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The vegetation of Ledges State Park was sampled with 54 plots placed in representative plant communities throughout the park. The plots were ordinated by tree species and compared with topography. Seven major vegetation types were defined: *Quercus alba* type, *Quercus alba-Quercus rubra* type, *Quercus rubra* type, *Quercus rubra-Tilia americana* type, *Tilia americana* type, *Juglans nigra* type, and slump forest type. A vegetation map of the park was constructed using field data and aerial photography. In comparison with eastern Iowa forests, the forests of Ledges State Park are a western extension of the species-rich eastern forests with the addition of xeric elements common in the Ledges but not as common in the east. Forests of the xeric uplands of the Ledges State Park do not succeed toward maple-basswood as in eastern Iowa, but remain oak dominated. The slump forest, a new vegetation community unique to the Ledges, is described.
INDEX DESCRIPTORS: Ledges State Park, forest communities, ordination, Iowa forests

The sandstone ledges and the associated flora of the Ledges State Park have long held the interest of botanists and geologists. The park's dissected topography contrasts sharply with the surrounding flat agricultural land, allowing an unusual assemblage of plants to exist within the various microhabitats of the park. The large number of eastern and northern species found at the Ledges State Park is unusual in central Iowa (Johnson-Groh and Farrar, 1985).

The Ledges State Park (see centerfold map) comprises 447 hectares (1,117 acres) located in central Iowa along the east side of Des Moines River, T83N, R26W, sections 9, 10, 15, 16, 20 and 21, in Boone County (Figure 1). Pease Creek drains into the Des Moines River from the northeast, forming a canyon lined with deep (75 m) sandstone cliffs. The Pennsylvanian sandstone ledges, for which the park was named, are the most prominent geological feature of the main canyon. Several other smaller drainages empty into Pease Creek and the Des Moines River, creating a complex of steep ravines and well-drained ridges.

The climate for central Iowa is midcontinental with hot humid summers and cold dry winters. Winter (December through February) average temperature is −6 °C with an average daily minimum of −11 °C. Summer (June through August) average temperature is 22 °C and the average summer daily maximum is 29 °C. The frost-free growing season averages 151 days and the total annual precipitation is 848 mm, of which 73% falls as rain from April to September. The prevailing wind is from the northwest. Summer weather is characterized by thunderstorms often associated with high winds and occasional hailstorms and tornados (U.S. Department of Agriculture, 1941; Waite, 1967; Anderson and Dideriksen, 1981).

Although it has long been known by local botanists that the Ledges State Park contains a variety of interesting and unusual plants, only two studies have quantitatively sampled the flora. Diehl (1915) sampled a small belt transect in the vicinity of Reindeer Ridge (see map in Johnson-Groh, 1983) and subsequently published an extensive species list of the park. Kucera (1952) studied the relationship between microhabitat and the composition of forests at several sites along the Des Moines River including the Ledges. Neither of these studies delimited or described the communities of the Ledges.

Several studies in Iowa have contributed to our knowledge of Iowa forest communities. A few include quantitative analyses of community composition. Bach (1982) analyzed forests of central Iowa including a few sites in the Ledges. Niemann and Landers (1974) conducted a transect sampling of the forest communities of Woodman Hollow State Preserve in Webster County, and Cahayla-Wynne and Glenn-Lewin (1978) documented the forest vegetation types of northeast Iowa.

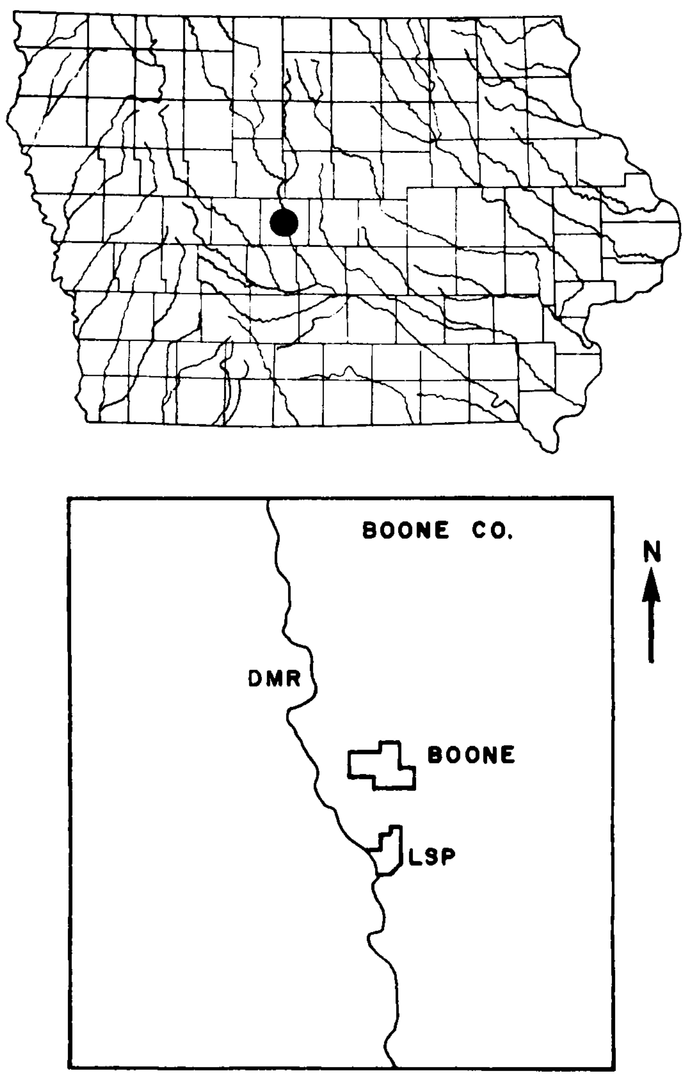

Fig. 1. Location of Ledges State Park in Iowa, and location of Ledges State Park (LSP), Des Moines River (DMR), and Boone, in Boone County, Iowa.

