Past and Present Forest Composition and Natural History of Deep Woods, Hocking County, Ohio[1]

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ABSTRACT. Deep Woods, a 114-ha private preserve in Hocking County, OH, is the site of an all taxa biotic inventory (ATBI) coordinated by the Ohio Biological Survey. Here we describe the forest vegetation and natural history of the site and evaluate the role of human disturbance in structuring the regional landscape. Due to various abiotic factors, the area offers a diversity of habitats and species. The bedrock geology consists of sedimentary rock from the Mississippian and Pennsylvanian formations with alluvial deposits along a riparian corridor. At least three soil orders are represented: alfisols, inceptisols, and ultisols. As is typical of most of unglaciated Ohio, the forests here have been subjected to a long history of anthropogenic disturbance. The first inhabitants of the area were ancient moundbuilders (ca. 2500 YBP). During the 1700s, Shawnee and Delaware groups resided throughout the county. Anglo settlers drove all Native American groups out of the area by the early 1800s. The original land survey data (1801) suggested that the dominant vegetation at Deep Woods was composed of *Quercus alba*, *Q. velutina*, *Carya* spp., and *Cornus florida* (relative importance value, RIV = 34, 13, 12, 11%, respectively). Tax records show that Anglo-ownership of the property dates from the mid-1830s. County death records indicate occupations of 19th century landowners primarily as farmers. Dominant vegetation types include: hydric floodplain, mesic upland, and xeric ridgetop. *Betula nigra*, *Carpinus caroliniana*, *Ulmus americana*, and *Liriodendron tulipifera* (RIV = 16, 11, 11, 10%) dominate the floodplain. Whereas *L. tulipifera*, *Acer saccharum*, and *B. alleghaniensis* (RIV = 21, 15, 11%) and *A. rubrum*, *Q. prinus*, and *Q. alba* (RIV= 27, 13, 9%) dominate the upland and ridgetop, respectively. Several other minor habitats also exist such as pasture fields, hemlock ravines, sandstone outcrops, and rockhouse formations. We conclude that the present species composition resembles the 1801 land survey, even though the post settlement disturbances were different than Native American disturbance regimes.

OHIO J SCI 103 (3):42–51, 2003

INTRODUCTION

Early conservation efforts tended to focus primarily on a single species—usually an animal. However, during the last decade, there has been a reawakening of the values of habitats and ecosystems, so the emphasis has shifted to plants and diversity as a whole. The key element to this new approach has been an interest in ecosystem management, instead of a species-by-species approach. One of the many positive by-products of this form of management has been the proliferation of biological inventories. These inventories provide a wealth of information regarding species composition, native versus non-native flora and fauna, species status (threatened, endangered, rare), and species-habitat relationships. In particular, floristic data can be used for regional biological inventories, research, impact assessment, and policy formation (Palmer and others 1995). Thus, information regarding vegetation is becoming increasingly important for land management decisions, especially in heavily populated states such as Ohio. Moreover, there is an increasing need to identify representative habitats in major physiographic provinces of Ohio and to establish all taxa biotic inventories (ATBI). The Ohio Biological Survey has recently identified and is coordinating just such an ATBI at Deep Woods, a 114 ha privately owned preserve located in Hocking County (Anonymous 1998). The area lies within the Cliff Section of the Cumberland and Allegheny plateaus of the mixed mesophytic forest region of Braun (1950). Deep Woods is dominated by sandstone cliffs and hemlock-lined ravines and is thus representative of much of the Hocking Hills Region.

Unfortunately, conservation efforts are often hampered by a lack of historical data. This is true of much of southeastern Ohio. Recently, there has been a resurgence of interest in understanding the American landscape before it was heavily impacted by Anglo-settlement (Williams 1989; Whitney 1994). The need to characterize and understand the natural variability in ecosystems has made vegetation records prior to European settlement quite valuable (Russell 1997; Swetnam and others 1999; Maines and Mladenoff 2000). Also, the reconstruction of presettlement forest communities and original vegetation patterns (Bourdo 1956; Maines and Mladenoff 2000; Black and Abrams 2001; Dyer 2001) is essential if presettlement data are to be used as a benchmark for conservation efforts. Use of historical documentation (Russell 1997) further aids in the identification of prior forest communities and the factors that shaped them.

Here we describe the historical patterns of regional land-use, dominant vegetation, and natural history of Deep Woods, a mature second-growth forest community in Hocking County, OH. The specific objectives of this study are to 1) collate and summarize baseline information

[1]Manuscript received 3 July 2000 and in revised form 5 May 2002 (#00-11).

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on physiography, geology, climate, and forest ecology of Deep Woods to assist researchers of the ATBI, 2) elucidate the anthropogenic history of the area, 3) quantitatively assess the current vegetation, and 4) compare the current vegetation to historical forest composition.

Study Site Description

Physiography: Southeastern Ohio, including Deep Woods, is located within the unglaciated Allegheny Plateau region of the Appalachian Plateau Province identified by Fenneman (1938). Brockman (1998) subdivides the Allegheny plateau into 5 divisions of which the Shawnee-Mississippi and Ironton Plateaus, respectively, describe the Deep Woods area. Even though it is part of the unglaciated Allegheny Plateau, the area was clearly affected by glaciers since it was subjected to the glacial meltwaters (Anonymous 1997). The powerful force of several major glacial events and subsequent production of meltwaters changed the preglacial northwest-flowing drainage known as the Teays River system (Stout and Lamb 1938; Hansen 1995) to the current southeast-flowing drainage pattern. The majority of Ohio's landforms can be attributed to the Wisconsin glacial stage (Peacefull 1996). The meltwaters of the Wisconsin created large terraces along valleys with the deposition of large amounts of sand and gravel (Lemaster and Gilmore 1989). Dissected hills and valleys dominate the area around Deep Woods resulting in a total relief of 134 m. The broken terrain is not conducive to agriculture, which is generally confined to valley floors or windswept ridgetops (Lemaster and Gilmore 1989).

