STAND COMPOSITIONAL DYNAMICS IN A MATURE ILLINOIS OZARKS FOREST: IMPLICATIONS FOR MANAGEMENT

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ABSTRACT.—The Ozark Hills region of southern Illinois is characterized by the severe topography typical of the Ozark Plateau, but is overlain by loess deposits and therefore supports site conditions more typical of mesophytic forests. As is common in lightly disturbed and undisturbed mesic upland sites throughout this region, mature stands in Trail of Tears State Forest are characterized by an oak and hickory-dominated overstory and an under- and mid-story where sugar maple and American beech predominate. Between 1980 and 2000, oak and hickory species generally declined in importance while sugar maple, American beech, and yellow-poplar increased, a trend consistent with those reported in other southern Illinois forests of similar species composition. However, the sugar maple and American beech component at Trail of Tears State Forest are larger and expanding more rapidly than those reported elsewhere within the region. Management options to address these changes are discussed.

Continuously forested public lands in the lower Midwest commonly exhibit a land-use pattern where grazing, occasional burning, and partial cutting have given way to exclusion of all non-recreational activities. These stands commonly feature an overstory dominated by oaks and an understory dominated by shade tolerant mesophytic tree species (Schlesinger 1976, Shotola and others 1992, Zaczek and others 1999).

Trail of Tears State Forest is located in one of the largest blocks of contiguous forest in the lower Midwest. Superficially, most of the forest resembles a maturing-to-old growth, undisturbed stand because much of the forest has been under continuous forest cover and subjected to only partial cutting through the 1980s. A Technical Forestry Plan prepared for the Illinois Department of Conservation in 1984 called for management through selective harvesting. All aspects of the plan involving overstory manipulation have been curtailed since 1989. The availability of data from permanent plot inventories collected in 1980 and again in 2000 provides a unique opportunity to evaluate 20 years of changes across much of this mature oak-dominated forest following cessation of harvesting and burning disturbances.

The objective of this study is to describe changes in tree species composition and dominance within the context of developing guidelines to manage Trail of Tears State Forest.

METHODS

Trail of Tears State Forest encompasses 2,089 ha of the Ozark Hills in Union County, IL. Roughly 93 percent of the terrain is characterized by long narrow ridges dropping off sharply on either side 45 to 60 m to the bottomlands of ephemeral streams, which constitute the remaining 7 percent of the landscape. Slopes are typically steep, restricting roads to ridgetops. Soils are predominantly well-drained silt loams and cherty silt loams.

Most overstory trees originated during one of two periods of recruitment; the 1850s (primarily oak species) and the 1930s (primarily oaks and maples in the absence of fire) (Van de Gevel and others 2002). Since coming under state control in 1929, Trail of Tears State Forest has been

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actively managed for multiple objectives including that of maintaining full stocking with healthy trees. This has involved in part, fire suppression, exclusion of cattle, and partial cutting during the first 55 years of public ownership. A total of 1,017,400 board feet of sawtimber and 1,364 cords of pulpwood were harvested from the forest between 1930 and 1980. No overstory manipulation has occurred on the forest since 1989.

Data Collection and Analysis

Trail of Tears State Forest was inventoried in 1980 using a permanent plot system where 809 m^2 plots were placed across the forest on a 281 m grid for a total of 238 plots. Within these plots, all trees larger than 7.61 cm dbh were identified by species and their diameter measured. These plots were again inventoried in 2000. Plots containing planted pines (n=9) and those subjected to partial cutting following the 1980 inventory (n=38) were excluded from the data presented here (n=191). During the 2000 inventory, four 9 m^2 circular regeneration plots each were established at cardinal directions 7.93 m from the center of each permanent overstory plot. Within these plots, individuals of arborescent species were identified by species and those <7.62 cm dbh but ≥ 1 m tall were classified as saplings. Stems <1 m in height were classified as seedlings.

Stocking was calculated using standards developed for even aged upland central hardwood stands (Roach and Gingrich 1968). Significance of changes in density and basal area between 1980 and 2000 inventories were compared using paired t-tests (Pallardy and others 1988)

RESULTS AND DISCUSSION

Over the 20 year period of this study, basal area and mean diameter have increased while stem density has decreased (table 1). Overall, stand stocking has increased reflecting a fully stocked condition (Roach and Gingrich 1968).