The primary objective of this study was to quantitatively sample, identify, and describe vegetation communities of the Ledges State Park. This information is basic to understanding the relationship of vegetation to topography as well as to interpreting the Ledges flora relative to other Iowa forest communities.

METHODS

Field work was conducted from March, 1981 through October, 1982. Data on woody species were gathered from 54 permanent plots. Data on herbaceous plants were gathered from 25 of the 54 plots in August and September of 1981. A vegetation map was constructed from these data, aided by aerial photographs from seven flights, two in the spring and five in the fall of 1982.

The 54 permanent plots were placed throughout the park to represent all aspects, slope levels, slope inclinations, and degrees of disturbance. Each plot consisted of a 0.1 hectare quadrat with a 50 meter center line parallel to the contour of the slope (Figure 2). A line intercept was taken along the 50 meter center line to determine cover of canopy, understory, and shrub layers. Sapling density was determined by a count in three 10 by 10 meter subplots (Figure 2). Shrubs were included as part of the sapling counts for analyses. Only saplings with a diameter at breast height (dbh) less than three centimeters and a height greater than 10 cm were recorded in the subplots. Tree density and basal area were obtained from the dbh for all trees with a dbh greater than 3 cm in the plot. Cover for herbs was estimated for each species in 25 $1 m^2$ microplots at alternating meters and sides along the center line. These sampling procedures are recommended for Iowa (D. Glenn-Lewin, pers. comm.) since the areas sampled are generally small and because it is effective in areas where gradients are steep and homogenous stands are narrow. Each plot was permanently marked by two iron stakes and photographed.

Detrended correspondence analysis (DECORANA) ordinations (Hill, 1979a; Hill and Gauch, 1980) were used to reduce the dimensionality of the data of the upland plots and to search for environmental gradients that were related to species distributions. Bottomland and disturbed sites were treated separately due to their pronounced differences from upland sites. The vegetation types were defined by the dominant overstory species which had the highest basal area. Species which had at least half as much basal area as the dominant species were listed as codominant. Binomials were taken from Fernald (1950) and Pohl (1978).

The individual plot summaries and species lists can be found in Johnson-Groh, 1983. The raw data have been deposited in the Iowa State University archives for future reference.

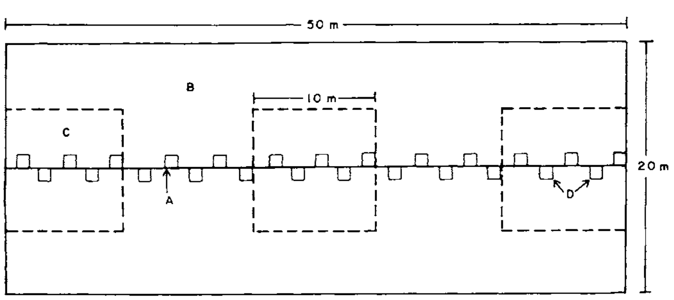

Fig. 2. Diagram of permanent plot used in vegetation sampling.
A. Line intercept for estimating cover of canopy, understory and shrubs.
B. Entire plot used for dbh of all trees greater than 3 cm.
C. Subplots used for sapling counts for trees and shrubs less than 3 cm dbh and greater than 10 cm tall.
D. Square meter microplots used to estimate cover for herbs.

RESULTS AND DISCUSSION

A DECORANA ordination of upland plots based on basal area of the tree species is shown in Figure 3. The ordination illustrates a vegetation continuum. *Quercus alba*[1] dominates plots on the right, *Quercus rubra* dominates plots in the lower left and *Tilia americana* dominates plots in the center left of the ordination. Between is a mixture of all three species and several other less common species. Ordinations based on line intercept cover values produced a similar pattern, as did an ordination based on herbaceous species. Results from Bray-Curtis ordinations (Bray and Curtis, 1957) and two-way indicator species analysis classification (Hill, 1979b) also reiterated the results of the DECORANA ordination.

Comparisons of the ordinations to environmental factors show that aspect is closely related to ordination position of the plots (Figure 4). *Q. alba* is found on flat or south-facing aspects. *Q. rubra* is found primarily on south and east aspects although it characterizes the most variable type of vegetation relative to aspect. *Tilia americana* is found on north and east slopes. *Quercus alba* stands represent the most xeric sites, and *Tilia americana* stands represents the most mesic sites, excluding the bottomland. Percent slope showed no relationship to the community types and does not appear to be an important factor. Position on the slope (elevation) has a minor influence on the vegetation type. Bottomland vegetation was not included in the ordinations but was clearly associated with moist drainages where flooding is common.

Based on these ordinations and field sampling, seven major woodland vegetation types can be recognized. Defined on the basis of dominant overstory species, these are *Quercus alba* type (QA), *Quercus rubra* type (QR), *Tilia americana-Acer nigrum* type (TA), and bottomland type with *Juglans nigra* as the most common dominant (JN) and three intermediate types, *Q. alba-Q. rubra* type (QAR), *Q. rubra-Tilia americana* type (QRTA), and "slump forest" type (QARS). The distribution of these vegetation types and a number of minor types in the park has been mapped (see centerfold map) and the types are described below. Tables 1-4 list the distribution of dominant species in each of the major vegetation types by basal area of the tree species, understory cover, sapling counts, and herbaceous cover.

