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RESEARCH ARTICLE

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Fire History and Stand Structure of High Quality Black Oak (*Quercus velutina*) Sand Savannas

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ABSTRACT: We surveyed high quality, remnant black oak sand savannas across four sites in northeastern Illinois to compare characteristics of stand structure and tree vigor with fire history. Dendrochronological methods were applied to 289 dated fire scars identified on 60 *Quercus velutina* trees. Stand structure was characterized using 30 circular plots (0.04 ha each) per stand during summer 2007. Tree recruitment dynamics differed among the four stands, suggesting that canopy decline dynamics among them is likely to differ in coming decades. Frequent fire intervals (less than two years) were associated with canopy openness, but also a paucity of future canopy trees. Under these frequent fire regimes, we predict a loss of canopy cover, as no smaller trees were present to assume dominance. Fire intervals longer than two years were associated with transition to closed canopy forests. These results suggest that savanna managers should consider other disturbances, such as selective cutting and or grazing, along with fire to sustain both herbaceous and canopy tree components.

Index terms: dendrochronology, fire frequency, forest stand dynamics, Illinois, Kankakee Sands, natural areas management, oak savanna, *Quercus*, restoration

INTRODUCTION

Oak savannas represent some of North America's most threatened ecosystems, with < 0.02% of the 11-13 million hectares estimated at the time of Euro-American settlement (Nuzzo 1986; Anderson et al. 1999). Fire suppression has been identified as a key factor in the transition of Midwestern savannas to closed canopy forests (Auclair 1976; Taft 1997; Anderson and Bowles 1999; Wolf 2004). As tree density increases, the understory becomes shaded and unfavorable for savanna species dependent on an open canopy structure. Reconstructing disturbance regimes that maintain an open tree canopy structure is a high priority among savanna managers and researchers (Anderson and Bowles 1999; Nielsen et al. 2003).

Fire is widely documented as a major influence in many wooded systems (Abrams 1992; McPherson 1997; Holzmueller et al. 2009). However, the exact relationship between fire frequency and oak savanna structure is poorly documented (Peterson and Reich 2001). Historically, Native Americans' frequent use of fire (Guyette et al. 2006) likely maintained the structure of these systems prior to Euro- and African-American settlement (Henderson and Long 1984). Most studies addressing fire influence on sand savannas use sites where restoration burning was sustained over relatively short periods of time (Henderson and Long 1984; Faber-Langendoen and Davis 1995; Peterson and Reich 2001; Abella et al. 2004; Haney et al. 2008). These studies indicate that stem density and canopy cover decreases with fire frequencies ranging from 3-6 fires per decade. Also, fire in combination with tree removal can restore open canopy conditions (Nielsen et al. 2003). However, what is needed are specific savanna management protocols to sustain 25% - 50% canopy cover while also allowing for regeneration of the age classes needed to perpetuate an open-grown tree component. Besides fire, large ungulates and tree cutting (Native Americans) for fuel wood have historically been a part of these systems, yet the role of grazing and tree removal on canopy structure and herbaceous diversity remains to be fully explored.

We related fire history to current stand structure and vigor across four savanna stands in northeastern Illinois. Inferring past conditions from current structure and composition is often difficult (Egan and Howell 2001). Further, visual assessments of stand structure alone are frequently inaccurate for oak savanna ecosystems, particularly when relating past land uses with time of tree establishment. These assumptions can distort our understanding of system functionality and limit our ability to successfully restore and maintain these systems (Karnitz and Asbjornsen 2006). Therefore, the principal objectives of this study were to: (1) document current stand structure, (2) reconstruct the post-settlement fire history through dendrochronological methods, and (3) compare fire history with current stand structure and vigor using dendroecological methods. Our overall goal was to better understand the relationship between fire intervals and stand structure in black oak sand savannas.

METHODS

Study Site

This study was conducted within a 77 km^{-2} portion of Pembroke Township (41° 04' N, 87° 37' W), located in the moraine and sand deposits of Kankakee County, Illinois (Kankakee Sands). Elevations at the site ranged from 203 m - 212 m. The 30-year (1971-2001) mean annual temperature was 9.9 °C, with average monthly highs 23.6 °C (July) to -5 °C (January). The 30-year (1971-2001) mean annual precipitation was 980 mm, with the month of May receiving the greatest mean amount of 115 mm (Midwest Regional Climate Center 2008). Numerous state and federally designated rare plant and animal species are present, including the largest Illinois population of orange-fringed orchid (*Platanthera ciliaris*), the only Illinois population of yellow false indigo (*Baptisia tinctoria)*, and primrose violet (*Viola primulifolia*). Distinct faunal species include ornate box turtle (*Terrapene ornatata*), western glass lizard (*Ophisaurus attenuates)*, six-lined racerunner *(Cnemidophorus sexlineatus*), and the only Illinois gopher species, plains pocket gopher (*Geomys bursarius*). Populations of red-headed woodpecker (*Melanerpes erythrocephalus)* are stable throughout Kankakee Sands (Brawn 1998), even though they are declining at an annual rate of 2.5% throughout their range (Sauer et al. 2001). The ground layer vegetation survey of Pembroke Township in 2002 documented 574 plant species, and the overstory tree species composition was dominated by black oak (*Quercus velutina*) (Phillippe et al. 2003).