The trend of decreasing density and increasing basal area is typified by white oak (*Quercus alba* L.) and northern red oak (*Q. rubra* L.). Dominant individuals of these species will be attaining their maximum ages during the next several decades (Loehle 1988, Van de Gevel and others 2003). Canopy disturbances more severe than have been experienced since the onset of public ownership will be required to maintain these species as a significant component of this forest. The typically shorter-lived sassafras (*Sassafras albidum* (Nutt.) Ness) is also following a similar pattern. As is the case with the oaks, the continued presence of sassafras appears to be dependent upon the occurrence of at least partial canopy disturbance. At Kaskaskia Woods, sassafras declined from its

Table 1.—*Summary of stand characteristic changes over 20 years at Trail of Tears State Forest, Illinois*

Stand Characteristic	1980 inventory	2000 inventory	Percent change
Overstory density (stems/ha)	505	468	-7.3
Basal Area (m^2/ha)	21.3	24.6	+15.5
Quadratic mean diameter (cm)	23.2	25.9	+11.6
Stocking (percent)	83	93	+12.0
Regeneration Density (stems/ha)	NA	12,839	NA

status as the fourth most frequently occurring species in 1935 to extirpation by 1983 (Zaczek and others 2002).

In contrast to the oaks, sugar maple (*Acer saccharum* Marsh.), American beech (*Fagus grandifolia* Ehrh.), and yellow-poplar (*Liriodendron tulipifera* L.) are increasing in both density and basal area (table 2). Sugar maple and American beech are widely recognized as capable of regenerating and recruiting under a fairly closed forest canopy (Hibbs 1982, Canham 1985). In contrast, yellow-poplar requires at least a partially open canopy to grow beyond regeneration (Orwig and Abrams 1997). Increased density of this species may in part reflect the increasing presence of canopy gaps, through the death of canopy dominant and super dominant individuals, particularly on the lower slope and bottomland positions.

Black oak (*Quercus velutina* Lam.), other oak species, and flowering dogwood (*Cornus florida* L.) showed significant declines in both density and basal area (table 2). The decline of black oak is consistent with the fact that individuals in the 1850s cohort are approaching the recognized maximum age of this species (Sander 1990). Decreased black oak density and basal area in this stand will likely continue, as younger individuals do not replace the senescent cohort.

The decrease in flowering dogwood density and dominance may be at least in part attributed to the emergence of dogwood anthracnose (*Discula destructiva*) as a major cause of decline in the species over the past 2 decades (Carr and Banas 2000). Other factors may also be contributing to decreased dogwood importance as is evidenced by a decline in dogwood density and basal area at Kaskaskia Woods that began decades before

Table 2.—*Density and basal area changes over 20 years among major tree species at Trail of Tears State Forest, Illinois*

	Density (stems/ha)				Basal Area (m^2/ha)			
Species	**1980**	**2000**	**Change**	**p-value**	**1980**	**2000**	**Change**	**p-value**
Acer rubrum L.	10.2	7.6	-2.6	0.08	0.2	0.2	0	0.53
Acer saccharum Marsh.	60.0	102.7	+42.8	0.00	1.1	2.1	+1.0	0.00
Carya spp.	67.7	55.9	-11.8	0.00	2.4	2.5	+0.1	0.56
Cornus florida L.	25.9	21.7	-4.1	0.04	0.2	0.1	-0.1	0.00
Fagus grandifolia Ehrh.	20.0	46.3	+26.3	0.00	0.9	1.5	+0.6	0.00
Fraxinus spp.	21.1	13.6	-7.4	0.00	0.5	0.5	0	0.56
Liquidambar styraciflua L.	8.7	6.0	-2.8	0.04	0.3	0.3	0	0.36
Liriodendron tulipifera L.	12.8	15.0	+2.2	0.04	1.2	2.1	+0.9	0.00
Nyssa sylvatica Marsh.	9.3	11.9	+2.7	0.03	0.2	0.3	+0.1	0.06
Ostrya virginiana (Mill.)K Koch	17.5	17.2	-0.3	0.85	0.2	0.1	-0.1	0.16
other non-*Quercus*[1]	13.5	9.4	-4.1	0.00	0.4	0.3	-0.1	0.09
Quercus alba L.	99.4	72.5	-26.8	0.00	5.4	6.8	+1.3	0.00
Quercus rubra L.	41.9	24.0	-17.9	0.00	2.6	3.1	+0.5	0.02
Quercus velutina Lam.	36.3	18.2	-18.0	0.00	4.7	3.5	-1.2	0.00
other *Quercus* spp.[2]	6.5	2.0	-4.5	0.00	0.4	0.2	-0.2	0.03
Sassafras albidum (Nutt.)Ness	47.9	37.7	-10.2	0.00	0.6	0.7	+0.1	0.01
Ulmus spp.	6.7	5.8	-0.9	0.34	0.4	0.2	-0.2	0.84

