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Woody Vegetation of Davis-Purdue Research Forest

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Introduction

The Davis-Purdue Research Forest (DPRF) is a 20.6 ha old-growth deciduous forest dedicated to investigations of long-term forest dynamics. The forest is located in Randolph County (Section 23, T21N, R12E) in east-central Indiana. It is recognized as one of the finest old-growth stands remaining on the Tipton Till Plain and is a Registered National Natural Landmark. The forest was probably grazed before Martha Davis donated the land to Purdue University in 1917 (5). There was limited harvesting of dead and dying trees prior to 1960. In 1971 there was a surface fire of 2-3 hectares in the western part of the forest.

Topography is gently rolling with low relief; elevation changes less than five meters over the forest. Areas of seasonal ponding are scattered throughout the forest. These wetter areas are associated with Pewano and Brookston silty clays. Morley silt loams are found on the well-drained slopes. The somewhat poorly drained Blount silt loam is found on the level higher locations. More extensive descriptions topography and soils can be found elsewhere (5, 6).

Earlier research of DPRF examined compositional dynamics of stems ≥ 10 cm dbh (5, 6, 9) or was limited to canopy gaps (6). The objective of this research was to expand the vegetation inventory to include all stems ≥ 2 cm dbh (diameter at 1.37 m) and determine which species were present in the 0-1.9 cm dbh size class. This information allows for a more comprehensive examination of stand structure, especially of the large reproduction or sapling size classes. In addition these data will facilitate future research on recruitment in the larger diameter classes by providing baseline data of present conditions.

Methods

In 1986 a 10x10 m grid system was installed in an interior study area (9 ha) of the forest with a transit and 50 m tape. Corners were marked with numbered plastic stakes. The study area was located in the center of the forest to minimize any edge effects on vegetation composition. The data reported here is based on a 100% inventory of the eastern 4 ha (200 x 200m) of the interior study area, which excludes the area burned in 1971.

All woody stems ≥ 2 cm dbh were recorded within each 10x10 m quadrat. Stems less than 10 cm dbh were recorded by 2 cm diameter classes: 2.0-3.9 cm, 4.0-5-9 cm, 6.0-7.9 cm, and 8.0-9.9 cm. Stems greater than 10 cm dbh were measured to the nearest 0.1 cm dbh. Five diameter classes were used: small regeneration (2.0-5.9 cm dbh), large regeneration (6.0-9.9 cm dbh), intermediate trees (10.0-19.9 cm dbh), small overstory trees (20.0-49.9 cm dbh), and large overstory (≥ 50 cm dbh). Presence/absence of each species in the 0.0-1.9 cm diameter class within each quadrat was also recorded. Plants with multiple stems were considered as one individual. For multiple stemmed individuals with the largest stem less than 10 cm dbh, only the largest stem diameter was recorded. The diameters of all stems ≥ 9 cm dbh were recorded when the diameter of the largest stem was greater than 10 cm.

Results

Density

The 4 ha study area contained 5260 stems, ≥ 2.0 dbh, distributed among 40 species (Table 1). An additional six species were present only in the 0.0-1.9 cm diameter class (Table 1). Examination of the diameter strata revealed three distinct vegetation

TABLE 1. Density (stems/ha) by diameter class and species at the Davis-Purdue Research Forest based on a 100% inventory of 4 hectares.