The study site was located on sand dunes formed by wind-transported sediment scoured from the post-glacial Illinois River Valley by the Kankakee Torrent (King 1981). Soils were Oakville soils (excessively drained with a dark grayish brown surface horizon and 152 cm of fine sand extending into the soil profile) with small areas of somewhat poorly drained Morocco soils on lower landscape positions (Paschke 1979).

Prior to and during initial European and African-American settlement, the Potawatomi Indians controlled much of the Kankakee Sands region. The region was sparsely populated until the early 1860s (Warwick 2007), when a regionally unique African American settlement (currently the town of Hopkins Park) was founded by Joseph Tetter and his 18 children who escaped slavery and the strife of Civil War in North Carolina. A second wave of African American immigration occurred during the depression.

Over the last 160 years, the area has been burned, grazed (White 1999), and logged throughout the Kankakee Sands landscape. During the mid 1800s to early 1900s, Kankakee Sands region was subjected to extensive cattle grazing. During this time, the intentional use of fire to maintain and improve pasture and clear fields was a common practice region-wide (McClain and Elzinga 1994; Wolf 2004; Nelson et al. 2008). Due to the poverty of the inhabitants, burning of household refuse remains a common practice, and is thought to be the source of many wildfires at Kankakee Sands (Robert Littiken, Kankakee Sands Program Coordinator, The Nature Conservancy, Peoria, IL, pers. comm., July 10, 2007). Among the stands included in this study, formal management efforts are limited primarily to land acquisition (initiated 1997), prescribed burning, and exotic species control. Analysis of aerial photographs indicated that woody canopy cover increased from 26.9 ha in 1939 to 41.4 ha in 1980 across the stands included in this study (Figure 1) (Phillippe et al. 2003).

Sampling Methods

Permanent study plots were established and surveyed on five stands in the summer of 2002 (Phillippe et al. 2003). Four of those stands Bentley-Crawford (BC), Big Dune (BD), Leesville (L), and Mskoda (M), were re-inventoried for the present study during summer 2007 (Table 1). At each sampled stand, 30, 11.28 m radius plots (0.04 ha) were placed at 25 meter intervals along line transects randomly selected along cardinal compass directions (Phillippe et al. 2003). In total, 114 plots were sampled because only 24 were taken at Mskoda.

Structural characteristics of the overstory were determined through the identification and measurement of living trees ≥ 10.0 cm diameter at breast height (dbh) and used to calculate density and dominance metrics, including importance value (IV_{300}) (Curtis and McIntosh 1951). The three variables summed to yield an IV_{300} were relative density (stems/ha), relative dominance (basal area m^2/ha), and relative frequency (total stems). The midstory/understory stratum was characterized by measuring living oak grubs/saplings < 10.0 cm dbh in each plot. Only the largest stem (the stem most likely to maintain dominance of an oak grub/sapling) was measured within a multi-stemmed clump. The percent cover of all woody species < 10.0 cm dbh (shrub canopy cover) was also visually estimated within each plot. Stem vigor was assessed as living or dead. Crown volume (m^3) was calculated by multiplying crown widths measured in North-South by East-West directions by the tree crown height above the lowest living branch, as determined with a clinometer. Crown volume index was calculated by dividing crown volume by tree diameter (cm). Other tree vigor measurements included percent of crown loss compared to overall live crown using multiple views of the canopy from a distance sufficient to see the canopy silhouette, total number of dead branches or stubs ≥ 7.6 cm at the point of tree branch attachment, occurrence of visible fire scar wounds, and visually observable incidence of hollow bole. Nine plots within Big Dune and one plot in Leesville were treeless and excluded from the tree vigor statistical analyses, which resulted in 104 plots.

To quantify stand age structure, increment cores were collected from a total of 154 *Q. velutina* across the four stands in the summer of 2007 and taken to the Forest History laboratory at Southern Illinois University Carbondale (FHL) for dendrochronological analysis using standard dendrochronological techniques (Stokes and Smiley 1968). Age to pith could only be confirmed on 63 of the 154 cores and four cross-sections were omitted due to extensive decay. Therefore, age distribution graphs were created using a total of 114 trees.