Quercus Alba Vegetation Type (QA)

The *Quercus alba* vegetation type (QA) is found on flat uplands throughout the park, and in a few areas extends over the edges of south-facing slopes. These QA south slopes are small in area and grade into the *Q. alba-Q. rubra* vegetation type as the aspect or elevation changes.

The dominant woody species is *Q. alba*, which reaches an average of 76.8% relative basal area (rba). *Q. rubra* (8.7% rba) and *Carya ovata* (2.8% rba) are of minor importance. Understory cover is dominated by *Ostrya virginiana* with lesser amounts of *Fraxinus* spp. and *Amelanchier arborea*. *Fraxinus* spp. has the highest sapling count, 83.7 saplings per 100 m^2. *Carex* spp. (7.7%) has the highest herbaceous cover followed by *Parthenocissus quinquefolia* (5.1%). Litter attains its highest cover (90.0%) in this type, whereas bare soil (3.9%) and bryophytes have their lowest cover (0.1%) in this type. An average of 6.5 woody species and 29 herbaceous species per 0.1 ha were found in QA.

Quercus Alba-Quercus Rubra Vegetation Type (QAR)

The mixed vegetation type, *Quercus alba-Quercus rubra* (QAR), is found on south and west aspects throughout the park. This type usually occurs on the mid to upper portion of the slope, frequently bordering *Quercus rubra* and *Quercus alba* vegetation types.

High values of relative basal area in this type are shared by *Quercus*

[1]Authorities for the scientific binomials are given in Johnson-Groh and Farrar (1985).

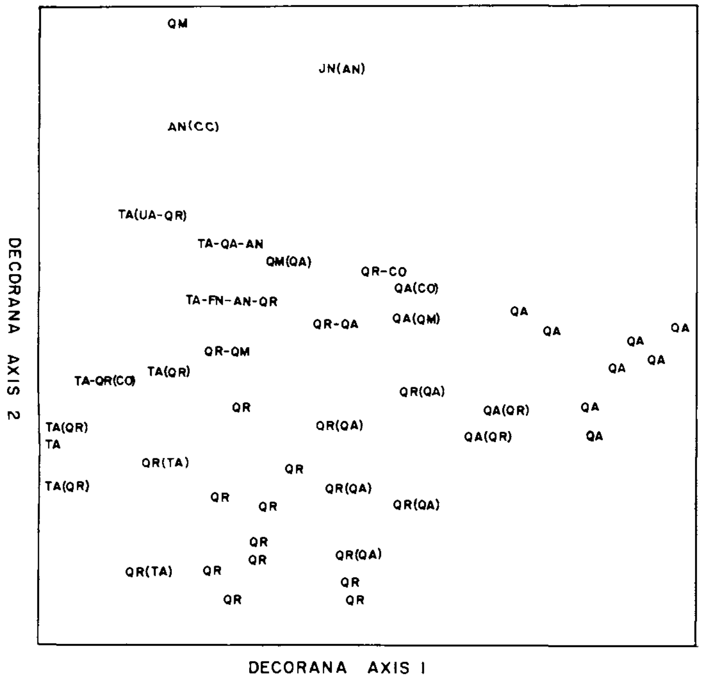

Fig. 3. Two dimensional DECORANA ordination of upland plots based on basal area of tree species. Plots are labelled according to their dominant species: AN = *Acer nigrum*, CC = *Carya cordiformis*, CO = *Carya ovata*, FN = *Fraxinus nigra*, QA = *Quercus alba*, QM = *Quercus muhlenbergii*, QR = *Quercus rubra*, TA = *Tilia americana*.

rubra (30.4%) and *Quercus alba* (29.4%) which are equally intermixed within the QAR vegetation type. Relative basal area of *Q. muehlenbergii* (6.9%) in this type is exceeded only by its relative basal area in the slump forest type. *Ostrya virginiana* has the highest understory cover (57%) and *Fraxinus* spp. has the highest average sapling count at 45.4 saplings per 100 m^2. The dominant herb cover is about equal between *Carex* spp. (4.7%) and *Parthenocissus quinquifolia* (4.5%). These are followed in cover values by *Amphicarpa bracteata* (1.4%) and *Solidago* spp. (1.6%). There is an average of 87.6% cover by litter in this vegetation type, 8.5% by bare soil, and 0.3% by bryophytes. An average of 10.3 woody species and 33.4 herbaceous species per 0.1 ha were recorded in this type.

Quercus Rubra Vegetation Type (QR)

The *Quercus rubra* type (QR) is found on east-, south-, and west-facing slopes. This vegetation type is typical of moderately moist sites but is also found in somewhat drier conditions and is consequently widespread. It generally borders QAR on the south and west slopes and QRTA on the north and east slopes.

The dominant tree in this type is *Quercus rubra* (62.9% rba). *Q. alba* has 10.5% rba. *Carya cordiformis* reaches its highest cover, 7.6% rba, in this type. The understory is dominated by *Ostrya virginiana* (55% cover) and *Fraxinus* spp. again has the highest sapling count (32.6 per 100 m^2). *Prunus* spp. and *Carpinus caroliniana* have counts of 10.5 and 13.5 saplings per 100 m^2 respectively. *Cornus* spp. counts (7.6 per 100 m^2) are highest in this type. *Desmodium glutinosum* (2.2% cover) and *Carex* spp. (2.0% cover) are the dominant herbs, followed by *Amphicarpa bracteata* (1.3% cover) and *Parthenocissus quinquefolia* (1.2% cover). Bryophytes account for 0.8% cover, and litter for 77.9% cover. Bare soil accounts for 18.4% cover of the area. An average of 8.9 woody species and 28.2 herbaceous species per 0.1 ha are found in this type. The QR type has the lowest species richness of herbs, excluding the bottomland type, and the second lowest species richness (number) of woody species.