Geology: The variable topography of the Hocking Hills Region has resulted in the exposure of different layers of bedrock geology. The oldest sedimentary rocks are found at elevations ranging from approximately 230-290 m and are part of the Mississippian system, composed of the Cuyahoga and Logan formations. The Cuyahoga formation is Cuyahoga shale topped with Black Hand sandstone; the Logan formation is a mixture of sandstone, shale, and conglomerate (Lemaster and Gilmore 1989). The Logan formation overlies the Cuyahoga formation. The Pennsylvanian system is found at the highest elevations, ca. 290 m, and is composed of the Pottsville, Allegheny, and Conemaugh Groups (Lemaster and Gilmore 1989). Only the Pottsville group is found within the boundaries of Deep Woods (DeLong 1968) and is composed mainly of sandstone, shale, and coal.

Soils: Various factors have resulted in three soil orders at Deep Woods: alfisols, inceptisols, and ultisols according to Woods and others (1999), and four soil orders according to Lemaster and Gilmore (1989): alfisols, entisols, inceptisols, and ultisols. The associated temperature and moisture regimes are mesic and udic, respectively (Woods and others 1999). The mixed nature of the parent materials coupled with the movement of rock material downslope has created soil complexes in southern Ohio (Nash and Gerber 1996). For the county as a whole, Lemaster and Gilmore (1989) refer to general soil associations rather than soil complexes and classify the lowland soils to the Chagrin-Orrville-Otwell association, while Shelocta-Dekalb-Lily association pertains to the upland soils. The former association is comprised of well-drained to rather poorly drained soils with slopes ranging from 0-18% whereas the Shelocta-Dekalb-Lily association is composed of well-drained soils with slopes of 8-70% (Lemaster and Gilmore 1989).

Climate: The climate of Deep Woods is temperate continental as temperature varies greatly throughout the year (Anonymous 1999). The July 30-year mean maximum and minimum temperatures are 29.3° and 16.1° C, respectively. The January 30-year mean maximum and minimum temperatures are 1.5° and -8.9° C, respectively. The growing season can vary from year to year but often approaches 180 days. From 1961-1990, 90% of the time the last spring frost occurred on or before April 15. During this same period, 90% of the first fall frost occurred on or after October 19. The mean annual precipitation is 92.3 cm, with 58% of the precipitation occurring during the growing season. The 30-year mean snowfall amount is 29.7 cm, with a record of 98.0 cm in 1938. The wettest month is July with a mean precipitation of 10.1 cm. The driest month is February with a mean precipitation of 5.4 cm. The regional fire season is divided into a primary fire season in March and April with a secondary season in October and November (Sutherland 1997).

Land Use History: Murphy (1975) and Gordon (1996) divide aboriginal Ohio into three cultural stages: Paleo-Indian (10,000-12,000 YBP), Archaic (8,000-10,000 YBP), and Woodland (3,000-3,500 YBP). In the Hocking Valley, Paleo-Indian artifacts are extremely rare whereas a larger body of evidence exists for Archaic and Early Woodland peoples (McKenzie 1967; Shane and Murphy 1967). The paucity of Paleo-Indian artifacts in southeast Ohio may be due to the rugged, hilly terrain which may have hindered access for both large Pleistocene mammals as well as the hunters (Murphy 1975). Archaeological evidence shows that Archaic people lived in riverine environments practicing small game hunting, fishing, and gathering, and gradually relying less on big-game hunting (Murphy 1975). The Archaic period is marked by the introduction of ground stone tools and freshwater shell heaps, which are rarely found in the Hocking Valley (Murphy 1975). Unfortunately, Archaic collection sites in the Hocking Valley, that have yielded clues, have been destroyed due to highway construction and development of a burial park (McKenzie 1967; Murphy 1975). Studies suggest (Davies 1976; Gordon 1996) that a warming trend of this time period resulted in the ecological succession of coniferous forests to deciduous forests, but exact transition dates are difficult to determine. The Late Archaic period, 4,500 to 3,000 YBP, is marked by the development of "modern" forest composition, increase in taxonomic diversity, acceleration in landscape disturbance, intensification in plant cultivation, and finally a shift towards more permanent settlement. The last stage, Woodland, was defined by the ancient moundbuilders, also known as the Adena and Hopewell, who are also the first long-term inhabitants recorded in southern Ohio. According to Murphy (1975) there is no evidence of Adena village sites and only one Hopewell site within the Hocking Valley. The decline and disappearance of these cultures was as much a mystery to later aboriginal Indian groups as to the European settlers (Gordon 1996).

Subsequent Native Americans extensively utilized eastern forests and consequently influenced vegetation (Maxwell 1910; Day 1953). During the 1700s, parts of Hocking County were utilized by the Shawnee as hunting grounds. The Wyandot established a village close to present-day Logan, however, the village was abandoned around 1774. The Delaware also inhabited portions of the area. All Native American groups were driven out of the area by the early 19th century.