	DIAMETER CLASS[1]					
SPECIES	2.0 –5.9	6.0 –9.9	10.0 –19.9	20.0 –49.9	>50	TOTAL
Acer negundo	11.0	4.0	2.3	–	–	17.3
Acer rubrum	.3	.5	.3	.3	–	1.3
Acer saccharinum[2]	3.3	1.5	3.3	2.3	.8	11.0
Acer saccharum	412.5	77.0	50.8	17.0	1.3	558.5
Aesculus glabra	41.8	20.5	19.3	2.0	.3	83.8
Asimina triloba	19.5	.3	–	–	–	19.8
Carpinus caroliniana	60.8	20.3	6.8	–	–	87.8
Carya cordiformis	5.3	6.0	4.5	2.5	.3	18.5
Carya glabra	.3	.5	.8	.3	–	1.8
Carya ovata	7.8	9.5	17.3	12.0	.8	47.3
Celtis occidentalis	11.0	2.3	4.5	2.5	–	20.3
Cornus florida	2.3	.5	.3	–	–	3.0
Cornus racemosa	3.3	–	–	–	–	3.3
Corylus americana	1.3	–	–	–	–	1.3
Crataegus sp.	6.0	1.8	5.5	–	–	13.3
Fagus grandifolia	2.0	1.8	5.0	6.8	.3	15.8
Fraxinus americana[3]	8.5	2.5	1.8	6.0	9.0	27.8
Fraximus nigra	.5	.5	1.5	–	.3	2.8
Fraxinus quadrangulata	32.5	7.5	3.3	.5	.3	44.0
Gleditsia triacanthos	–	–	–	1.0	.8	1.8
Juglans nigra	–	–	1.0	7.0	2.0	10.0
Lindera benzoin	17.5	–	–	–	–	17.5
Morus rubra	.8	–	–	–	–	.8
Ostrya virginiana	12.8	3.0	3.3	.3	–	19.3
Platanus occidentalis	–	–	–	.5	.3	.8
Populus deltoides	–	–	–	–	.3	.3
Prunus serotina	3.3	.8	2.0	.8	–	6.8
Quercus alba	–	–	–	1.0	5.3	6.3
Quercus bicolor	2.3	.5	.8	5	2.0	6.0
Quercus macrocarpa	.3	.8	.5	1.8	7.5	10.8
Quercus muehlenbergii	.3	–	–	1.0	3.8	5.0
Quercus palustris	.3	–	–	.5	3.3	4.0
Quercus rubra	–	.5	.3	1.3	11.0	13.0
Quercus shumardii	–	–	–	–	3.0	3.0
Tilia americana	–	.3	–	.5	–	.8
Ulmus americana	31.3	24.8	43.0	17.3	–	116.3
Ulmus rubra	69.3	15.0	16.5	6.5	.3	107.5
Viburnum prunifolium	7.8	–	–	–	–	7.8
Total, stems/ha	775.0	202.3	194.0	91.8	52.3	1315.3

[1]Diameter (cm) at 1.37 m.

[2]Includes individuals of *Acer nigrum*.

[3]Includes individuals of *Fraxinus pennsylvanica*.

complexes: a overstory stratum dominated by mixed oaks, a mesophytic intermediate strata, and the regeneration strata dominated by sugar maple.

Like many of the old-growth forests in the Central Hardwood Region most of the stems in the upper canopy were *Quercus-Carya*, with oak species comprising over 68% of stems greater than 50 cm dbh. *Quercus rubra* was the most common large overstory species on the mesic ridges where it was associated with *Fraxinus americana* and *Quercus alba*. Overstory trees in the seasonally ponded areas formed a *Quercus macrocarpa-Q. palustris-Q. bicolor* complex. Less than 4% of this diameter class was *Acer sp.* or *Ulmus sp.*

While *Quercus sp.* and *F. americana* comprised 80% of the large overstory stems, these species accounted for only 13% of stems in the 20.9-49.9 cm diameter class. The small overstory stratum was not dominated by any one species group. The most abundant species were *Acer saccharum* and *Ulmus americana* with approximately 40% of the stems in this diameter class. Other common species were *Carya ovata* (13% of stems), *Juglans nigra* (8%), *Fagus grandifolia* (7%), and *Ulmus rubra* (7%).
(7%).

Acer saccharum, U. americana, and *U. rubra* were the dominant species in the 10.0-19.9 cm diameter class with 26%, 22%, and 9% of all stems, respectively. The hickories—*Carya ovata, C. cordiformis*, and *C. glabra*—accounted for another 12% of stems. Slightly less than 10% of stems were *Aesculus glabra*. Only six oaks were found in this diameter class in the 4 ha study area.

The trend of increasing dominance by *Acer saccharum* into smaller diameter classes continued with the large regeneration. Nearly 40% of stems 6.0-9.9 cm dbh were *A. saccharum*. *Ulmus americana, A. glabra*, and *U. rubra* accounted for 12%, 10%, and 8% of stems, respectively. Understory species[1], species which do not grow large enough to form part of the canopy, were of increased importance, 12% of stems, in this diameter class compared to the larger diameter classes. Slightly over 10% of the large regeneration was *Carpinus caroliniana*.

There were over 400 stems/ha of *A. saccharum* in the small regeneration diameter class. Although *Ulmus sp.* comprised less than 13% of the small regeneration stems, their combined density was still over 100 stems/ha. Two other species had relatively high small regeneration densities: *A. glabra* (61 stems/ha) and *Fraxinus quadrangulata* (32 stems/ha). Together the understory species accounted for over 16%, 125 stems/ha, of all small regeneration stems. Of the 19 oaks ≤ 10.0 cm dbh found in the study area, 11 were *Q. bicolor*.