Quercus Rubra-Tilia Americana Vegetation Type (QRTA)

The *Quercus rubra-Tilia americana* vegetation type (QRTA) is found on east-facing slopes primarily, but also on north-facing slopes. This type is frequently encountered at the head of small drainages where the slopes are very steep and unstable. Basswood and red oak are established in these ravines where the soil is wet. With time these areas stabilize and QRTA persists on the north and east aspects.

Q. rubra and *T. americana* share the dominance in this vegetation type although not equally. *Q. rubra* has 43.7% rba and *T. americana* has 21.4% rba. This is not unexpected, as even where basswood is dominant in the TA type its relative basal area is only 34.1%. The understory is dominated by *Ostrya virginiana* with 53% cover, followed by *Carpinus caroliniana* with 15%, *Tilia* with 10%, and *Acer* with 10%. The sapling count is dominated by *Carpinus caroliniana* (41.5 saplings per 100 m^2). *Parthenocissus quinquefolia* (5.9%) dominates the herb layer, followed by *Thalictrum dioicum* (2.3%), *Sanicula* spp. (1.9%), and *Adiantum pedatum* (1.5%). An average of 14.4% bare soil characterizes this type. Litter has 85.1% and bryophytes have 1.6% cover. The QRTA vegetation type has an average of 8.0 woody species and 33.3 herbaceous species per 0.1 ha.

Tilia Americana Vegetation Type (TA, TAN)

The *Tilia americana* type (TA) is found on steep north-facing slopes. These are the wettest and coolest sites in the park. This type frequently extends a short way up all aspects along drainages where soil moisture is high. TA generally grades into QRTA or QR as the aspect changes.

Tilia americana is the dominant species with 34.1% rba, *Quercus rubra* is an important species with 13.4% rba, as well as *Acer nigrum* with 11.9% rba. The understory is dominated by *Ostrya virginiana*,

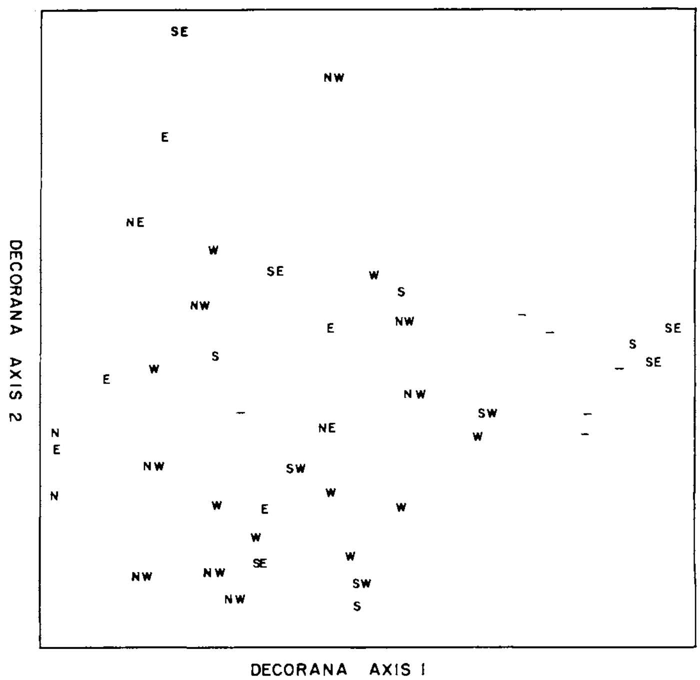

Fig. 4. DECORANA ordination of upland plots based on tree basal area with aspect represented: E = East, N = North, NE = Northeast, NW = Northwest, S = South, SE = Southeast, SW = Southwest, W = West, — = flat.

Table 1. Overstory vegetation. Percent relative basal area of dominant species in each vegetation type.

Species	QA	QAR	QR	QRTA	TA	Slump	Bottom
Number of samples	6	9	11	3	8	3	3
Acer nigrum	----	5.9	4.1	12.7	11.0	3.3	4.8
Carya cordiformis	----	2.2	7.6	----	4.6	7.0	1.3
Carya ovata	2.8	5.8	1.6	3.7	3.3	13.7	----
Fraxinus nigra	----	.7	----	.7	2.7	2.7	11.3
Fraxinus spp.	1.8	3.9	1.6	3.0	4.5	----	----
Juglans cinerea	----	.8	----	----	.4	----	----
Juglans nigra	----	.4	----	----	1.3	6.7	52.5
Ostrya virginiana	4.7	9.8	5.9	4.3	9.3	4.3	4.0
Quercus alba	76.8	30.4	10.5	5.3	7.7	17.3	2.5
Quercus muehlenbergii	----	6.9	----	----	.6	20.3	2.5
Quercus rubra	8.7	29.4	62.9	43.7	13.4	11.7	----
Tilia americana	----	1.2	3.4	21.0	33.6	6.0	.3

(59%) which attains its greatest cover in this type. *Acer* reaches its highest understory cover here, 16%. The highest sapling count for this type is for *Fraxinus* spp., 34.8 saplings per 100 m^2. The herbaceous layer is dominated by *Parthenocissus quinquefolia* (4.7% cover) and *Thalictrum dioicum,* which reaches its highest cover in this type (3.1% cover). There is an average richness of 10.1 woody species and 36.7 herbaceous species per 0.1 ha. Bryophytes reach their highest cover with 12.5%, litter has its lowest value of 59.7% cover, and conversely bare soil attains its greatest value at 24.4% cover.