Christian Westenhaven in 1798 was the first settler in what is now Hocking County. The county itself was not formed until 31 March 1818. The current county seat, Logan, was laid out approximately in 1816 and had a population of 250 in 1825 (Howe 1904). Benton is in township 11 of range 18 and is one of the original townships of Hocking County. The first settler of Benton Township was Christian Eby. His cabin was located along Queer Creek close to South Bloomingville (Anonymous 1883) approximately 5.0 km from Deep Woods.

Tax records from the mid-1830s indicate that John Chilcote was the first owner of portions of Deep Woods. For the next 150 years the property was divided and subdivided among many owners. County death records indicate many of the 19th century owners as farmers. Indeed, Williams (1989) confirms this status by reporting the results of the Ohio State Forestry Bureau's 1885 survey of authorities and educated farmers who responded that agricultural clearing was the primary cause of forest destruction. Interestingly, no second or third ranking causes were given for Hocking County. The current property boundaries are a result of a purchase by the Blyth family (personal communication, D. Blyth) completed in 1979.

MATERIALS AND METHODS

Vegetation Analysis

Pre-settlement Vegetation: The original field notes of surveyor Jesse Spencer and a copy of the plat map dated June 1801 were consulted at the Ohio Historical Society, Columbus, OH. The original land survey (OLS) of Hocking County occurred from 27 April to 12 June 1801. Mr. Spencer recorded the diameter (in inches) of 182 trees at the section corners (that is, two witness trees were recorded at 91 points). We converted the data into metric units and the vegetation was assessed by standard descriptors of mean diameter, total basal area ($m^2 \cdot ha^{-1}$), abundance, frequency, and relative importance value (RIV; 0-100%) (Barbour and others 1987; Brower and others 1990; Kent and Coker 1992). Frequency (FRQ) was calculated as the number of points at which a species occurs divided by the total number of points sampled, and RIV (expressed as a percent) was calculated as the sum of the relative basal area and relative frequency divided by two (Brower and others 1990). A subsample consisting of trees within the sections adjacent to and including Deep Woods were analyzed resulting in a subset of data from 12 of the 36 sections, which provided 2 witness trees recorded at 35 points. Again basal area was derived from the original data and abundance, frequency, and RIV of 70 trees at section corners was calculated. Diameter class distribution based on the relative frequency (%) was plotted using 20.0 cm increments starting with the 20.0 cm size class. Number Cruncher Statistical Systems (NCSS, Hintze 1997) was used to fit the size class data to the best model. Finally, standard estimators of species diversity, such as richness (S), Shannon-Wiener (H'), and evenness (E), were also calculated (see Magurran 1988 for formulae).

Present Vegetation: On two site reconnaissance visits, we evaluated the area to better understand the property boundaries, topography, and vegetation-site relationships. Visual estimates of indicator species as well as topography were used to identify three major forest communities: hydric floodplain, mesic upland, and xeric ridgetop. Sample stands were then subjectively selected to represent each vegetation type and sampling occurred during the Fall 1998. All woody vegetation ≥2.5 cm diameter at breast height (DBH) was sampled in twenty-two 0.1 ha circular plots. Seven plots were sampled in the floodplain and ridgetop whereas eight were done in each of the upland communities. Vegetation was assessed by standard descriptors of the mean diameter, density ($stems \cdot ha^{-1}$), total basal area ($m^2 \cdot ha^{-1}$), frequency, and relative importance value (RIV; 0-100%) (Barbour and others 1987; Brower and others 1990; Kent and Coker 1992). Density (DEN) is the number of individuals expressed per unit area, FRQ is the number of points at which a species occurs divided by the total number of points sampled, and RIV, expressed as a percent, is calculated as the sum of the relative density, relative frequency, and relative basal area divided by three (Brower and others 1990). Diameter class distribution based on the relative frequency was plotted using 20.0 cm increments starting with the 20.0 cm size class. Data <20.0 cm was not used in this analysis since equivalent data was not recorded in the historical survey. NCSS (Hintze 1997) was utilized for two statistical procedures. First, to fit the size class curve to the best model and second, to test for a significant difference between the historical and present diameter means. Due to outliers in both historical and present vegetation data sets, the minimum and maximum diameters were winzorized (Sokal and Rohlf 1995). The nonparametric two-sample Kolmogorov-Smirnov (*D*) test was employed due to a failure in the normality and variance assumptions (Sokal and Rohlf 1995). The taxonomic authority used is Gleason and Cronquist (1991). Finally, standard estimators of species diversity were calculated: richness (S), Shannon-Wiener (H'), and evenness (E) (see Magurran 1988 for formulae).

RESULTS AND DISCUSSION

Pre-settlement Vegetation

Clearly, anthropogenic influences on the southeastern Ohio landscape have been profound. Unfortunately, Native Americans did not leave comprehensive written records and early Anglo documentation of their influence on ecosystems is often incomplete or non-existent. The influence of Native Americans on the landscape is the subject of considerable controversy (Day 1953; Russell 1983; McCarthy and others 2001), particularly with respect to the use and frequency of fire. Presettlement dendrochronological data is too limited for adequate inference. However, limited documentation is available on the use of forest communities in southern Ohio by Anglo-settlers during the mid- to late-19th century. According to Diller (1983) 25 million of the 26.3 million acres of land, or 95%, of what was to become the state of Ohio was forested at the beginning of the settlement era. The 1840 census ranks Ohio after North Carolina and New York in the production of naval stores and potash, respectively (Diller 1983). Trees were also used as fuel in charcoal fired furnaces for the production of pig iron. Lord (1884 cited in Beatley 1959) estimated that 325-350 acres of forest were required to sustain one blast furnace per year, so that by the 1880s second-growth forests on company lands were being utilized. Burgeoning human populations also created high demand for wood in order to build businesses, homes, railroads, and other related structures. The completion of the Hocking canal in 1838 opened the former wilderness to trade, facilitating an influx of settlers and resulting in a population of 17,057 recorded in 1860 (Howe 1904). After the Civil War, the iron market decreased, the supply of trees was exhausted, rich agricultural land of the Midwest was discovered, and people pushed westward. In time, the forests began to recover as pioneer species invaded and resulted, through succession, in the vast stands of second- and third-growth vegetation that now cover much of southern Ohio (Millers and others 1989; Williams 1989; McCarthy 1995).

