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POINT-CENTERED QUARTER ANALYSIS OF FOUR FOREST TYPES AT HAYES ARBORETUM IN WAYNE COUNTY, INDIANA

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ABSTRACT. Analysis of four different woodland types occurring at Hayes Arboretum in Wayne County, Indiana was performed using the point-centered-quarter (PCQ) technique to sample stems ≥ 10 cm dbh. Based on PCQ analysis, each woodland type was identified using the method of classifying midwestern U.S. hardwood forests introduced by Lindsey & Schmelz (1969). The older growth woodland located north of the Nature Center on the west side of the arboretum is of the beech-maple forest type. The most important species, based on relative importance values (RIV), are *Fagus grandifolia, Acer saccharum, Prunus serotina* and *Fraxinus americana*. The woodlands lying along Culmer's Run on the east side and Salamander Creek on the west side are of the lowland-depressional forest type. The most important species at these sites were *Juglans nigra, Populus deltoides, Ulmus americana, Aesculus glabra* and *Fraxinus pennsylvanica*. The moist, lowland successional forest occurring along seasonal creeks on the east side of the arboretum is best described as poorly-drained mixed woods forest type. However, if not for the dominance of *A. saccharum*, this woodland community would be a lowland-depressional forest type. The most important species in this woodland type were *A. saccharum, F. pennsylvanica, J. nigra, Celtis occidentalis* and *A. glabra*. The upland, successional forest located on the east side of the arboretum is best described as of the well-drained mixed woods forest type. The most important species in this forest type were *F. americana, A. saccharum, Quercus muhlenbergii, Q. alba* and *Ulmus rubra*.

Keywords: Point-centered-quarter, Hayes Arboretum, flora – Wayne County, Indiana, beech-maple forest, lowland-depressional forest, floodplain forest, mixed woods forest

Hayes Arboretum, located in the northeast corner of Richmond, Indiana, is owned and maintained by the Stanley W. Hayes Research Foundation, Inc. for the use and benefit of the public on a regulated basis. It is both an educational facility and a managed nature preserve. As a nature preserve, it is a repository for native wild plants indigenous to Wayne County and the counties of the Whitewater Valley Drainage Basin in Indiana and Ohio.

As a follow-up to the vascular flora and vegetational communities study of Hayes Arboretum (Ruch et al. 2007), a PCQ analysis of the woody vegetation for four different woodland types was conducted. During pre-settlement times, this region of Indiana was comprised of beech-maple forests with scattered sections of oak-hickory forests (Lindsey et al. 1965; Homoya et al. 1985; Wiseman & Berta 1998). Today, it is mostly agricultural land with scattered, frequently isolated, woodlands. Except for the older growth forest north of the Nature Center, the land that comprises Hayes Arboretum today was primarily fields in the early 1900s. Under the ownership of Stanley W. Hayes, and continuing after the inception of the arboretum in April, 1963, effort was made to reforest the land with native trees. Due to natural encroachment and the continuing effort to reforest the land, most of the arboretum is forested today.

The point-centered quarter (PCQ) method provides quantitative data to study forest structure parameters such as population density, basal area (m^2/ha), and biomass. Being a plot-less method, PCQ is a fast, efficient method that does not sacrifice accuracy when compared to plot-based methods (Cottam et al. 1953). One important use of the PCQ method is to determine the relative importance of the various tree species in a community. The three factors used to determine the importance value

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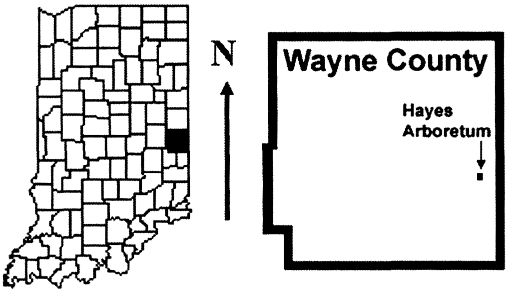

Figure 1.—Map of Indiana (left) showing the location of Wayne County and Hayes Arboretum (right) in Richmond.

of a species are density/ha, size (basal area/ha), and frequency (distribution) (Cottam & Curtis 1956; Bonham 1989; Elzinga et al. 2001).