Acer nigrum is codominant in some of the TA sites. These, denoted as *Tilia americana-Acer nigrum* vegetation type (TAN), are recognized on the vegetation map but are considered to be a variation of the TA type on the basis of ordinations and other species present. TAN is most frequently found on east-facing slopes.

Slump Forest Vegetation Type (QARS)

Slump forest vegetation type (QARS) is found in areas where in the past major blocks of soil have slid or 'slumped' down the slopes. These can be recognized as gentle slopes with a bench appearance. They have been identified as soil slumps and dated by geological methods (Osolin, 1983). These are on east, south, and west aspects. Normally on these aspects one would expect to find QR or QAR, but slumping seems to have altered the vegetation.

There are no well-defined dominant species in this type. *Quercus muehlenbergii* has its greatest abundance (20.3% rba) in this type, followed by *Q. alba* (17.3%), *Carya ovata* (13.7%) and *Q. rubra* (11.7%). These three species of oak occur consistently in this type, along with *Carya ovata* which reaches its highest abundance of any type. This type also has relatively high amounts of *Juglans nigra* (6.7%) and *Fraxinus nigra* (2.7%) which otherwise are mostly limited to bottomlands and north slopes. The total understory cover is low in this type, being lower only in the QA type. *Ostrya virginiana,* the dominant understory species, has only 22% cover. *Fraxinus* spp. has the highest number of saplings, 20.6 per 100 m^2. The total herb cover in this type is exceeded only in the bottomland. The highest cover is by *Amphicarpa bracteata* (4.8%), followed by *Sanicula gregaria* (4.2%), *Parthenocissus quinquefolia* (2.7%), *Desmodium glutinosum* (2.1%), *Carex* spp. (1.9%), and *Hydrophyllum virginianum* (1.5%). There is an average of 73.6% litter cover and 0.1% bryophyte cover. The type is characterized by 19.7% cover of bare soil. The slump forest type has the highest richness of woody species, 12.7 species per 0.1 ha, and the highest richness of herbaceous species, 38 species per 0.1 ha.

The vegetation of this type is not consistent with that predicted by the overall topography. Plants characteristic of both moist and dry habitats are intermixed. The mesic vegetation is represented by high amounts of *Juglans nigra* and *Fraxinus nigra* and a dense herbaceous cover. Common dry habitat species include *Carya ovata, Quercus alba,* and *Quercus muehlenbergii.* This mixture of species is probably due to disturbance by slumping. Slumping of this magnitude creates canopy openings and exposes bare soil, allowing species intolerant of shade to become established. The slump also changes the soil drainage and moisture characteristics, creating areas with poor drainage and areas which are dry and hummocky. It is the diversity of habitats and species as well as the lack of understory cover which makes this type distinctive. The slump forest vegetation type resulting from massive soil slumping has not been previously described in Iowa.

Table 2. Understory vegetation. Percent cover of common species in each vegetation type.

Species	QA	QAR	QR	QRTA	TA	Slump	Bottom
Number of samples	6	9	11	3	8	3	3
Acer nigrum	—	8	12	10	16	12	15
Amelanchier arborea	4	4	—	6	—	—	—
Carpinus caroliniana	—	6	8	15	5	7	17
Carya cordiformis	—	8	—	—	—	3	5
Fraxinus spp.	13	5	3	1	6	13	15
Ostrya virginiana	31	57	55	53	59	22	5
Quercus alba	1	—	1	—	—	—	—
Quercus rubra	—	—	2	—	2	—	—
Tilia americana	—	—	2	10	5	5	—
Ulmus spp.	2	—	6	2	—	1	2

Table 3. Sapling and shrub vegetation. Average number of stems per 100 m^2 in each vegetation type.

Species	QA	QAR	QR	QRTA	TA	Slump	Bottom
Number of samples	6	9	11	3	8	3	3
Acer nigrum	1.2	4.5	4.3	9.9	10.9	3.6	9.0
Amelanchier arborea	2.0	5.4	7.4	.3	7.9	.7	----
Carpinus caroliniana	----	16.1	13.5	41.5	12.1	5.1	15.0
Carya cordiformis	1.4	3.0	1.0	4.8	5.5	4.6	2.2
Cornus spp.	1.7	3.6	7.6	1.0	3.8	5.2	5.7
Fraxinus spp.	83.7	45.5	32.6	28.8	34.8	20.6	9.3
Lonicera spp.	10.6	3.8	2.3	.4	----	----	4.6
Ostrya virginiana	42.2	41.4	25.6	11.8	24.3	8.7	1.4
Prunus virginiana	----	3.4	10.5	14.9	6.6	1.3	.7
Quercus alba	7.0	----	----	----	----	----	----
Quercus rubra	.4	----	1.3	.5	1.5	1.2	----
Ribes missouriensis	24.3	14.4	5.9	5.0	9.0	4.8	17.6
Rhus radicans	1.4	2.2	3.5	1.5	9.4	18.2	8.1
Rubus spp.	8.8	2.2	.7	1.0	1.3	5.5	79.5
Smilax hispida	1.0	1.8	.6	1.2	----	7.3	1.2
Tilia americana	5.5	3.5	2.3	----	7.3	2.7	1.3
Zanthoxylum americanum	1.4	1.0	1.8	----	1.2	.3	2.7

Bottomland Vegetation Type (JN)

The bottomland vegetation type (JN) is found along the major drainages in the park. These include the easternmost edge of the floodplain along the Des Moines River, and the floodplains of Pease Creek, Davis Creek, and Chinkapin Creek. (Bottomland vegetation is distinguished from the low floodplain vegetation type which has no woody plants and is artificially maintained this way.) This is the wettest vegetation type and is generally restricted to the bottoms of ravines, extending only a few meters up slope.