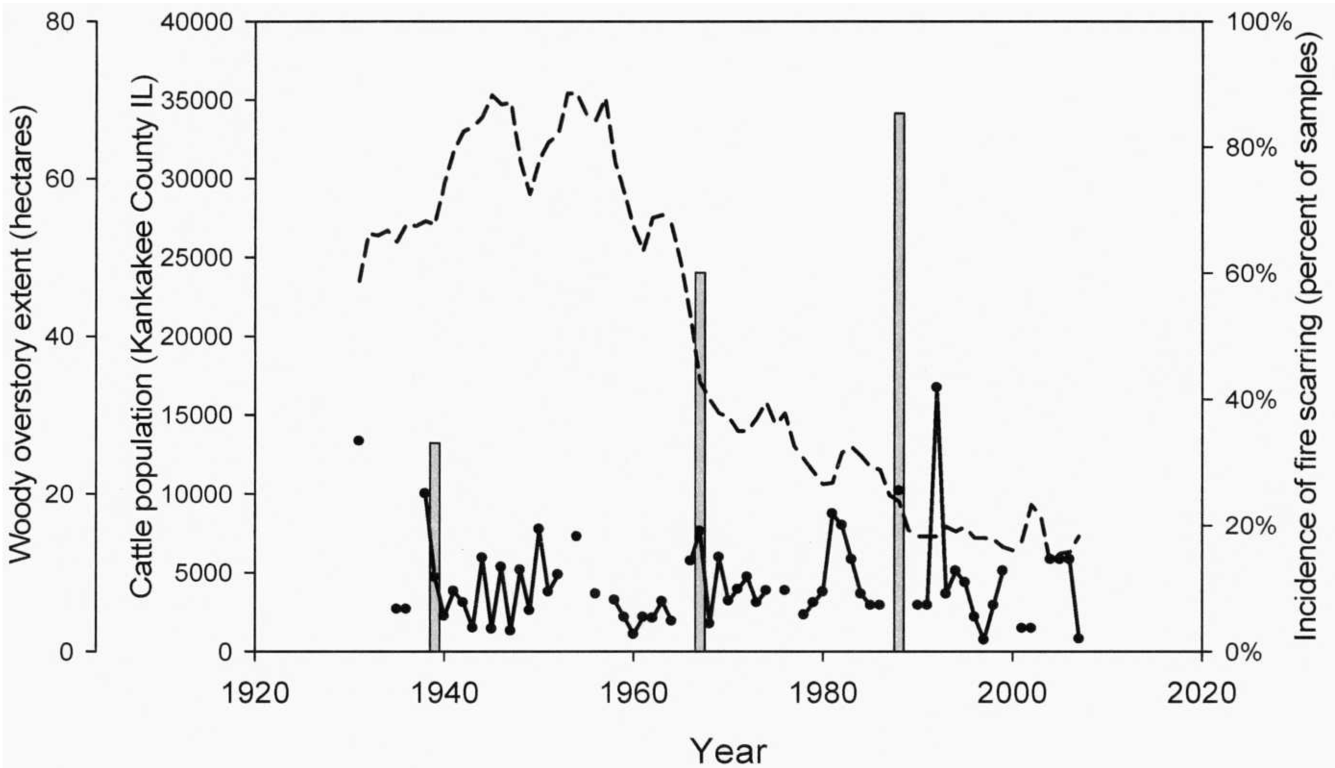

Figure. 1. Cattle population of Kankakee County, IL (dashed line), fire history (interrupted solid line) of the four stands, and woody overstory extent for 1939, 1967, and 1988 (gray bars) (Considine 2009). The United States Department of Agriculture National Statistics Service (2008) was used to determine the population of non-feedlot cattle from 1926 to 2007 in Kankakee County, Illinois.

In January of 2008, sixty-one *Q. velutina* cross-sections were collected 7 cm above the ground and georeferenced from randomly selected living trees in the same four stands (BC = 15, BD = 15, L = 16, and M = 15). In order to minimize unnecessary removal of tree stems, living trees were visually inspected and sounded with an ax to identify potential specimens with a high likelihood of having a solid bole. An increment borer was used to core questionable trees. In the few instances when the originally selected trees were hollow, the nearest solid tree was collected. Cross-sections were also collected from two stumps of trees that had been removed from Leesville since the end of the previous growing season, presumably by firewood collectors.

Cross-sections were air dried, sanded, steel wooled, and examined under a 10x stereomicroscope. Visual cross-dating procedures using the skeleton plot method were carried out to identify signature years through graphically expressing the width of each annual ring of every cross-section (Stokes and Smiley 1968). Each annual ring of the 35 cross-sections was measured with a stereomicroscope using a Velmex measuring system with *Measure J2X* (Voorhees 2000). The quality-control program COFECHA (Holmes 1983; Grissino-Mayer and Holmes 1993) was used to check cross-dating and measurement accuracy and a master chronology was

Table 1. Description of the four Kankakee Sands stands included in this study.

	Stand			
	Bentley Crawford	Big Dune	Leesville	Mskoda
Size (ha)	26	27	75	268
Ownership	The Nature Conservancy	The Nature Conservancy	Illinois Department of Natural Resources	The Nature Conservancy
Location (latitude/longitude)	41° 05'N, 87° 34W	41° 04'N, 87° 38W	41° 01'N, 87° 32W	41° 04'N, 87° 39W

created using the ARSTAN program (Cook and Holmes 1984). The tree-ring chronology was then compared with a *Quercus alba* chronology from Kankakee State Park (Duvick 1980) to further corroborate the Kankakee Sands tree-ring chronology.