METHODS

Hayes Arboretum, consisting of 202.4 ha, is located in the northeast corner of Richmond, Indiana in Wayne County (New Paris Quadrangle, north part of the NW one-quarter of Section 35, Township 14 North, Range 1 West; or UTM coordinates for the parking lot west of the Nature Center are Zone 16 S, 0684106E by 4412094N, NAD83 (Fig. 1).

Based on observation from an inventory of the vascular flora (Ruch et al. 2007), four woodland types were recognized: 1) an older growth forest located on the west side of the arboretum just north of the Nature Center, 2) a floodplain forest located along Culmer's Run on the east side of the arboretum and a small floodplain located along Salamander Creek on the west side near the railroad track, 3) a successional lowland forest located on the east side of the arboretum in low-lying moist areas, and 4) a successional upland forest located on drier hilltops and slopes of the east side of the arboretum. Analysis of these four woodland types was conducted using the point-centered-quarter (PCQ) method to sample stems ≥ 10 cm dbh (diameter at breast height).

The location of transects for the four forest types are seen in Fig. 2. For the floodplain forest, two transects were used, one along Culmer's Run on the east side of the arboretum and one along Salamander Creek adjacent to the railroad track on the west side of the arboretum. Points on these transects were 20 m apart and a total of 26 points (or 104 stems) was monitored, i.e., 20 from the Culmer's Run transect and 6 from the Salamander Creek transect. The area covered by floodplain forests is approximately 20–25 ha. For the older growth forest located north of the Nature Center, two transects were used with points 25 m apart. A total of 20 points (or 80 stems) was monitored. The area covered by the older growth forest is approximately 10–12 ha. For the upland successional forest, one transect was used with points 20 m apart. A total of 25 points (or 100 stems) was monitored. The upland successional forest covers approximately 80–90 ha. Lastly, for the lowland, young successional forest, three transects were run along seasonal creeks. The first followed the seasonal creek just east of the dam for Scott Pond and contained nine points. The second followed the seasonal creek at the northern end near the railroad track and contained six points. The third transect contained 10 points and followed a seasonal creek running down the western side. Thus, 25 points (or 100 stems) were monitored. The area covered by the successional lowland forest is scattered, but includes approximately 20–25 ha. [In general, due to the limited area of each forest community type, points on transects were located 20 m apart. Effort was made to ensure that no tree was sampled twice. However, because the older growth forest contained fewer stems per unit area, points on transects were located 25 m apart. For statistical analysis, a minimum of 20

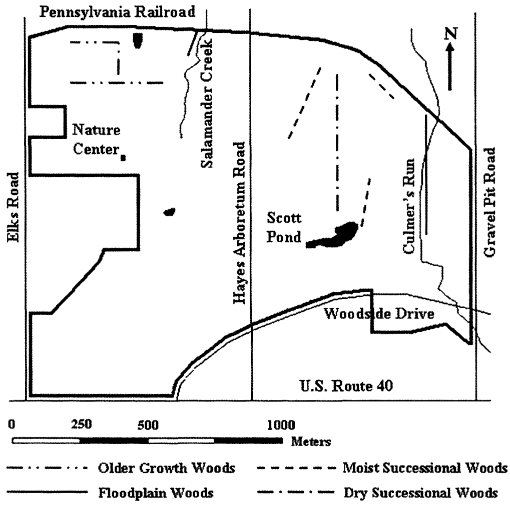

Figure 2.—Map of Hayes Arboretum giving reference points and the location of the PCQ transects.

points (80 stems) was necessary. Additional points were sampled if species diversity deemed it necessary.]