The 1801 survey of Hocking County suggested that the dominant vegetation was composed of *Quercus alba*, *Q. velutina*, *Carya* spp., and *Cornus florida* (Table 1). The subset of 12 sections surrounding and including Deep Woods suggested that the dominant vegetation was *Q. alba*, *C. florida*, *Q. velutina*, and *Carya* spp. In each case, a total of 16 tree species were recorded (Table 2). Community measures of diversity (Table 2) indicate a fairly even abundance of each species. The results of the historical vegetation may be more subjective and less indicative since witness tree selection is known not to occur randomly (Bourdo 1956). Trees were frequently chosen due to conspicuousness, indicator status, or quality of the timber. For example, note

TABLE 1

Abundance, basal area, frequency and dominance of trees surveyed in 1801 by Jesse Spencer during the original land survey of Hocking County. Two trees were identified and measured at each section corner. Species are in alphabetical order. Totals may not sum to 100 due to rounding error.

Species Name	Hocking County (N = 91)				12 sections around Study Site (N = 35)			
	Abundance	TOTBA*	FRQ**	RIV‡	Abundance	TOTBA*	FRQ**	RIV‡
Acer rubrum	9	4,429	0.1	3.4	5	2,620	0.1	4.1
Acer saccharum	1	993	†	0.6	1	993	†	1.4
Betula spp.	1	1,642	†	1.4	1	1,642	†	1.8
Carya spp.	27	16,772	0.3	12.0	8	7,180	0.2	11.0
Castanea dentata	8	21,059	0.1	7.0	2	1500	0.1	2.6
Cornus florida	38	5,422	0.3	11.3	18	2,711	0.4	13.5
Fagus grandifolia	5	4,358	†	1.7	4	4,175	0.1	5.0
Nyssa sylvatica	10	4,489	0.1	4.4	1	182	†	1.0
Oxydendrum arboreum	3	289	†	1.1	1	127	†	0.9
Platanus occidentalis	4	5,777	†	2.7	1	2,919	†	2.6
Quercus alba	46	92,393	0.4	34.2	17	35,921	0.4	34.1
Quercus prinus	6	3,390	0.1	2.5	1	730	†	1.3
Quercus rubra	5	9,121	†	3.2	3	5,067	0.1	4.7
Quercus velutina	16	38,034	0.1	13.3	4	15,100	0.1	12.4
Tilia americana	1	2,918	†	1.0	1	2,919	†	2.6
Ulmus spp.	2	375	†	0.4	2	375	†	1.1
TOTALS	182	211,459	1.6	100.0	70	84,159	1.7	100.0

*Total basal area (TOTBA) in m^2.
**Frequency (FRQ) expressed as number of points where a species occurs divided by total points sampled.
‡Relative importance value (RIV; 0 - 100%).
†Value ≤0.05.

TABLE 2

Species richness (S), Shannon-Wiener diversity index (H'), and evenness values (E) for present and historical vegetation in Hocking County, OH. Present vegetation sampled in three communities at Deep Woods Farm during 1998. Historical vegetation based on original land survey of Jesse Spencer in 1801.

	Present vegetation			Historical vegetation	
	Hydric floodplain	Mesic upland	Xeric ridgetop	Entire county	12 Sections*
S	25	25	23	16	16
H'	2.46	2.33	2.13	2.21	2.22
E	0.92	0.89	0.81	0.94	0.93

*Includes the 12 sections immediately adjacent to and including Deep Woods Farm.

the relatively high importance value for *C. florida* (Table 1). It comprised 20% of the witness trees chosen by Spencer. The survey was done in the spring so the tree was conspicuously in bloom. Additionally, Peattie (1948) notes that the inner bark was used by the Native Americans as a remedy for malaria and by the pioneers as a remedy for ague (chills and shivering) and, due to its non-splitting nature, as a wood for handles. It may also have been used as an indicator species for calcareous soils.

One the earliest botanical surveys of this area, and one of the most comprehensive to date, was done by Griggs in 1914. During this time the area was referred to as the Sugar Grove Region, having been named after the local railroad station (Griggs 1914). Transeau (1905) and Sears (1925) used survey data to look at vegetation distribution in Ohio; however, we do not rely heavily on their studies because of the large scale employed. Specific data are difficult to extract from the regional work of Transeau and the county-level of Sears. The comprehensive local survey of Griggs (1914) provides the most appropriate scale for detailed comparison to the 1801 and present data.