Once the annual rings of each sample were dated, fire scars were identified and assigned to the corresponding calendar year. Fire scars were identified by the presence of charcoal, vascular cambium injury, and/or a disruption of an annual ring that showed healing in later years (Smith and Sutherland 1999; Wolf 2004). Calendar dates of fire scars were assigned according to the season and year of cambial injury with dormant season fires dated to the following growing season (Baisan and Swetnam 1990; Guyette et al. 2006). Fire scar dates and seasonality information were compiled using the fire history program, FHX2 (Grissino-Mayer 2001), to yield Weibull median fire intervals (WFI) and mean fire intervals (MFI) for each stand. The start date for determining MFI and WFI was set at 1930 when at least one tree from each stand was present; any trees that had fire scars prior to 1930 were not included in the analysis due to inadequate sample size (n=289).

RESULTS

The overstory stratum across all four stands was dominated by *Q. velutina* (IV_{300} of 244.6 (82%) with white oak (*Quercus alba*) and pin oak (*Quercus palustris*) constituting the remaining 17 and one percent of IV_{300}, respectively. Stands exhibited a wide range in woody plant structural attributes (Table 3, Figure 2). Among all the stands, age was inconsistently related to diameter (e.g., 35-40 cm dbh ranged from 39-128 years). Stands with a mean 2-3 y fire-free intervals (Bentley Crawford, Mskoda), diameter class distribution differed among the four stands (Figure 2). Big Dune had the lowest total tree density, oak sapling density, shrub canopy cover, and no trees < 25 cm dbh. Mean dbh was > 10 cm larger than the other stands (Table 3). Leesville had both the highest total woody stem density in the smallest (10-15 cm) size class and oak sapling density (Table 3).

Table 2. Fire regimes of the four Kankakee Sands stands. Weibull median fire interval calculated by FHX2 (Grissino-Mayer 2001) for the time period 1930-2007.

	Stand			
	Bentley Crawford	Big Dune	Leesville	Mskoda
Tree cross-sections included in analysis (n)	15	14	14	12
Total fire scars (n)	86	80	46	78
Total fire events (years)	31	42	26	34
Minimum/Maximum fire-free intervals (years)	1/7	1/10	1/8	1/6
Mean fires per decade	4	6	4	5
Weibull mean fire interval	2.24	1.45	2.32	2.02

Across all stands, 64 out of the 77 years between 1930 and 2007 had a recorded fire event (Figure 3). From 1930 to 2007, the four stands contained 129 fire intervals ranging from one to 10 years duration (Figure 4, Table 2). First scarring occurred prior to age 45 years for 92% of the trees, and 66% of those trees were initially scarred prior to age 10 years. Of the 289 fire scars, 156 (54%) occurred during the dormant season, 98 (34%) in the early growing season, seven (2%) in the middle growing season, five (1%) in the late growing season, and 23 (8%) fire scars were undetermined. Weibull mean fire interval was shortest at Big Dune and longest at Leesville.

Although the tree diameter distributions at Big Dune, Mskoda, and Bentley Crawford were consistent with those usually associated with even-aged structure, the age diameter relationships suggest a diversity of age distributions of fairly continuous recruitment and the origin of some cohorts appeared to be related to periods with long fire return intervals (Figure 4). In contrast to the other stands, Big Dune was consistent with an even-aged structure. However Mskoda, as well as Leesville, have two distinct recruitment cohorts dating from the mid 1930s-40s after which an annual burning cycle affected regeneration for over a decade (Figure 3). Bentley Crawford's diameter distribution resembled that of the two-aged Mskoda, but age analysis indicated continuous recruitment over a 25-year time period suggesting an unbalanced, uneven aged structure.

Stands with shorter fire-free intervals (i.e., more fire) had the lowest tree density, sapling/grub density, total stem density of all woody vegetation, total tree basal area, and total percent canopy cover of all woody saplings and shrubs (Tables 2 and 3). Also, shorter fire-free intervals corresponded with larger and older trees, whereas smaller diameter and younger trees were associated with longer fire-free intervals. Hollow boles and visible fire scar wounds on tree boles were most numerous in the two stands with the shortest fire-free intervals (Tables 2 and 4). Other measured crown and bole characteristics did not exhibit a clear association with fire frequency.

DISCUSSION

Our results indicate a frequent fire presence on the Kankakee Sands landscape throughout the 1930-2007 study period. This contrasts with fire suppression characteristic of most other portions of the Midwest and Eastern United States (Shumway et al. 2001; Ruffner and Groninger 2006; Abrams and Nowacki 2008). It is likely the fire events of this period were accurately detected at Kankakee Sands given the abundance of trees initially scarred when they were young and of small diameter and, therefore, of high susceptibility to fire scarring (Guyette et al. 2006). The high frequency of fire scars in the dormant