At each sample point four quadrants were defined using the transect line as one line and imposing an imaginary line perpendicular to the transect line to establish four quadrants. Quadrants were then numbered from one to four with quadrant one being the first clockwise quadrant from north. The nearest tree to the point in each quadrant with a dbh ≥ 10 cm was selected. For each tree selected, the dbh (to the nearest 0.1 cm), the distance from the middle of the stem to the point (to the nearest 0.1 m), the species, and any pertinent observations concerning the site were recorded, such as tree fall or the density of the canopy. Distance measurements were made using a Haglof Forestor DME 201 Distance Measuring Kit.

Data were analyzed to obtain information on the structure and composition of each woodland type. For each species, density (number of stem per ha), relative density (percent density of one species compared to all other species), basal area (m^2/ha), relative basal area (percent basal area for one species compared to the total basal area for all species), frequency (percentage of points in which each species occurred), relative frequency (frequency of occurrence of each species relative to all species), importance value (sum of relative density, relative basal area, and relative frequency), and relative importance value (average of relative density, relative basal area, and relative frequency) were calculated. For protocols of data analysis, see Ruch et al. (2008).

For a description of soil types occurring at the arboretum, see Lindsey et al. (1969), Blank (1987), and Ruch et al. (2007). For a description of the study site and species inventory, see Ruch et al. (2007). Nomenclature for all species follows Gleason & Cronquist (1991).

RESULTS

Older growth forest.—The results of PCQ analysis for the older growth forest are recorded in Table 1. A total of 12 species was recorded for this woodland site. The six most important species, based on RIV (in descending order), were *Fagus grandifolia*, *Acer saccharum*, *Prunus serotina*, *Fraxinus americana*, *Carya cordiformis* and *Quercus rubra*. The sum of the RIV for the remaining six tree species was 11.3, and five species recorded only one stem each.

Floodplain forest.—The results of PCQ analysis for the floodplain woodlands are recorded in Table 1. For this forest type, a total of 20 species was recorded. The six most important species, based on RIV (in descending order), were *Juglans nigra*, *Populus deltoides*, *Ulmus americana*, *Aesculus glabra*, *Fraxinus pennsylvanica* and *Acer negundo*. For the remaining 14 species, none have a RIV > 6.1, and the sum of their RIVs was less than 30. Additionally, eight species contained only one stem each.

Lowland, young successional forest.—The results of the PCQ analysis for the successional, lowland forest on the east side of the arboretum are recorded in Table 1. Twenty-two species were recorded from this woodland type. The single most important species was *Acer saccharum* (RIV = 23.5). No other species had an RIV ≥ 10.0, and eight species included only one stem each. The next five most important species, e.g., *Fraxinus pennsylvanica*, *Juglans nigra*, *Celtis occidentalis*, *Aesculus glabra* and *Ulmus rubra*, were typical of moist lowland woodland sites.

Upland successional forest.—The results of PCQ analysis for the upland successional forest are recorded in Table 1. Sixteen species were recorded for this woodland type. Plainly, the two most important species, based on RIV, were *Fraxinus americana* (23.1) and *Acer saccharum* (21.5). No other species has an RIV > 9.0, and three species included only one stem each. Of the next five important species, three were oak species, e.g., *Quercus muhlenbergii*, *Q. alba*, and *Q. rubra*. The RIV for all *Quercus* spp. was 22.3, for all *Carya* species (e.g., *C. cordiformis* and *C. ovata*) was 10.2, and for *A. saccharum* plus *F. grandifolia* was 23.5.

DISCUSSION

The older growth forest north of the Nature Center (referred to as the 'field laboratory' by Lindsey) was evaluated by Lindsey et al. (1969). These authors pointed out that "since a stringent native preserve was not the original concept for its management, some planting (of native tree species) in the woods was done in the 1930's." Additionally, *Quercus alba* and *Liriodendron tulipifera* were planted in and around this area in 1922 (Lindsey et al. 1969). Based on relative density and relative basal area of trees with a dbh ≥ 10 cm (4 in), they reported 17 species, and the seven species with

Table 1.—Stand table for overstory trees in the four woodland types at Hayes Arboretum. BA = basal area in m^2/ha; Density = number of stems/ha; RIV = relative importance value = (relative basal area + relative frequency + relative density)/3. PCQ analyses were based on the following number of points (and stems) along transects: older growth forest = 20 points (80 stems); floodplain forest = 26 points (104 stems); successional lowland forest = 25 points (100 stems); and successional upland forest = 25 points (100 stems).