1 Includes *Amelanchier arborea* (Michx.) Fern., *Juglans nigra* L., *Magnolia acuminata* L., *Platanus occidentalis* L., *Prunus serotina* Ehrh., and 16 additional species.
2 Includes *Quercus bicolor* Willd., *Q. coccinea* Muenchh., *Q. macrocarpa* Michx., *Q. michauxii* Nutt., *Q. muhlenbergii* Engelm., *Q. prinus* L., and *Q. stellata* Wangenh.

the first documented occurrence of anthracnose in Illinois (Schwegman and others 1998, Zaczek and others 2002). Perhaps a similar decline will occur in the Trail of Tears State Forest as well.

The seedling stratum is dominated by intermediate to tolerant tree species including sugar maple, red maple (*Acer rubrum* L.), hickory (*Carya* Nutt. spp.), white ash (*Fraxinus americana* L.), and hophornbeam (*Ostrya virginiana* (Mill.) K.Koch) (table 3). Other important understory and mid-story species in the seedling and sapling strata include paw paw (*Asimina triloba* (L.) Dunal) and spicebush (*Lindera benzoin* (L.) Blume). Although many other species, including oaks, are present in the understory, only sugar maple and American beech are consistently recruiting into the sapling size class and beyond. These results are consistent with observations at Kaskaskia Woods where no oak recruitment has occurred in 62 years of observation (Zaczek and others 2002). Similarly, few oak saplings were recorded at Weaver Woods (Shotola and others 1992).

Our results suggest that the low intensity of disturbances at Trail of Tears State Forest is permitting the development of only shade tolerant species. Therefore, the decline of oaks and other disturbance dependent species and the emergence of sugar maple and American beech is likely to continue as long as a management

Table 3.—*Regeneration composition of Trail of Tears State Forest, Illinois during summer 2000*

Species	Seedlings (< 1 m height)		Saplings (>1 m height and <7.61 cm dbh)	
	Density (stems/ha)	Relative Density	Density (stems/ha)	Relative Density
Acer rubrum	908	7.9	23	1.7
Acer saccharum	744	6.5	279	21.4
Asimina triloba	2225	19.3	44	3.3
Carya spp.	637	5.5	48	3.7
Cornus florida	99	0.9	59	4.5
Fagus grandifolia	811	7.0	508	38.8
Fraxinus spp.	899	7.8	13	1.0
Lindera benzoin	445	3.9	11	0.9
Liriodendron tulipifera	155	1.3	24	1.8
Nyssa sylvatica	154	1.3	14	1.1
Ostrya virginiana	684	5.9	92	7.0
other non-*Quercus*	3,223	28.0	169	12.9
Quercus alba	461	4.0	10	0.8
Quercus rubra	162	1.4	0	0
Quercus velutina	458	4.0	1	0.1
other *Quercus* spp.	42	0.4	0	0
Sassafras albidum	1,654	14	44	3.3
Ulmus spp.	440	3.8	24	1.8
Total	11,531	100	1,308	100

program characterized by little or no canopy disturbance is pursued (Trimble 1965, Schlesinger 1976).

Similarities among Trail of Tears State Forest and the less disturbed Kaskaskia Woods and Weaver Woods are striking despite differences in the disturbance regimes (table 4). Kaskaskia Woods was last partially cut during the 1910s (Schlesinger 1976). Fire and grazing have been excluded since 1933. Weaver Woods was free of grazing and subjected to removal of fewer than 100 trees over 7.2 ha from 1871 until 1950 when all cutting ceased (Weaver and Ashby 1971).