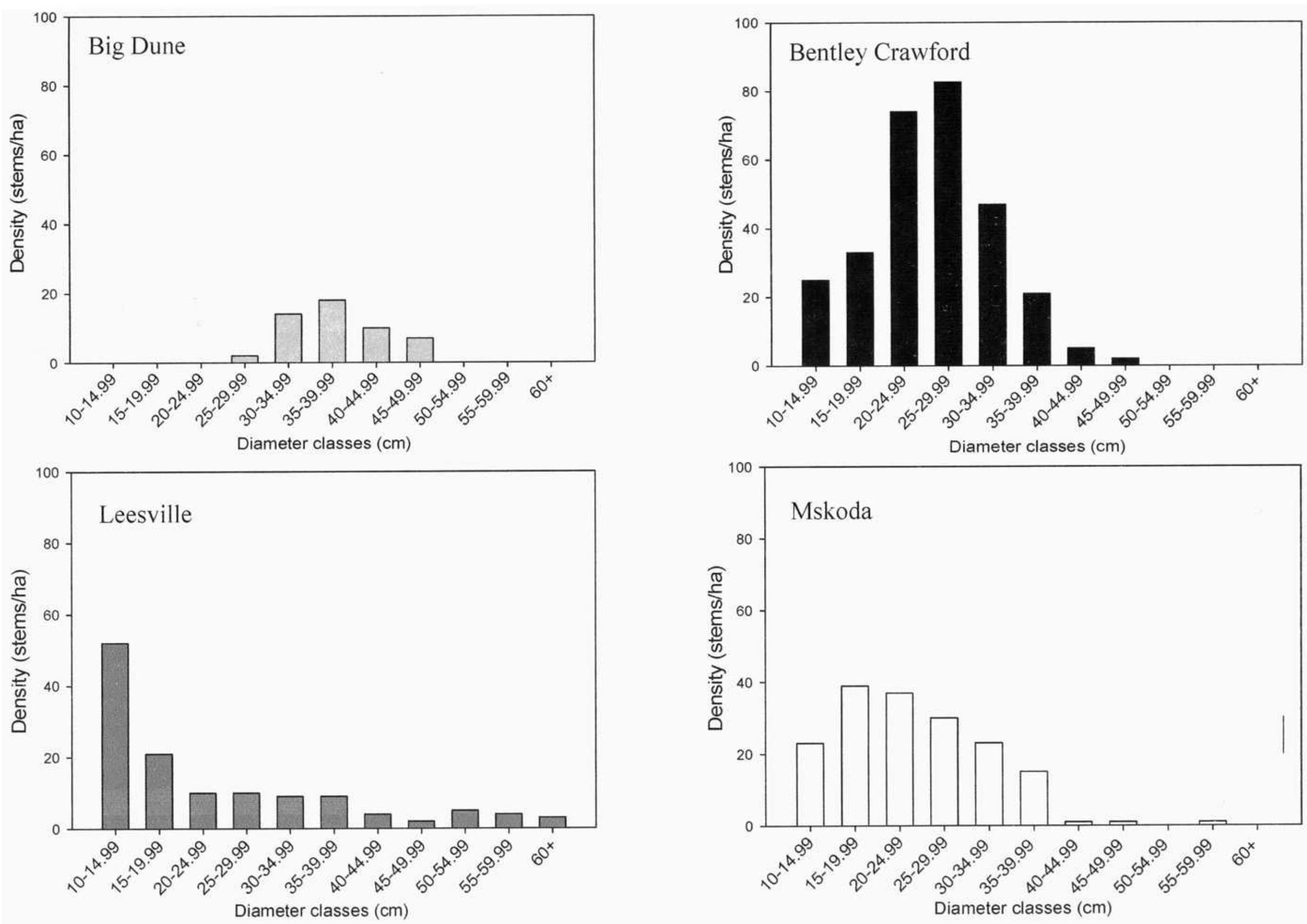

Figure 2. Tree distribution by 0.05-m diameter size classes for four Kankakee Sands stands.

Table 3. Structural components and age demographics of trees within four Kankakee Sands stands measured in 2007.

	Stand			
	Bentley Crawford	Big Dune	Leesville	Mskoda
Total tree density (stems ≥10 cm dbh//ha)	245 ± 22	43 ± 7	108 ± 14	145 ± 7
Oak sapling density (stems <10cm dbh/ha)	1061 ± 171	551 ± 115	1883 ± 199	1190 ± 256
Total woody stem density (stems/ha)	1327 ± 178	593 ± 119	1973 ± 198	1355 ± 259
Small tree (10-15cm dbh) density (stems/ha)	21 ± 6	0	43 ± 10	21 ± 6
Tree basal area (m^2/ha)	13.5 ± 0.9	4.9 ± 0.8	7 ± 1	7.5 ± 0.9
Shrub canopy cover (%)	36 ± 7	8 ± 2	24 ± 3	28 ± 4
Mean tree diameter (cm) (stems ≥10 cm dbh)	27 ± 1	39 ± 1	28 ± 2	26 ± 1
Mean age (y)	57 ± 2	67 ± 4	52 ± 5	45 ± 3
Minimum/Maximum age (y)	37/89	30/128	27/108	26/74