Griggs (1914) divides the forested areas into two broad categories of Lowland Forest and Upland Forest. He then further subdivides the former into the Hemlock Forest and the *Liriodendron* Forest, while the latter is partitioned into three subdivisions: the Cliff-top, the Pine Forest, and the Oak Forest. Interestingly, of the Lowland forest associations, Griggs (1914) notes that hemlock (*Tsuga canadensis*) and tulip tree (*Liriodendron tulipifera*) are common throughout the region. However, there is no record of either species in Spencer's field notes, in fact there is no record of any coniferous species in the notes (Table 1). The Oak Forest subdivision of Griggs somewhat coincides with the OLS and is generally composed of a mixture of oaks that is often dominated by *Quercus prinus*, associated with *Q. alba*, *Q. velutina*, *Oxydendrum arboreum*, and *Castanea dentata*. In addition, Sears (1925), Braun (1950), and Gordon (1969) have all labeled the area as an oak-hickory forest type coupled with the presence of hemlock, chestnut, and pine. Note that the chestnut blight, *Cryphonectria parasitica*, appeared in the United States in 1904 (Braun 1950; Keever 1953; Woods and Shanks 1959; Mackey and Sivec 1973) and, by the 1930s, had decimated most populations of *Castanea dentata*, including those found in Ohio. The absence of chestnut, which originally accounted for 10% of the basal area, highlights a major difference between the historical and present forest. Likewise, *Cornus florida* populations may soon be dramatically altered by Dogwood anthracnose (*Discula destructive*).

Present Vegetation

Betula nigra, *Carpinus caroliniana*, *Ulmus americana*, and *L. tulipifera* (Table 3) dominated the floodplain. The hydric floodplain had a mean density of 577.1 stems$\cdot$ha^{-1} and a basal area of 21.4 m$^2\cdot$ha^{-1}. Community measures of diversity indicate that the floodplain area exhibited the greatest evenness and diversity values (Table 2). It is interesting to note that this community was dominated by river birch, which is generally considered to be a more southern tree species (Cribben and Ungar 1974). Other abundant species include *Platanus occidentalis*, *Prunus serotina*, *Carya cordiformis*, and *C. laciniosa*.

Griggs (1914) divides the Bottom-lands into three divisions: The Bottom-land Swamp, the Birch Bottom-land, and the River-bank association. Reconstruction of these communities is difficult since valleys are historically the first areas subjected to clearing and settlement. However, according to Griggs (1914) *Acer rubrum*, *Alnus rugosa*, and *Ulmus americana* are typical of the wetter areas, whereas *Quercus palustris*, *Juglans nigra*, *Fraxinus pennsylvanica*, and *Prunus serotina*, to mention a few, typify the drier sites of the Bottom-land swamp. The Birch Bottom-land is dominated by *Betula alleghaniensis* and *B. lenta*, with scatterings of *B. nigra*, *Platanus occidentalis*, *A. rubrum*, and *Carpinus caroliniana*. The River-bank association is typified by herbaceous species and is not considered here. The woody species comprising the hydric floodplain of Deep Woods are a mixture of Griggs' Bottom-land Swamp and Birch Bottom-land associations. Several species had relatively low importance values (<5). One of them, *A. negundo*, was found to be characteristic of areas disturbed by

TABLE 3

Density, basal area, frequency and dominance of trees (stems ≥2.5cm DBH) on 0.1 ha plots in three habitats at Deep Woods Farm, Hocking County, OH. Species are listed in alphabetical order. Column totals may be slightly off due to rounding errors.

Species Name	Hydric floodplain (N = 7)				Mesic upland (N = 8)				Xeric ridgetop (N = 7)			
	DEN*	BA**	FRQ***	RIV‡	DEN*	BA**	FRQ***	RIV‡	DEN*	BA**	FRQ***	RIV‡
Acer negundo	5.7	1.0	0.6	2	-	-	-	-	-	-	-	-
Acer rubrum	12.9	4.1	0.7	4	16.3	1.2	0.5	2	301.8	57.4	1.0	27
Acer saccharum	14.3	3.6	0.6	3	190.0	16.4	0.9	15	47.2	6.5	0.9	6
Betula alleghaniensis	-	-	-	-	73.8	31.3	0.8	11	-	-	-	-
Betula lenta	-	-	-	-	-	-	-	-	2.9	0.4	0.1	1
Betula nigra	71.4	39.6	1.0	16	2.5	1.4	0.3	1	-	-	-	-
Carpinus caroliniana	132.8	3.7	1.0	11	32.5	0.9	0.9	4	4.3	†	0.1	1
Carya cordiformis	70.0	7.7	0.9	8	-	-	-	-	-	-	-	-
Carya glabra	-	-	-	-	-	-	-	-	34.3	8.8	0.6	5
Carya laciniosa	1.4	1.3	0.6	3	-	-	-	-	-	-	-	-
Carya ovalis	-	-	-	-	-	-	-	-	2.9	0.8	0.1	1
Carya ovata	1.4	0.2	0.1	†	5.0	4.0	0.4	2	-	-	-	-
Carya sp.	1.4	0.9	0.1	1	6.3	4.9	0.4	2	-	-	-	-
Carya tomentosa	-	-	-	-	3.8	2.9	0.3	1	2.9	0.8	0.1	1
Cornus florida	8.6	0.5	0.6	2	70.0	2.3	0.9	7	27.2	0.7	0.9	4
Diospyros virginiana	-	-	-	-	2.5	1.2	0.1	1	-	-	-	-
Fagus grandifolia	8.6	1.8	0.4	2	33.8	8.1	0.9	6	4.3	0.1	0.1	1
Fraxinus americana	-	-	-	-	2.5	0.7	0.3	1	-	-	-	-
Fraxinus pennsylvanica	1.4	0.6	0.1	1	-	-	-	-	8.6	1.7	0.4	2
Juglans cinerea	4.3	1.1	0.3	1	-	-	-	-	-	-	-	-
Juglans nigra	11.4	3.9	0.4	3	-	-	-	-	-	-	-	-
Liriodendron tulipifera	34.3	27.1	0.9	10	92.5	90.7	1.0	21	12.9	14.7	0.4	4
Nyssa sylvatica	1.4	0.3	0.1	1	2.5	1.8	0.3	1	2.9	0.8	0.1	1
Ostrya virginiana	-	-	-	-	-	-	-	-	47.2	2.5	1.0	6
Oxydendrum arboreum	1.4	†	0.1	†	8.8	1.0	0.5	2	1.4	†	0.1	1
Platanus occidentalis	15.7	23.3	0.7	8	3.8	5.7	0.1	1	-	-	-	-
Prunus serotina	47.1	12.6	1.0	8	2.5	†	0.3	1	17.2	15.2	0.7	5
Quercus alba	2.9	0.2	0.1	1	13.8	28.7	0.5	7	41.5	33.4	0.6	9
Quercus coccinea	-	-	-	-	-	-	-	-	7.2	4.7	0.4	2
Quercus prinus	-	-	-	-	6.3	4.8	0.4	2	60.1	51.8	0.7	13
Quercus rubra	1.9	1.5	0.9	4	1.3	0.1	0.1	†	21.5	3.2	0.7	4
Quercus velutina	0.1	0.2	0.1	1	2.5	0.3	0.3	1	18.6	13.8	0.6	5
Sassafras albidum	0.6	0.4	0.3	1	-	-	-	-	4.3	1.1	0.3	1
Tilia americana	-	-	-	-	1.3	0.2	0.1	†	-	-	-	-
Tsuga canadensis	2.9	0.5	0.1	1	65.0	9.2	0.5	6	5.7	1.0	0.3	1
Ulmus americana	87.1	13.7	1.0	11	10.0	0.5	0.4	2	-	-	-	-
Ulmus rubra	-	-	-	-	6.3	1.8	0.5	2	1.4	0.3	0.1	1
TOTALS	577.1	149.8	12.9	100	655.0	220.1	11.3	100	678.0	219.6	10.6	100