Frequency

A modified perspective of woody vegetation structure is seen by examining frequency of occurrence, the proportion of the 400 quadrats occupied by the different species in each diameter class (Table 2). The high relative density of *A. saccharum* in the regeneration diameter classes, 53 and 38% of all stems, does not necessarily translate to its eventual domination of the overstory. While small regeneration of *A. saccharum* was found in four-fifths of the quadrats; less than one-fifth of the quadrats had at least one *A. saccharum* larger than 20 cm dbh. Intermediate stems of *A. saccharum* were absent in 60% of the quadrats having an intermediate sized stem.

A number of species were far more frequent than would be suggested by their relative densities. *Fraxinus americana* and *C. cordiformis* each accounted for less than 1% of the large regeneration, yet were found in 12% and 10% of the quadrats respectively. Large regeneration of *F. quadrangulata* grew in one-fifth of the quadrats. The elms were widely dispersed, both species were observed in over two-thirds of the quadrats.

TABLE 2. Frequency (% of 10 × 10m quadrats occupied) by diameter class and species at the Davis-Purdue Research Forest based on a 100% inventory of 4 hectares.

	DIAMETER CLASS[1]						
SPECIES	0.0 −1.9	2.0 −5.9	6.0 −9.9	10.0 −19.9	20.0 −49.9	>50	TOTAL
Acer negundo	7.5	9.0	3.5	2.0	–	–	17.3
Acer rubrum	1.5	.3	.5	.3	.3	–	2.0
Acer saccharinum[2]	3.3	3.0	1.5	2.5	1.3	.8	7.8
Acer saccharum	79.9	78.3	56.5	32.8	15.0	1.3	95.8
Aesculus glabra	52.3	25.3	17.5	16.5	2.0	.3	73.0
Asimina triloba	9.8	6.8	.3	–	–	–	10.3
Carpinus caroliniana	20.0	28.0	17.8	6.5	–	–	50.0
Carya cordiformis	10.8	4.8	5.3	4.5	2.3	.3	23.5
Carya glabra	–	.3	.5	.8	.3	–	1.5
Carya ovata	5.0	7.0	8.5	12.5	11.8	.8	33.3
Celtis occidentalis	12.5	9.0	2.3	4.0	2.5	–	25.0
Cephalanthus occidentalis	.3	–	–	–	–	–	.3
Cercis canadensis	.3	–	–	–	–	–	.3
Cornus florida	2.5	2.0	.5	.3	–	–	4.5
Cornus racemosa	6.3	2.3	–	–	–	–	7.0
Corylus americana	.8	.5	–	–	–	–	.8
Crataegus sp.	17.8	5.0	1.8	4.3	–	–	25.5
Euonymus sp.	4.0	–	–	–	–	–	4.0
Fagus grandifolia	1.5	2.0	1.8	4.5	6.8	.3	15.8
Fraxinus americana[3]	11.8	6.5	2.3	1.8	5.5	9.0	29.5
Fraxinus nigra	.5	.5	.5	1.0	–	.3	2.5
Fraxinus quadrangulata	21.3	18.5	6.5	3.3	.5	.3	34.3
Gleditsia triacanthos	–	–	–	–	1.0	.8	1.8
Juglans nigra	–	–	–	1.0	6.5	2.0	9.5
Lindera benzoin	38.8	9.5	–	–	–	–	39.5
Morus rubra	1.8	.8	–	–	–	–	2.5
Ostrya virginiana	7.0	7.5	2.5	2.8	.3	–	13.3
Platanus occidentalis	–	–	–	–	.5	.3	.8
Populus deltoides	–	–	–	–	–	.3	.3
Prunus serotina	3.3	3.3	.8	1.8	.8	–	9.8
Quercus alba	.3	–	–	–	1.0	5.3	6.3
Quercus bicolor	1.8	2.0	.5	.8	.5	2.0	6.8
Quercus macrocarpa	1.0	.3	.8	.5	1.8	6.8	10.3
Quercus muehlenbergii	–	.3	–	–	1.0	3.8	5.0
Quercus palustris	.5	.3	–	–	.5	3.3	4.3
Quercus rubra	.8	–	.5	.3	1.3	10.0	12.8
Quercus shumardii	–	–	–	–	–	2.8	2.8
Sambucus canadensis	5.3	–	–	–	–	–	5.3
Staphylea trifolia	1.0	–	–	–	–	–	1.0
Tilia americana	–	–	.3	–	.5	–	.8
Ulmus americana	21.3	23.3	21.5	32.3	15.8	–	69.3
Ulmus rubra	40.8	34.8	14.5	13.5	6.0	.3	66.0
Viburnum dentatum	.5	–	–	–	–	–	.5
Viburnum prunifolium	21.8	5.0	–	–	–	–	23.5
All species combined	99.0	99.8	85.3	85.0	60.5	44.8	100.0

[1]Diameter (cm) at 1.37 m.
[2]Includes individuals of *Acer nigrum*.
[3]Includes individuals of *Fraxinus pennsylvanica*.