The dominant species in the bottomland type is *Juglans nigra* (52.5% rba). Associated species include *Fraxinus nigra* (11.3% rba), *Celtis occidentalis* (7.3% rba), and *Acer nigrum* (4.8% rba). The understory in the bottomland type is dominated by *Celtis* with 28% cover. *Ribes missouriensis* has 17.6 stems per 100 m^2. The highest herbaceous cover (87.0%) of any type is found in the bottomland. *Eupatorium* spp. has the highest cover (26.3%), followed by *Hydrophyllum virginianum* (23.9%). Litter has an average cover of 76.4% and bryophytes 2.7%. There is an average of 15.6% cover of bare soil. The average number of woody species for the bottomland is 9.5 per 0.1 ha. Although it has the highest herbaceous cover, an average of only 20 herbaceous species per 0.1 ha is present in the bottomland. This is the lowest herb species richness.

In recent decades Dutch elm disease has eliminated many large trees of *Ulmus americana* and *Ulmus rubra* from the bottomlands of Ledges (R. Q. Landers, pers. comm.). The absence of these dominants has created gaps in the canopy and influenced subsequent species composition. This must be accounted for in any comparison of current bottomland communities with those reported in earlier studies.

Table 4. Herbaceous vegetation. Estimated percent cover of common species in each vegetation type.

Species	QA	QAR	QR	QRTA	TA	Slump	Bottom
Number of samples	3	5	5	3	4	3	1
Adiantum pedatum	----	----	----	1.5	.6	----	----
Amphicarpa bracteata	.3	1.4	1.3	.4	1.5	4.8	.2
Asarum canadensis	----	----	----	1.1	1.7	----	----
Aster cordifolius	----	.3	.3	.6	.3	----	----
Carex spp.	7.7	4.7	2.0	.8	1.4	1.9	1.3
Desmodium glutinosum	.4	.8	2.2	1.3	.5	2.1	----
Eupatorum spp.	----	----	----	----	----	----	26.3
Hepatica acutiloba	----	----	----	.8	1.4	----	----
Hydrophyllum virginiana	----	.1	----	.3	.4	1.5	23.9
Hystrix patula	.2	----	.1	----	----	.4	----
Muhlenbergia spp.	.1	.4	----	----	----	1.2	----
Osmorhiza claytoni	----	----	----	.3	1.2	.2	.3
Parthenocissus quinquefolia	5.1	4.5	1.2	5.9	4.7	2.7	.7
Sanicula spp.	----	.2	.1	1.9	1.0	4.2	6.3
Solidago spp.	.7	1.6	.7	.6	----	.5	----
Thalictrum dioicum	----	.6	.8	2.3	3.1	----	----
Total cover	16.4	19.7	12.5	23.5	23.2	27.5	87.0
Average number of species	29.0	33.4	28.2	33.3	36.7	38.0	20.0
Bare soil	3.9	8.5	18.4	14.4	24.4	19.7	15.6
Bryophytes	.1	.3	.8	1.6	12.5	.1	2.7

Minor Vegetation Types

The following vegetation types are minor components of the vegetation of the Ledges State Park. The last three types (floodplain, open pasture and conifer plantation) were not sampled quantitatively because of their artificial nature and the uncertainty of their future management.

Disturbed Woods Vegetation Type (DW)

Disturbed woods vegetation type (DW) occurs throughout the park irrespective of slope or aspect, and is primarily disturbed by recent grazing. This is a broadly-defined vegetation type including several areas which are disturbed but differ greatly in composition. Species such as *Gleditsia triacanthos, Ostrya virginiana, Ulmus* spp., *Rubus* spp., *Rhus glabra, Rhus radicans, Zanthoxylum americanum, Juniperus virginianum,* and *Corylus americanum* are common. Areas which were grazed very recently are open and have only a few large open-grown oaks. Many thorny species can be found here, including large areas of *Rosa multiflora*.

Disturbed Bottomland (JND)

In the disturbed bottomland vegetation type (JND) *Juglans nigra* is less important than in the *Juglans nigra* type. These areas are more open, disturbed by man or livestock, and have fewer canopy species. *Gleditsia triacanthos* and *Populus deltoides* are the major overstory and understory species. Sapling counts within this type are highest for *Rubus* spp. (79.5 per 100 m^2). *Poa pratensis* is the predominant herb. The major area of disturbed bottomland vegetation type is the upper section of Pease Creek. This area has been severely grazed and is in poor condition.

Prairie Vegetation Type (PR, PRH)

Two prairie types occur in the park, the restored prairie (PR) and the remnant hill prairies (PRH). The prairie at the park's east entrance was restored in 1949. Common planted grasses include *Andropogon gerardii, Schizachyrium scoparius (Andropogon scoparius), Panicum virgatum, Elymus canadensis,* and *Sorghastrum nutans*. There are very few forbs in this prairie.