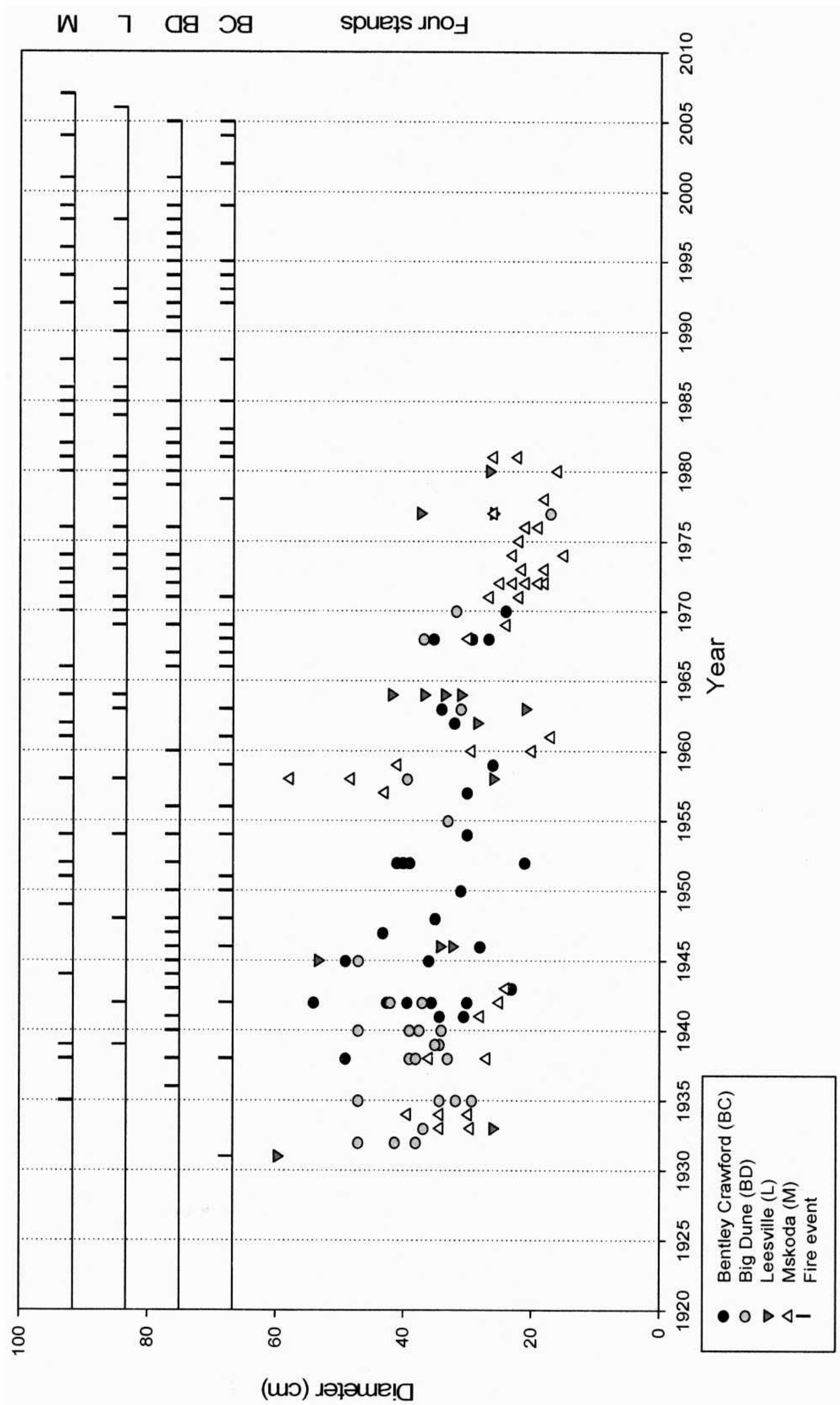

Figure 3. Year of fire occurrence and tree origin versus stem diameter in 2007 for *Quercus velutina* in four Kankakee Sands stands. (Sample sizes were BC = 30; BD = 28; M = 40; L = 16).

Table 4. Canopy tree crown and bole characteristics within four stands at Kankakee Sands measured in 2007.

	Stand			
	Bentley Crawford	Big Dune	Leesville	Mskoda
Mean number of dead branches (branches/ha)	156 ± 10	176 ± 17	169 ± 154	180 ± 20
Canopy volume index (m^3/ha)	1779 ± 99	3002 ± 332	2473 ± 247	1507 ± 76
Mean canopy loss (%)	19 ± 2	16 ± 3	19 ± 3	18 ± 3
Trees with hollow boles (%)	4 ± 1	21 ± 7	4 ± 2	22 ± 6
Trees with visible fire scars (%)	36 ± 3	72 ± 7	40 ± 6	57 ± 6

season and the unlikelihood of lightning ignition in this region suggest that human activity was the primary source of ignitions (McClain and Elzinga 1994; Sauer 1975; Anderson 2006).