Discussion

The results of this research are consistent with other research in oak-hickory forests which found increased importance of late seral species in the smaller diameter classes (1, 3, 4, 6). *A. saccharum* was both the most numerous and frequent species in the regeneration strata. However, the wide dispersion of the regeneration of many species allows future stand development to proceed along several alternative routes depending on future disturbance patterns.

Eventual conversion of the upper canopy to an *A. saccharum* association must be qualified. Many of the small maples in the seasonally ponded areas were established on micro-hammocks (<4m[1]). The small size of these hammocks limits the development of flood sensitive species such as *A. saccharum* (8). As the trees on the hammocks grow into the larger diameter classes there is insufficient root space in mesic soil to support the trees during periods of high water tables. The summer of 1986 had higher than average rainfall and we observed many intermediate-sized maples on micro-hammocks exhibiting symptoms of fooding stress. Another qualification is the decreasing relative importance of *A. saccharum* in the larger diameter classes noted in the results section. While over 50% of small regeneration was *A. saccharum*; only one-quarter of the intermediate diameter class were maple.

The low stand regeneration densities exhibited by *U. rubra, C. ovata* and *F. grandifolia* appears to be related to a factor which limits their establishment, rather than a factor which limits their development. The density of these species declined only slightly or was stable with increasing diameter class.

One and two year old oak seedlings were common throughout the forest (pers. obs.). However, growth of oak seedlings appears to be restricted to the areas of seasonal ponding where many of the more shade tolerant, and flood intolerant, species were excluded.

Without a change in the disturbance regime the densities of many of the mid-successional species will most likely continue to decline and some early successional species will eventually be lost from the stand. Six species with stems in the overstory strata did not have stems in the regeneration diameter class; and the regeneration density of seven other species was ≤ 1 stem/ha. The aesthetic appeal of managing forests as preserves, allowing nature to run its course, must be balanced by the consequence of a possible decline in biotic diversity.

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Literature Cited

1. Schmelz, D.V. and J.D. Barton. 1974. "Donaldsons Woods" two decades of change. Proc. Indiana Acad. Sci. 84: 234-243.
2. Johnson, H.S., J.S. Berkebile, and G.R. Parker. 1974. An ecological inventory of Bryan Nature Preserve. Proc. Indiana Acad. Sci. 83: 167-172.
3. Newman, J.A. and J.E. Ebinger. 1985. Woody vegetation of Baber Woods: composition and change since 1965. In J.O. Dawson and K.A. Majerus, (eds.). Proc. Central Hardwood Forest Conference Univ. Illinois. Urbana-Champaign, IL. 5: 178-180.
4. Parker, G.R. and D.L. Leopold. 1983. Replacement of *Ulmus americana* L. in a mature east-central Indiana woods. Bull. Torrey Bot. Club. 110: 482-488.
5. Parker, G.R., D.J. Leopold, and J.K. Eichenberger. 1985. Tree dynamics in an old-growth, deciduous forest. For. Ecol. Manage. 11: 31-57.
6. Parker, G.R. and P.T. Sherwood. 1986. Gap phase dynamics of a mature Indiana forest. Proc. Indiana Acad. Sci. 95: 217-223.
7. Teskey, R.O. and T.M. Hinckley. 1977. Impact of water level changes on woody riparian and wetland communities. Vol. III. Central Hardwood Region. U.S. FWS OBS-77760. 36 p.

8. Ward, J.S. and G.R. Parker. 1987. Fifty-five years of association and diversity dynamics in an old-growth forest in Indiana: Davis-Purdue Research Forest 1926-1981. In R.L. Hay et al. (eds.) Proc. Central Hardwood Forest Conference. Univ. Tenn. Knoxville, TN. 6: 369-376.

Note

[1]*Asimina triloba, Carpinus caroliniana, Cornus sp., Corylus americana, Lindera benzoin, Ostrya virginiana*, and *Vibrunum prunifolium*.