*Density (DEN) expressed as stems · ha^{-1}.
**Basal Area (BA) expressed as $m^2 \cdot ha^{-1}$.
***Frequency (FRQ) expressed as number of points were a species occurs divided by total points sampled.
‡Relative importance value (RIV; 0 - 100%).
†Value ≤0.05.

timbering and remains an important component of floodplain forests for approximately 100 years (Hardin and others 1989).

The mesic upland community is interesting because it closely resembles northern hemlock-hardwood forests of New England. Its presence is explained by geological factors. The Black Hand sandstone cliffs that dominate Deep Woods create environmental and soil conditions that encourage the growth of the following dominant tree species: *Liriodendron tulipifera*, *Acer saccharum*, and *Betula alleghaniensis* (Table 3). Other abundant species include *Cornus florida*, *Quercus alba*, and *Fagus grandifolia*. The mesic upland had a mean density of 655.0 stems·ha^{-1} and a basal area of 27.5 $m^2 \cdot ha^{-1}$. A total of 25 species of woody plants was identified, and yielded a relatively high evenness index (Table 2). The mesic upland community at Deep Woods is similar to the Upland Forest association of Griggs (1914), and the Oak-hickory Forest coupled with hemlock, chestnut, and pine of Sears (1925), Braun (1950), and Gordon (1969). In addition, McCarthy and others (1987) found *Q. alba*, *A. saccharum*, *L. tulipifera*, and *Q. prinus* to be of the greatest importance in the tree stratum in a nearby forest. The RIV of *Tsuga canadensis* was higher in the upland forest compared to the other areas (Table 3). It is characteristically found along the moist ravines typical of the region. The presence of this stately conifer is certainly one of the special aspects of Deep Woods. As Griggs (1914) states, *T. canadensis* is often found in association with *B. lenta*, as is the case at Deep Woods.

Yet another group of characteristic tree species dominates the xeric ridge-top community. These include *A. rubrum*, *Q. prinus*, and *Q. alba* (Table 3). Other abundant species include *A. saccharum*, *Ostrya virginiana*, *P. serotina*, and *C. glabra*. The ridgetop had the greatest mean density of 677.1 stems·ha^{-1} and basal area of 31.4 $m^2 \cdot ha^{-1}$. However, it had the lowest community diversity (Table 2). The relatively dry conditions of the ridge-top favor an oak-hickory association in southeastern Ohio (Braun 1950). This is partially supported by Held and Wistendahl (1978) who sampled an upland forest and found *Q. rubra* the dominant species associated with *Q. prinus*, *Q. alba*, and *Q. velutina* at a site in adjacent Athens County. The abundance of red maple in this community can be attributed to ecological features that allow this species to thrive as both an early and late successional species (Abrams 1998). In addition, research suggests that disturbance associated with fire played a major role in establishment and maintenance of oak dominance in eastern forests (Lorimer 1984; Abrams 1992). There has been no forest fire activity at Deep Woods for at least 20 years (personal communication, D. Blyth). Abrams (1998) states that gypsy moth and deer herbivory are less of a problem for red maple than other species since it is not a preferred food item. Gypsy moth has not yet been a problem at Deep Woods. Deer herbivory is a serious problem in many areas (Marquis and others 1976; Tilghman 1989; Gill 1992) but to date has not been recorded as a problem in the forests at Deep Woods. Finally, in Ohio, pitch pine (*Pinus rigida*) is often a component of the ridge-top communities. Pitch pine can occur in stands or as individuals scattered on ridge-tops, or occasionally on old-field sites in valleys (McClenahen and McCarthy 1990). Pitch pine is present in low numbers at Deep Woods in the xeric ridge-top community, even though no individuals fell within the sample quadrats.