Hill prairies are found at five sites in the park. All of these sites are steep south- or southwest-facing slopes. All of the hill prairies of the Ledges have been invaded partially by *Ostrya virginiana* with only a few prairie species, mainly grasses, persisting. Each of the hill prairies has *Andropogon gerardii*, while fewer have *Bouteloua curtipendula, Schizachyrium scoparius,* and *Sorghastrum nutans*.

Floodplain (FP)

This area adjacent to the Des Moines River has been disturbed by the removal of trees for flood management. It contains many weedy herbaceous species and is frequently inundated by floodwaters.

Open Pasture (OP)

There are several pasture-like areas and old fields throughout the park. These contain many weedy herbaceous species with no trees or shrubs.

Conifer Plantation (CP)

There is a conifer plantation on the upland north of Chinkapin Creek and several smaller ones south of this one. These areas include *Pinus banksiana, P. strobus, P. resinosa,* and *P. nigra*.

Vegetation Trends

Within the upland vegetation types (QA, QAR, QR, QRTA, TA) several trends in coverage by individual species can be identified. Relative basal area of the dominant tree species is shown in Figure 5 with a moisture gradient increasing from left to right along the x-axis. *Quercus alba* is clearly highest in the driest vegetation type, QA, and decreases in the more mesic types. *Quercus rubra* is highest in the vegetation type of intermediate moisture, QR, and decreases as the habitat becomes more moist or drier. *Tilia americana* increases in the mesic vegetation types and is highest in the most mesic type, TA. The response of *Acer nigrum* is similar to that of *Tilia*, but the increase is not as large. *Carya ovata* is fairly uniform throughout the highest cover in the relatively dry QAR type.

Total herbaceous cover is highest in TA and lowest in QR vegetation types (Figure 6). The highest litter cover is found in the QA type, decreasing to a low in the TA type. Bare soil increases conversely. Bryophytes are lowest in QA and increase to the highest cover in TA. Since the highest herbaceous cover and bryophyte cover are in TA where the highest percent of bare soil also occurs, it is possible that available bare soil influences species distributions. However, these are also the areas of highest soil moisture.

Comparison To Other Iowa Studies

Bach (1982) reported three major oak vegetation groups: *Quercus alba, Quercus rubra,* and a mixed group containing both species. She also noted *Acer nigrum* and *Tilia americana* as important in mesic sites, associated with *Quercus rubra*, but did not define this as a distinct unit. Constancy for shrubs and herbs were recorded by Bach and these appear roughly the same as this study; *Ostrya virginiana, Fraxinus* spp. *Parthenocissus quinquefolia,* and *Ampihicarpa bracteata* were widely distributed in both studies.

Niemann (1971) and Niemann and Landers (1974) defined two woodland vegetation types at Woodman Hollow, excluding the bottomland. In a north-facing type they define *Hepatica acutiloba* and *Mitella diphylla* as indicator species, along with *Tilia americana, Acer nigrum,* and *Carya cordiformis*. On the south-facing slope, *Quercus alba* and *Carya ovata* were the dominant trees with *Galium aparine, Sanquinaria canadensis,* and *Thalictrum dioicum* as common herbs. No mention was made of *Parthenocissus*, although results of the current study and that of Bach (1982) indicate that it is widespread in central Iowa forests.

Sanders (1967) reported that *Ostrya* saplings tended to have high densities in white oak stands, and lower densities but larger individuals in the maple-basswood forests in central Iowa. This is in agreement with the findings of this study; *Ostrya virginiana* had a density of 42.4

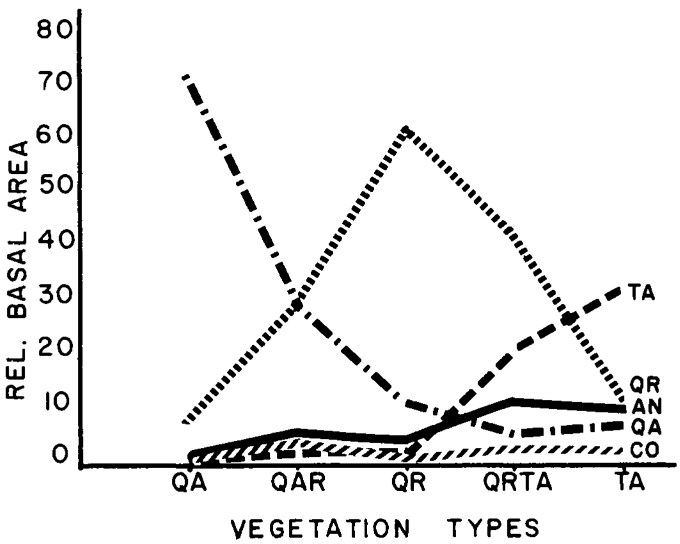

Fig. 5. Relative basal area of dominant tree species for each vegetation type: AN = *Acer nigrum*, CO = *Carya ovata*, QA = *Quercus alba*, QR = *Quercus rubra*, TA = *Tilia americana*.