Variation in fire frequency between stands appeared to influence current stand structure. Within the four stands, the shortest fire-free intervals were associated with lowest densities of trees of all size classes. These results are consistent with those from other sand savannas with high fire frequencies (Johnson and Ebinger 1992; Peterson and Reich 2001). Conversely, longer fire-free intervals or lack of fire in oak-dominated stands have been associated with higher tree density, basal area, and canopy cover (Stout 1944; Cooper 1960; Abrams 1986; Faber-Langendoen and Davis 1995).

Haney et al. (2008) reported that non-oak species established in eastern sand savannas during longer fire-free intervals may be difficult to remove with low intensity prescribed burns at a return rate as high as three fires per decade. Fire return intervals in this study were shorter than three years and, in all cases, were associated with the absence of fire intolerant canopy tree species. The lack of long fire-free periods favored fire tolerant species, specifically *Q. velutina*, which is adapted to thrive in nutrient poor soils while under a frequent disturbance regime (Korstian 1927). *Quercus velutina* also re-sprouts vigorously following fire (Cole and Taylor 1995) and is represented by several cohorts that date to several key fire years.

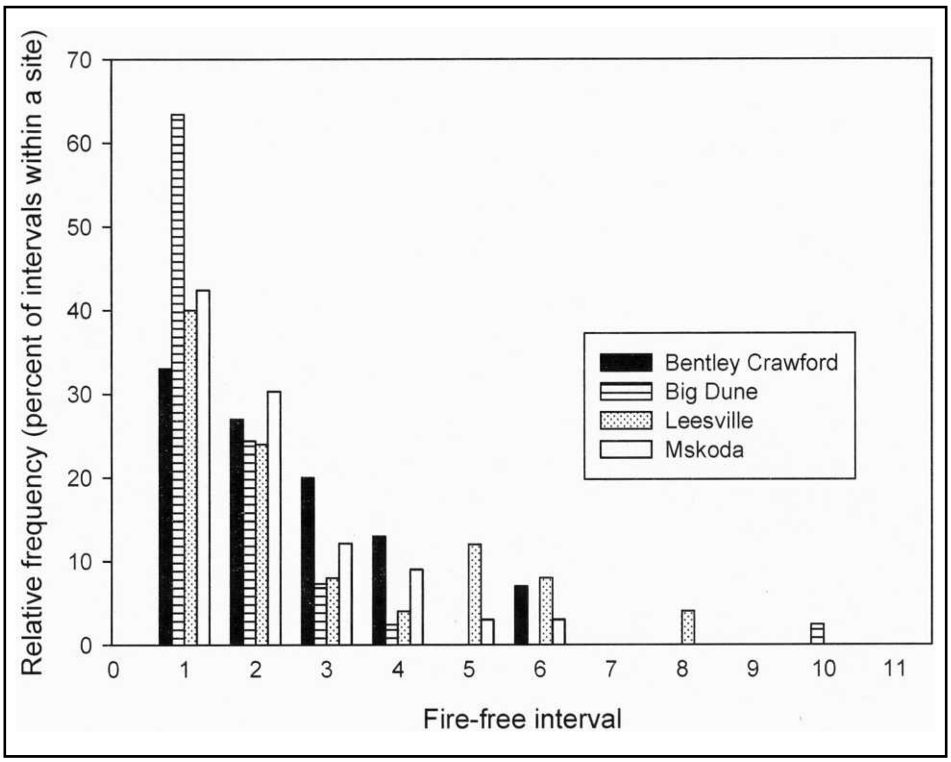

Figure 4. Fire-free interval distribution (number of years) obtained from 58 cross-sections indicating fire occurrences in four Kankakee Sands stands.

Substantial structural differences between these stands with similar fire regimes suggest that fire alone may not be able to maintain an open canopy while regenerating canopy trees. For instance, fire return intervals of less than two years at Big Dune resulted in an open canopy characteristic of a pre-settlement black oak sand savanna tree density (Haney et al. 2008), but eliminated potential future canopy trees. Under present fire regimes and associated lack of tree recruitment, much of the tree canopy will be lost within several decades, because *Q. velutina* is a relatively short lived tree, rarely exceeding age 150 y (Guyette and Stambaugh 2004). The Kankakee Sands stands were considerably younger, with only three sampled trees exceeding 100 years and the oldest tree cored aged 128 years. High fire frequency coupled with *Q. velutina* susceptibility to heart rot prevents definitive determination of maximum tree age and stem origin across these stands (Figure 5).

The fire history and stand structure results suggest fire played a considerable role in the composition and structural development of the four oak savanna stands at Kankakee Sands. Dominance of oak species and absence from all plots of fire sensitive, mesophytic tree species with dbh > 10 cm, such as regionally common maple (*Acer* spp.) or cherry (*Prunus* spp.), suggests a strong presence of fire (Abrams and Nowacki 2008). However, stand structural characteristics and their variation among the four stands suggest the presence of other influences as well.