The relative frequency distribution of DBH of the historical Hocking County data and the present day vegetation data (floodplain, upland, and ridge-top combined) was plotted in order to compare the historical and present forests (Fig. 1). Even though the historical mean tree diameter is significantly greater than the present (42.3 vs. 34.5; $D = 0.26$, $P = 0.05$), the greater mean of the historical data may be due to the subjective nature of the original land survey. In other words, it could be due to surveyor bias. Alternatively, it could be that the trees were actually larger than those found today. Also, note that there are currently more trees in the smaller diameter classes than present in the historical data. Finally, the historical data suggest that the past structure was influenced by pulsed disturbance (model influences at 40.0 and 70.0 cm DBH) compared to the present structure which bears a relatively smooth exponential function, suggesting a very different disturbance regime. Both distributions are best explained ($R^2 = 0.899$) by a negative exponential curve ($y = e^{-x}$) (Fig. 1), as it typical of mature hardwood forests of the region (McCarthy and others 1987).

There are several other interesting habitats within Deep Woods that merit attention. Sandstone rockhouses dot the property. Four of these rockhouses at Deep Woods are referred to as: Big Falls, Circle Falls, Deer Falls, and Rock Falls (Fig. 2). Three distinct habitats characterize the rockhouses: backwall, ceiling, and floor (Walck and others 1996), each often harboring endemic species. The rockhouses show characteristic erosion features of Black Hand sandstone such as a recess of

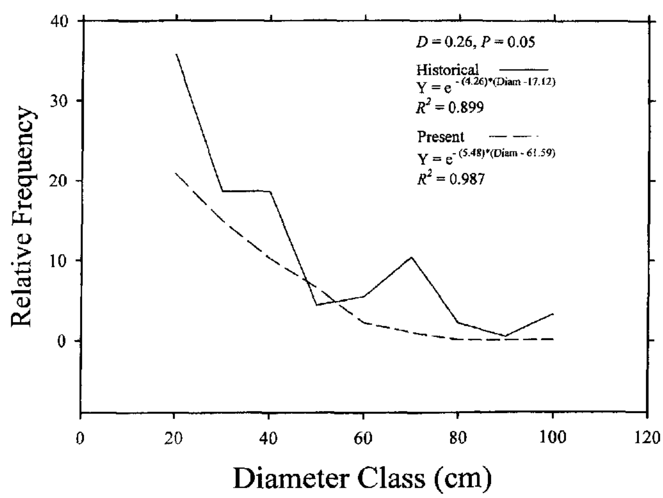

FIGURE 1. Relative frequency distribution of diameter class of trees of present vegetation in three communities at Deep Woods Farm and historical vegetation sampled by J. Spencer. Dash-dot line represents present vegetation and solid line is the historical data. Kolmogorov-Smirnov test indicates a significant difference between the historical and present vegetation mean diameter. A negative exponential curve is the best fit for the data.

