anthropogenic) and control of deer browsing where it limits the reproduction. A management plan currently being developed by the Iowa Department of Natural Resources recognizes this dilemma and incorporates the application of managed disturbances (including burning and cutting) in the upland where mature eastern white pines are currently most abundant.

Table 7. Density (number ha^{-1}) comparisons for trees and saplings on two stands. The 1965 data are from Cawley (1965), and saplings were 2.5–9.9 cm dbh. For the 1994 data, saplings were 2.0–9.9 cm dbh. The 1965 data for saplings are approximate because values were read from a chart.

		Stand 1		Stand 2	
Species	Size Class	1965	1994	1965	1994
White pine	Saplings	20	0	8	0
	Trees	477	220	141	50
White oak	Saplings	0	0	25	0
	Trees	12	0	220	0
Sugar maple	Saplings	341	360	178	510
	Trees	20	300	77	130
Ironwood	Saplings	403	40	326	30
	Trees	49	20	30	0

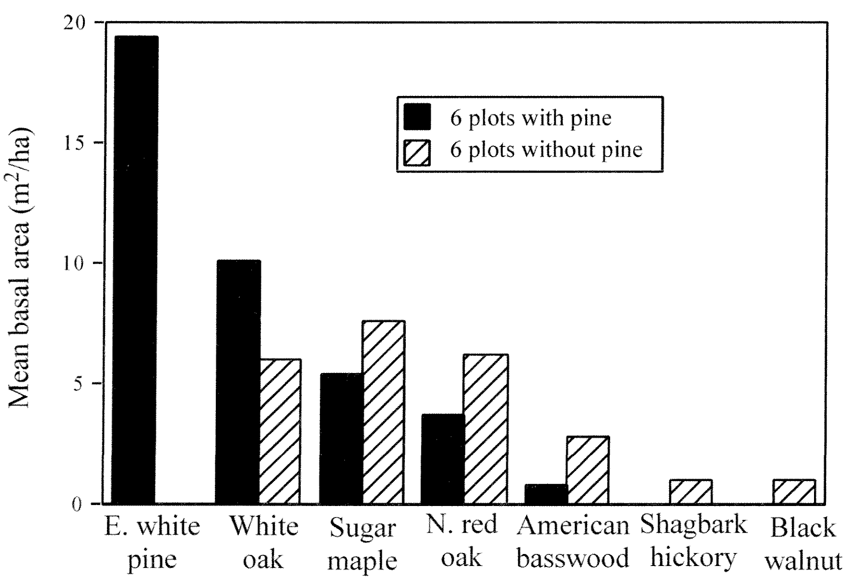

Figure 6. Basal area by species groups for plots with white pine (n=6) and plots without white pine (n=6), White Pine Hollow, Iowa. Species groups are defined in Table 1.

ACKNOWLEDGMENTS

We thank John Pearson, Iowa Department of Natural Resources for facilitating work at White Pine Hollow. He and John Pleasants, Department of Zoology and Genetics, Iowa State University, provided essential maps and information about site history, tree ages, and prior inventories. We are indebted to R. Hoyt Richards, David Roberts, and Anne Shifley who worked long hours assisting with collection of field data.

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