	Older growth forest			Floodplain forest			Lowland successional forest			Upland successional forest		
Species	BA	Density	RIV	BA	Density	RIV	BA	Density	RIV	BA	Density	RIV
Acer negundo	0.0	0.0	0.0	0.9	36.5	8.7	0.2	14.7	3.6	0.0	0.0	0.0
Acer nigrum	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.9	1.0	0.0	0.0	0.0
Acer saccharum	3.4	90.4	20.4	1.1	23.2	5.1	6.3	82.2	23.4	4.7	###	21.5
Aesculus glabra	0.0	0.0	0.0	1.2	46.4	10.0	2.0	26.4	7.5	0.2	4.2	1.0
Carya cordiformis	2.1	23.6	8.0	0.1	3.3	0.7	0.9	11.7	4.1	2.3	29.2	7.1
Carya ovata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	12.5	3.1
Celtis occidentalis	0.0	0.0	0.0	0.9	23.2	5.9	3.2	17.6	7.9	0.0	0.0	0.0
Cercis canadensis	0.0	0.0	0.0	0.0	0.0	0.0	0.1	11.7	2.8	0.1	4.2	0.9
Cornus florida	0.1	3.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crataegus punctata	0.0	0.0	0.0	0.1	3.3	0.7	0.1	2.9	0.8	0.0	0.0	0.0
Fagus grandifolia	12.6	66.8	25.1	0.2	3.3	1.0	0.0	0.0	0.0	0.3	8.3	2.0
Fraxinus americana	5.7	31.5	12.3	0.1	6.6	1.6	0.8	8.8	3.2	10.6	79.1	23.1
Fraxinus pensylvanica	0.0	0.0	0.0	4.3	23.2	9.4	3.0	23.5	9.1	0.0	0.0	0.0
Fraxinus quadrangulata	0.7	3.9	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Juglans nigra	0.0	0.0	0.0	4.9	56.4	16.3	2.8	20.6	8.2	0.0	0.0	0.0
Liriodendron tulipifera	0.1	3.9	1.0	1.1	3.3	2.0	2.5	5.9	4.5	1.2	12.5	3.2
Maclura pomifera	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.9	1.0	0.0	0.0	0.0
Malus sylvestris	0.0	0.0	0.0	0.2	3.3	0.9	0.8	2.9	1.7	0.0	0.0	0.0
Ostrya virginiana	0.4	19.7	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	8.3	1.8
Platanus occidentalis	0.0	0.0	0.0	2.1	6.6	3.8	1.6	2.9	2.6	0.0	0.0	0.0
Populus deltoides	0.0	0.0	0.0	8.6	16.6	13.0	0.0	0.0	0.0	0.0	0.0	0.0
Prunus serotina	6.4	43.2	16.5	1.2	16.6	4.5	0.3	8.8	2.6	0.5	16.7	3.3
Quercus alba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	29.2	8.1
Quercus muhlenbergii	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.9	0.8	4.1	29.2	9.0
Quercus rubra	2.1	19.7	6.4	0.0	0.0	0.0	1.0	2.9	2.0	2.0	20.8	5.2
Robinia pseudoacacia	0.0	0.0	0.0	0.2	3.3	0.9	0.2	2.9	1.0	0.0	0.0	0.0
Salix nigra	0.0	0.0	0.0	0.1	3.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Tilia americana	0.7	3.9	1.7	0.1	6.6	1.1	0.2	5.9	1.8	0.5	8.3	2.1
Ulmus americana	0.0	0.0	0.0	1.7	56.4	12.8	0.3	14.7	4.2	0.5	4.2	1.3
Ulmus rubra	0.1	3.9	1.1	0.1	3.3	0.8	1.4	17.6	6.2	2.1	33.3	7.3
Totals	34.4	314.4	100.0	29.2	314.7	100.0	28.2	293.3	100.0	32.6	416.6	100.0