The higher density and basal area of shade tolerant sugar maple and American beech at Trail of Tears State Forest may be attributed to the fact that this forest is in an earlier stage of stand development than Kaskaskia Woods and Weaver Woods. In Kaskaskia Woods, the rate of sugar maple density increase has slowed somewhat since the 1950s. Alternately, the use of partial cutting at Trail of Tears State Forest without subsequent control of the shade tolerant mid-story may be contributing to increased growth of maple and beech. Partial cutting regimes may in effect simulate gap phase regeneration and recruitment dynamics displayed by these species (McGee and others 1999), potentially hastening the conversion to late successional species (Abrams and Scott 1989) if midstory control measures are not implemented.

Inherent site quality differences among the three stands discussed here may play a role in species composition and growth patterns. Trail of Tears State Forest is western-most along a gradient of surficial loess deposits that decrease from West to East. This, along with the presence of bottomland sites may be responsible for the rapid rate of increase in sugar maple and yellow-poplar basal area exhibited in the Ozark Hills.

MANAGEMENT IMPLICATIONS

The results presented here suggest that restricting overstory manipulation to partial cutting has produced stand conditions similar to those observed in forests where cutting has been curtailed for several decades. Regeneration and recruitment of overstory tree species, although abundant, is restricted to a small number of shade tolerant species. Failure to accomodate the regeneration and recruitment requirements of less shade tolerant species will, in the absence of natural catastrophic disturbance, result in their decline and likely eventual extirpation.

Some form of canopy disturbance will likely be necessary to secure sufficient regeneration of current canopy dominant species. These might include the use of shelterwood or two age systems, including the use of prescribed fire (Moser

Table 4.—*Annualized percent changes among major overstory tree species density and basal area in three southern Illinois forests*

Species	Trail of Tears State Forest		Weaver Woods[1]		Kaskaskia Woods[2]	
	Density	Basal Area	Density	Basal Area	Density	Basal Area
Acer saccharum	+3.6	+4.5	-0.2	+2.6	-0.4	+3.4
Carya spp.	-0.9	+0.2	-1.5	+0.3	-1.8	+0.1
Fagus grandifolia	+6.6	+3.3	-0.7	+0.2	NA	NA
Liriodendron tulipifera	+0.9	+3.8	-0.3	+0.9	+0.3	+2.1
Quercus alba	-1.4	+1.3	-0.5	+1.7	-2.2	+0.1
Quercus rubra	-2.2	+1.0	-1.3	0.0	-2.3	-0.6
Quercus velutina	-2.5	-1.3	-1.8	-1.5	-1.9	-0.5

1 Adapted from Shotola and others (1992).
2 Adapted from Zaczek and others (2002).

and others 1996, Brose and others 1999, Ruffner and Davis 2001). Adjustment of a single tree selection regime (Loewenstein and others 2000) where shade tolerant mid-story and understory species are controlled (Kochenderfer and others 2001) may also accomplish this objective.

If a system dependent upon sustained partial cutting is implemented, care must be taken to assure that volume of trees removed is balanced by ingrowth of the same species so that a diverse overstory is maintained. If harvesting were continued at Trail of Tears State Forest in such a manner that oak regeneration is not secured, sugar maple and American beech ingrowth could produce a sustained flow of volume while resulting in a conversion to non-oak dominance. To date, management systems with relatively low visual impact have failed to secure regeneration of the dominant oaks and hickories, yet have also aroused sufficient public outrage to suspend overstory manipulation indefinitely. The more drastic disturbances required to secure a new cohort of oak and hickory species will be extremely challenging to implement in the current social and political environment.

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LITERATURE CITED

Abrams, M.D.; Scott, M.L. 1989. Disturbance-mediated accelerated succession in two Michigan forest types. Forest Science. 35: 42-49.

Brose, P.H.; Van Lear, D.H.; Keyser, P.D. 1999. A shelterwood burn technique for regenerating productive upland oak sites in the piedmont region. Southern Journal of Applied Forestry. 23: 158-163.

Canham, C.D. 1985. Suppression and release during canopy recruitment in *Acer saccharum*. Bulletin of the Torrey Botanical Club. 112: 134-145.

Carr, D.E.; Banas, L.E. 2000. Dogwood anthracnose (*Discula destructiva*) effects of and consequences for host (*Cornus florida*) demography. American Midland Naturalist. 143: 169-177.

Hibbs, D.E. 1982. Gap dynamics in a hemlock-hardwood forest. Canadian Journal of Forest Research. 12: 522-527.