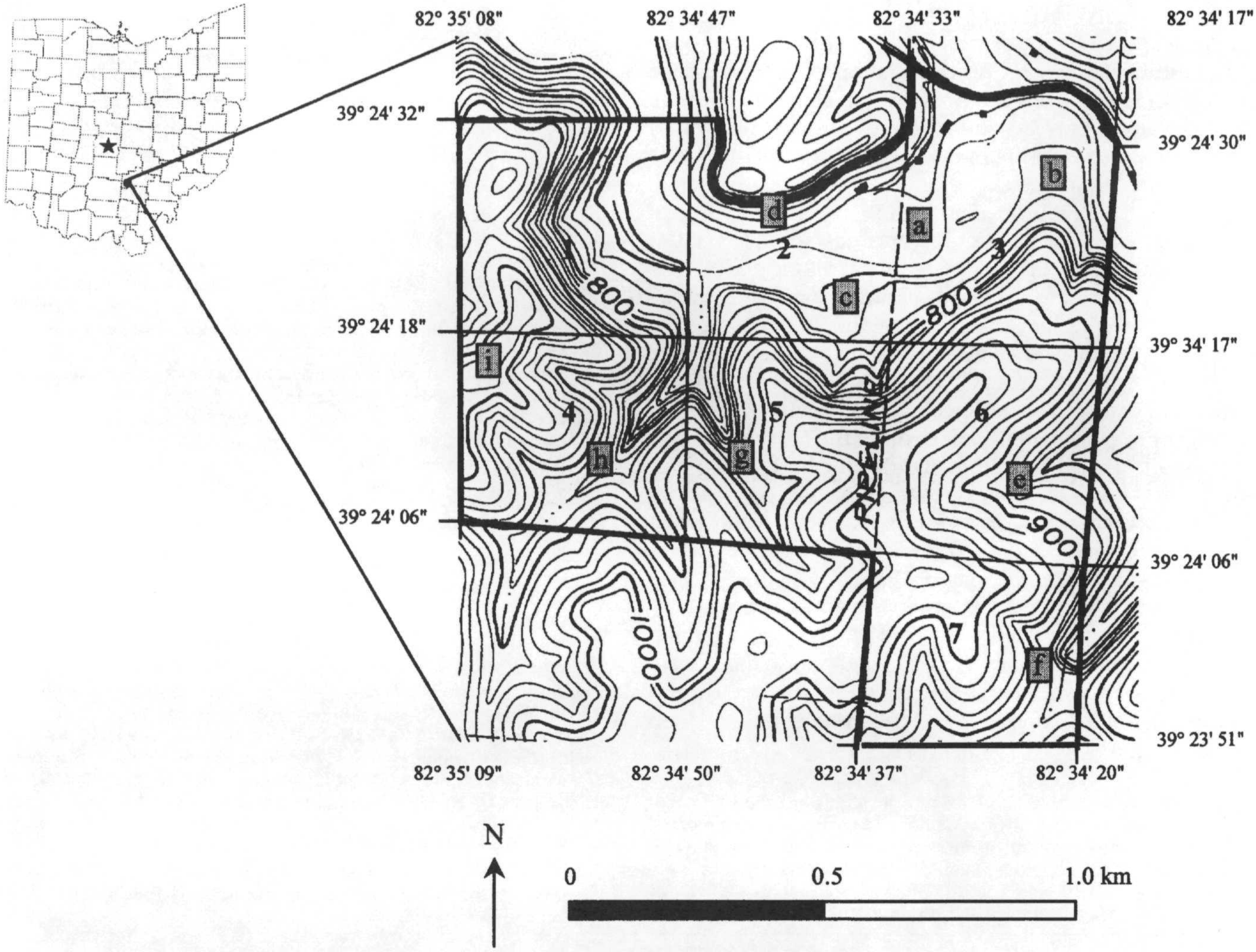

FIGURE 2. Topographic map (portion of South Bloomingville quadrangle, USGS 1990) of Deep Woods Farm showing property boundaries, quarter-quarter sections, and significant landforms. Heavy black lines mark property boundaries. Quarter-quarter sections are numbered from 1-7 and letters indicate major landmarks: a) Boot field, b) Potato field, c) Deer field, d) Rock shelters and associated trail, e) Deer falls, f) Big falls, g) Circle falls, h) Rock falls, and i) West ridge. All elevations are in feet. Latitude ranges from 30° 23' 51" to 30° 24' 31". Longitude values range from 82° 34' 17" to 82° 35' 09". Scale is 4.2 cm equals 1.0 km. Inset is map of Ohio showing the state capital (star), counties, and location of the study site.

several meters from the rim to the back wall. Water flows over Big, Circle, and Rock falls during wet periods. In addition, three similar habitats occur on the north side of the property. The owners refer to them as Indian caves since Native American artifacts have been discovered there. Unlike the four waterfalls, there is only an occasional dripline component to these south-facing sandstone recesses during wet periods. Native Americans used these shelters (Murphy 1975) probably because a cave-like, thermally regulated environment (Farrar 1998) would have offered increased protection from the elements. Sandstone outcrops are common at Deep Woods. Often the strong forces of water erosion cause cracking and breaking of the joints or other weak points. The result is the formation of narrow passageways among large boulders.

The current owners maintain three mowed pasture areas: Boot Field, Deer Field, and the Potato Field (Fig. 2). The species composition includes mostly indigenous and non-indigenous graminoid species. Common indigenous species include *Panicum clandestinum*, *Poa palustris*, *P. sylvestris*, and *Tridens flavus*, with *Bromus inermis*, *Festuca elatior*, *F. pratensis*, *F. rubra*, *Phleum pratense*, and *Poa pratensis* as common non-indigenous species found in the fields. The fields are mowed to discourage the initiation of old-field succession, thus maintaining the forb-herb cover. East Fork, a second-order stream that often experiences seasonal flooding, flows through the property.

CONCLUSION

The goal of this study was to evaluate and summarize the natural history and forest ecology of Deep Woods in the interest of providing baseline information to the many researchers involved in the ATBI. Despite the limitations of the historical data, it does provide an image of what pre-Anglo vegetation in this region of Ohio may have been. Spurr (1951) notes how little the forest of central Appalachia had changed from colonial times as recorded in the journals of George Washington. The

1801 land survey of J. Spencer also closely resembles present species composition except for the current lack of chestnut. However, the distribution of historical size classes deviated from the present size class distribution. The deviation may be due to surveyor bias, the lack of time for regeneration and growth since the last disturbance, or different disturbance regimes. As expected, the present vegetation distribution has a lower mean tree diameter. There are fewer trees in the smaller (<20.0 cm) size class, suggesting a difference in the structure of the forest. Community measures of diversity indicate that the floodplain area exhibited the greatest species diversity and greatest evenness value. However, evenness values from each community suggest a fairly equitable distribution of species in all communities. Finally, anthropogenic influences upon the landscape have a long and rich history, but we do not find strong evidence that it has dramatically altered forest composition.

The diversity of habitats and species is a product of the various abiotic factors found in the dissected ridges and valleys of the unglaciated Allegheny Plateau. Deep Woods lies within an area that has long been recognized to contain a number of unique species for Ohio (Griggs 1914; Schaffner 1915). The exceptional diversity of habitats and species characteristic of this area lends credence to the conservation and protection of Deep Woods.

ACKNOWLEDGMENTS. The authors extend our thanks to the Ohio Biological Survey, The John Houk Memorial Research Grant program, and the Department of Environmental and Plant Biology at Ohio University for their generous financial support. Special thanks go to JE Brown for field assistance and D Blyth for sharing his knowledge and the land. Appreciation is also extended to the Ohio University Cartographic Center and to two anonymous reviewers.

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