the highest importance values to be *Fagus grandifolia* (32), *Prunus serotina* (16), *Liriodendron tulipifera* (10), *Fraxinus americana* (10), *Carya cordiformis* (6.8), *Acer saccharum* (4.9), and *Quercus rubra* (2.4). Lindsey et al. (1969) concluded that this community was not a typical natural beech-maple forest of the region due to the high importance values of *P. serotina* and *L. tulipifera* and the low importance value of *A. saccharum*. However, they did indicate that *A. saccharum* had a stratum ranking (SR) of 5 for the 5–10 cm dbh class and a SR of 6 for the 4.6 m–5 cm dbh class. These SR values indicate that this species in these classes is common and probably co-dominant with other species (especially a SR of 6). [Stratum Ranking is a rapid non-quantitative method developed by Alton Lindsey, based on his years of experience, to assay vegetation. Assigning a stratum rank to a species in a stand is "an attempt to judge the influence of each species by observations on its numerical abundance and size (especially the lateral spread aspect of size that determines ground cover and shading) in relation to other species in its own layer or stratum" (Lindsey et al. 1969). SR numbers range from 1–9, with SR = 9 representing a species dominating a practically pure strand, and SR = 1 applied to species with only one individual in the stand. For more details, see pages 45–47 of Lindsey et al. (1996).]

A comparison of the data from the current study for the older growth forest (Table 1) to those of Lindsey et al. (1969) revealed similar findings with two major differences. First, with the exception of *L. tulipifera*, both studies noted the same species with the highest importance values. However, Lindsey et al. (1969) reported *L. tulipifera* as the third most important species, while we found its importance significantly reduced in the current woodland community (Table 1). Second, although Lindsey et al. (1969) found *A. saccharum* to be only the sixth most important species, we found it to be second only to *F. grandifolia* in importance.

As mentioned earlier, Lindsey et al. (1969) concluded that the older growth woodland at Hayes Arboretum was not a typical natural beech-maple forest of the region due to the high importance value of *L. tulipifera* and the low importance value of *A. saccharum*. However, based on the changes that have occurred in species composition over the last 35–40 years, this woodland community is best classified today as a typical beech-maple forest of east-central Indiana (Lindsey & Schmelz 1969).

The woodland communities along Culmer's Run on the east side and Salamander Creek on the west side are best described as the "lowland-depressional forest type" (Lindsey & Schmelz 1969). Based on species composition, location, and hydrology, these sites are what are typically referred to as floodplain forests.

The woodland community initially referred to as the lowland, young successional forest on the east side (Table 1) is best described as a "poorly drained mixed woods forest type" (Lindsey & Schmelz 1969). However, if it were not for the dominance of *A. saccharum*, this woodland community would clearly be a lowland-depressional forest type as described by Lindsey & Schmelz (1969).

The woodland community initially referred to as the upland successional forest on the east side (Table 1) is best described as a "well-drained mixed woods type" (Lindsey & Schmelz 1969). However, due to the high importance value of *A. saccharum*, this woodland community "leans" strongly toward the beech-maple forest type (Lindsey & Schmelz 1969). However, Lindsey et al. (1965) provide additional clarification for classifying the upland successional woodlands at Hayes Arboretum as well-drained mixed woods. According to these authors, for a wooded area to be classified as oak-hickory the total IV (Importance Value) of upland *Quercus* spp. + *Carya* spp. must be double that of *Acer saccharum* + *Fagus grandifolia*. Respectively, their IVs are 97.4 and 70.4, giving a ratio of only 1.38. Clearly, these IV values support the classification of the upland successional forest as a well-drained mixed woods forest type.