Kochenderfer, J.D.; Zedaker, S.M.; Johnson, J.E.; Smith, D.W.; Miller, G.W. 2001. Herbicide hardwood crop tree release in central West Virginia. Northern Journal of Applied Forestry. 18: 46-54.

Loehle, C. 1988. Tree life history strategies: the role of defenses. Canadian Journal of Forest Research. 18: 209-222.

Loewenstein, E.F.; Johnson, P.S.; Garrett, H.E. 2000. Age and diameter structure of a managed uneven-aged forest. Canadian Journal of Forest Research. 30: 1060-1070.

McGee, G.G.; Leopold, D.L.; Nyland, R.D. 1999. Structural characteristics of old growth, maturing and partially cut northern hardwood forests. Ecological Applications. 9: 1316-1329.

Moser, W.K.; Ducey, M.J.; Ashton, P.M.S. 1996. Effects of fire intensity on competitive dynamics between red and black oaks and mountain laurel. Northern Journal of Applied Forestry. 13: 119-123.

Orwig, D.A.; Abrams, M.D. 1994. Contrasting radial growth and canopy recruitment patterns in *Liriodendron tulipifera* and *Nyssa sylvatica*: gap obligate versus gap-facultative tree species. Canadian Journal of Forest Research. 24: 2141-2149.

Pallardy, S.G.; Nigh, T.A.; Garrett, H.E. 1988. Changes in forest composition in central Missouri: 1968-1982. American Midland Naturalist. 120: 380-390.

Roach, B.A.; Gingrich S.F. 1968. Even-aged silviculture for upland central hardwoods. Agric. Handb. 355. Washington, DC: U.S. Department of Agriculture, Forest Service. 39 p.

Ruffner, C.M.; Davis, M.B. 2001. Assessing the effects of prescribed burning on understory vegetation at Trail of Tears State Forest. Final Report. Springfield, IL: Illinois Department of Natural Resources.

Sander, I.L. 1990. Black oak. In: Burns, R.N.; Honkala, B.H., tech. coord. Silvics of North America, Volume 2, Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 744-750.

Schlesinger, R.C. 1976. Hard maples increasing in upland hardwood stands. In: Fralish, J.S.; Weaver, G.T.; Schlesinger, R.C., eds. Proceedings, 1st Central Hardwood Forest conference. Carbondale, IL: Southern Illinois University: 177-185.

Schwegman, J.E.; McClain, W.E.; Esker, T.L.; Ebinger, J.E. 1998. Anthracnose-caused mortality of flowering dogwood (*Cornus florida* L.) at the Dean Hills Nature Preserve, Fayette County, Illinois, U.S.A. Natural Areas Journal. 18: 204-207.

Shotola, S.J.; Weaver, G.T.; Robertson, P.A.; Ashby, W.C. 1992. Sugar maple invasion of an old-growth oak-hickory forest in southwestern Illinois. American Midland Naturalist. 127: 125-138.

Trimble, G.R., Jr. 1965. Species composition changes under individual tree selection cutting in cove hardwoods. Res. Note NE-30. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 6 p.

Van De Gevel, S.; Ozier, T.B.; Ruffner, C.M.; Groninger, J.W. 2003. Relating past land-use, topography, and forest dynamics in the Illinois Ozark Hills. In: Van Sambeek, J.W.; Dawson, J.O.; Ponder, F., Jr.; Loewenstein, E.F.; Fralish, J.S., eds. Proceedings, 13th Central Hardwood Forest conference; 2002 April 1-3; Urbana, IL. Gen. Tech. Rep. NC-234. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 246.

Weaver, G.T.; Ashby, W.C. 1971. Composition of an old growth forest remnant in unglaciated southwestern Illinois. American Midland Naturalist. 86: 46-56.

Zaczek, J.J.; Groninger, J.W.; Van Sambeek, J.W. 1999. Long-term changes in tree composition in an upland mixed mesic forest in southern Illinois. In: Stringer, J.W.; Loftis, D.L., eds. 12th Central Hardwood Forest conference. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 274-275.

Zaczek, J.J.; Groninger, J.W.; Van Sambeek, J.W. 2002. Stand dynamics in an old-growth hardwood forest in southern Illinois, U.S.A. Natural Areas Journal. 22(3): 211-219.