Although the aim of our study was limited to considerations of fire impacts on stand structure, the interactions among other disturbances - specifically fire, grazing, firewood cutting, and drought - may be considered in a future study (Curtis and McIntosh 1951; Rogers and Anderson 1979; Abrams 1992; Olson 1996; Anderson and Bowles 1999; Will-Wolf and Stearns 1999; Peterson and Reich 2001; Karnitz and Asbjornsen 2006). Historical accounts of bison in the Kankakee River Valley date back to 1679 (White 1999). Even though the last documented bison in Illinois was killed in 1837, cattle grazed over 68,825 hectares within the Kankakee Sands region in the mid-1800s to supply the Chicago beef industry (White 1999). Grazing was evident in the 1939 aerial photograph based on distinct lines (fencing) and cattle paths on the landscape. In addition, data from the U.S. Department of Agriculture Statistics Service (2008) indicated a 75% decline in pastured cows in Kankakee County, Illinois, from 1930 to 2007 (Figure 1). The Illinois Natural History Survey (INHS) concluded that woody overstory extent almost doubled from 1939 to 1988 (Figure 1) despite the high fire frequency sustained across all stands during that period. Analyses of the age and diameter distributions can help explain potential past land-use disturbances (Oliver 1981; Groven et al. 2002) that may have affected the development and current structure of the four stands at Kankakee Sands. Recruitment pulses may indicate periodic release of cohorts following one or more major disturbances, possibly including a lapse in grazing (Mast et al. 1998), reduced fire frequency (Brose et al.

Figure 5. A black oak sand savanna remnant in the Kankakee Sands region of northeastern Illinois. The effects of frequent fire over the last century are apparent; abundant *Quercus velutina* regeneration, open canopy, a visible healed fire scar near the base of a *Q. velutina* in the foreground, and the remnants of a dead *Q. velutina* in the background (photo by Fran Harty).

2001), or following tree cutting (Abrams and Downs 1990). We suspect that grazing impacts during the formative stages of the present stands may have influenced present conditions to an extent that is evident from current land-use patterns. Grazing, in combination with fire reduced midstory woody vegetation in the initial stages of savanna restoration in Wisconsin, suggests that livestock may play a useful role in savanna management programs (Harrington and Kathol 2008). While large ungulates reduce fuel loads and midstory vegetation through consumption and trampling, they maintain open canopies while reducing fire severity. This interaction facilitates recruitment of future canopy trees among those individuals escaping herbivory (Trollope 1984; Savage and Swetnam 1990; Kaufmann et al. 1994). Ascertaining grazing impacts are beyond the limitations of our analysis; this anecdotal evidence suggests future investigations should consider this potentially critical influence on savanna stand structure.

Tree removal may play a role in maintaining savanna stand structures. Leesville was the only stand displaying evidence of periodic stem removal and stem recruitment patterns consistent with a regenerating forest stand. Leesville also had the largest number of trees ranging from saplings to the largest size classes, suggesting consistent canopy recruitment and the prospects for consistently maintaining savanna stand structure for many decades, provided high fire frequency is maintained. This stand contained stumps at different stages of decay, a high incidence of wood burning stoves (stovepipes observed extending from homes), and woodpiles among surrounding habitations - all consistent with cultural and physical landscapes subjected to repeated partial cutting. Active tree removal is likely consistent with human use throughout the history of the region. This suggests cutting may be a keystone disturbance in the presence or absence of grazing (Putz 2003).

Our results suggest that fire alone does not fully explain the origin and current stand structure of the black oak sand savannas in our study area. Additional research into the interactions between fire and grazing and/or selective tree removal would be useful to support resource managers who may want to incorporate grazing and selective tree cutting to facilitate the long-term viability of black oak sand savannas. Management activities that incorporate grazing and/or selective tree removal with fire may maintain an open canopy while allowing recruitment of the next canopy trees. Kankakee Sands has had a history of wildfires and firewood cutting, which continues today. Over 160 years of cattle grazing has synergistically maintained a modern day landscape dominated by high quality savannas. Therefore, management of sand savannas with similar histories should consider these synergistic actions that are not typically viewed as traditional natural area management tools.

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John is a Professor at Southern Illinois University Carbondale in the Department of Forestry and a member of the Center for Ecology. His research interests include reforestation, stand dynamics, ecosystem management, and temperate agroforestry systems.

Charles studies the historical and current management activities of landscapes on our planet and teaches courses on Disturbance Ecology, Historical Ecology, Fire Management, and Forest Measurements within the Department of Forestry at SIUC.

Matthew's primary research expertise is in the development of high quality tree-ring chronologies for use in the study of paleoclimatology and human-environmental dynamics. His current research includes reconstructing drought in southern Africa and studying paleoflooding on the Mississippi River.

Sara is an Associate Professor at Southern Illinois University Carbondale in the Department of Plant Biology and a member of the Center for Ecology. Her research is primarily focused on ecological filters that affect the recovery of soil structure and functioning, plant community composition, and ecosystem processes during ecological restoration. She applies ecological theory to advance and inform restoration and uses quantitative ecological responses from restored systems to test the generality of theory in ecology.

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