Lastly, in all of the forest types previously described, except the lowland-depressional forest communities along the creeks, *A. saccharum* was either the most or second most important species (Table 1). This trend has been observed in several studies across east-central Indiana, e.g., Mounds State Park in Madison County (Rothrock et. al. 1993), Yuhas Woods in Randolph County (Baltzer et al. 2007), Lick Creek Summit Nature Preserve in Wayne County (Ruch et al. 2008), and both Bibler Nature Preserve in Jay County and Duning Woods Nature Preserve in Wayne County (Ruch unpubl. data). Additionally, if *Fraxinus* spp. succumb to the Emerald Ash Borer (*Agrilus planipennis* Fairmaire [Insecta: Family Buprestidae]), it is postulated that the number of trees, and consequently, the RIV, of *A. saccharum* will increase. Since one of the goals of Hayes Arboretum is to function as a managed nature preserve for the permanent habitat of the native flora of this region, it would seem prudent that the staff consider the implementation of some sort of *A. saccharum* management program.

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LITERATURE CITED

Baltzer, H., D.G. Ruch, B. Hess & B.G. Torke. 2007. Point-centered-quarter analysis of the upland forest at Yuhas Woods in Randolph County, Indiana. Proceedings of the Indiana Academy of Science 116:108–109.

Blank, J.R. 1987. Soil Survey of Wayne County, Indiana. U.S.D.A., Soil Conservation Service, Washington, D.C. 149 pp.

Bonham, C.D. 1989. Measurements for Terrestrial Vegetation. John Wiley & Sons, New York. 338 pp.

Cottam, G. & J.T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451–460.

Cottam, G., J.T. Curtis & B.W. Hale. 1953. Some sampling characteristics of a population of randomly dispersed individuals. Ecology 34:741–757.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby & J.P. Gibbs. 2001. Monitoring Plant and Animal Populations. Blackwell Publishing, New York. 368 pp.

Gleason, H.A. & A. Cronquist. 1991. Manual of the Vascular Plants of Northeastern United States and Adjacent Canada. 2nd Ed. New York Botanical Garden, Bronx, New York. 910 pp.

Homoya, M.A., D.B. Abrell, J.F. Aldrich & T.W. Post. 1985. The natural regions of Indiana. Proceedings of the Indiana Academy of Science 94:245–268.

Lindsey, A.A., W.B. Crankshaw & S.A. Qadir. 1965. Soil relations and distribution map of the vegetation of presettlement Indiana. Botanical Gazette 126:155–163.

Lindsey, A.A. & D.V. Schmelz. 1969. The forest types of Indiana and a new method of classifying midwestern hardwood forests. Proceedings of the Indiana Academy of Science 79:198–204.

Lindsey, A.A., D.V. Schmelz & S.A. Nicholas. 1969. Hayes Nature Preserve. Pp. 317–319. *In* Natural Areas of Indiana and Their Preservation. Indiana Natural Areas Survey. Purdue University.

Rothrock, P.E., H. Starcs, R. Dunbar & R.L. Hedge. 1993. The vascular flora of Mounds State Park, Madison County, Indiana. Proceedings of the Indiana Academy of Science 102:161–199.

Ruch, D.G., B.G. Torke, K.S. Badger, C.R. Reidy, P.E. Rothrock, R. Waltz, E.G. Urly, J.L. Chance & L. Click. 2007. The vascular flora and vegetational communities of Hayes Arboretum in Wayne County, Indiana. Proceedings of the Indiana Academy of Science 1161:11–41.

Ruch, D.G., B.G. Torke, K.S. Badger, B.R. Hess & Paul E. Rothrock. 2008. The vascular flora and vegetational communities of Lick Creek Summit Nature Preserve, Wayne County, Indiana. Proceedings of the Indiana Academy of Science 117:29–54.

Wiseman, D.J. & S.M. Berta. 1998. Indicator species analysis: An alternative approach to ecosystems geography. Pp. 125–140. *In* Prairie Perspectives: Geographical Essays, Volume 1 (J.C. Lehr & H.J. Selwood, eds.). University of Winnipeg Press, Winnipeg, Canada. http://wiseman.brandonu.ca/article2.htm.

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