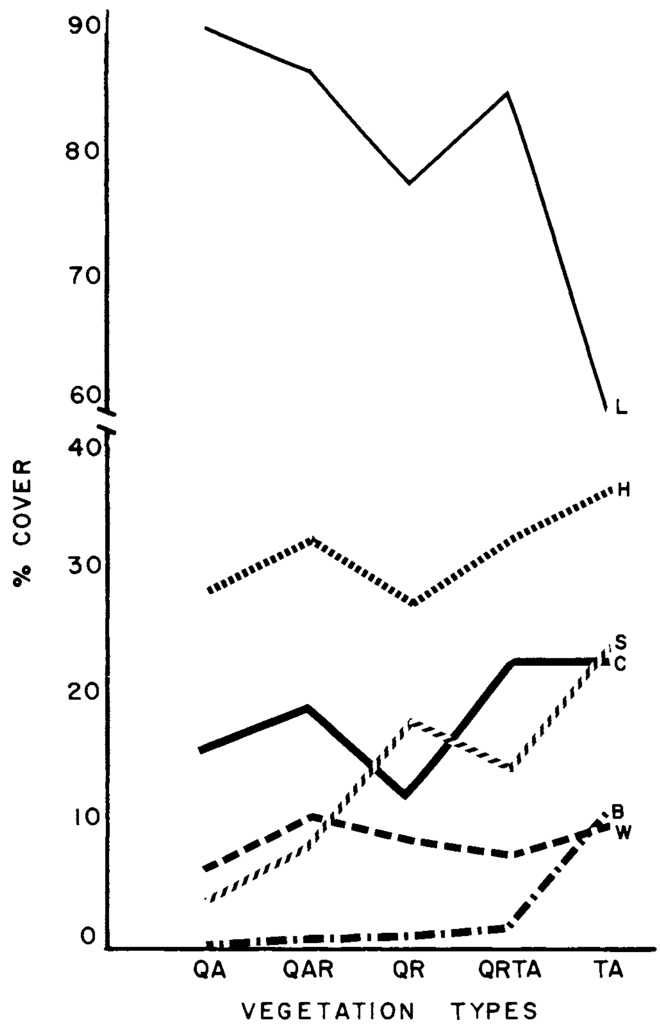

Fig. 6. Vegetation cover, excluding trees and saplings, and richness relative to the vegetation type. Herbaceous and woody species richness are the average total number of species found in each vegetation type. B = Bryophytes, C = Total herbaceous cover, H = Herbaceous richness, L = Litter, S = Bare soil, W = Woody richness.

stems per 100 m^2 and an average dbh of 5.5 cm in QA, and 24.3 stems per 100 m^2 and an average dbh of 7.0 cm in TA. He also reported that herbaceous species could be used as indicators of the canopy vegetation. The herbaceous vegetation of the Ledges is most distinctive in the TA type, where *Thalictrum diocium, Asarum canadense, Hepatica acutiloba,* and *Osmorhiza claytonia* consistently reach their highest cover (Table 4). No herbaceous species was both limited to a particular vegetation type and constant within that type.

In northeast Iowa, Cahayla-Wynne (1976) described five types of vegetation, three of which, white oak, red oak, and basswood, are in common with those found in the Ledges. Cahayla-Wynne noted that basswood and maple are minor components of the white oak type and that this type has the greatest tree species richness. He also noted that black walnut was abundant in the basswood type. These findings contrast with those from the Ledges where very few maple or basswood occur in the upland, and where the white oak type has low species richness. In addition, black walnut very rarely occurs in the basswood type, and is mostly limited to bottomlands at the Ledges.

In the herb stratum, Cahayla-Wynne (1976) noted high amounts of *Parthenocissus quinquefolia, Osmorhiza claytoni, Geranium maculatum,* and *Circaea quadrisulcata* in all types, and reported that *Hydrophyllum appendiculatum* replaced *Parthenocissus* in the mature maple-basswood stands in northeast Iowa. In this study *Osmorhiza claytoni, Geranium maculatum,* and *Circaea quadrasulcata* were found only in the wettest sites, and *Hydrophyllum appendiculatum* was found only on bottomland sites and did not occur in the TA type. More maple and basswood seedlings were noted in northeastern Iowa than exist in central Iowa in all community types. Cahayla-Wynne noted that maple, basswood, and ironwood seedlings were most successful in attaining sapling status, reaching constancies of 85%, 46%, and 49% in the shrub stratum.

Cahayla-Wynne's (1976) study indicates that mesophytic forests in northeast Iowa are more completely developed and more widespread than those in central Iowa. Northeast Iowa has a more dissected topography than that of central Iowa, was not glaciated during the Wisconsin glaciation, and has a climate that is somewhat cooler and wetter than central Iowa. In central Iowa forests, the topography is less dissected and the climate is drier especially in summer. The QAR type at the Ledges likely is a consequence of this drier more exposed topography. QAR is a transitional type between QA and QR which in northeast Iowa may be too narrow to warrant recognition, but at the Ledges is too extensive to be ignored. The QRTA type at the Ledges likewise warrants recognition. Kucera (1950, 1952), Sanders (1967), Niemann (1971), and Bach (1982) have also reported the coexistence of *Q. alba* and *Q. rubra* on moderately xeric sites in central Iowa.

Cahayla-Wynne and Glenn-Lewin (1978) and Christiansen et al. (1980) concluded that succession in northeastern Iowa will be to sugar maple-basswood on most upland sites if sufficient time passes without disturbance. Evidence for succession toward maple-basswood was not found in the most xeric types (QA and QAR) in the current Ledges study. Single static samplings cannot predict succession, but it is informative to examine the understory and sapling layers for evidence of the current reproduction of overstory species. *Quercus alba* is reproducing in dry sites with an average of 2% cover and a sapling count of 7.0 per 100 m^2 (see tables 2 and 3). No other major overstory species are present as understory in the QA type. *Tilia, Acer,* and *Carya cordiformis* have high sapling counts in some QA and QAR types but are not present as understory. While it is possible that these species may have just begun to reproduce in the uplands, given the age of the forest and absence of grazing or fire for more than 65 years, it seems more likely that seedlings of these species are unable to survive to the understory tree stage in these xeric sites. It seems plausible that these areas will maintain a white or red oak canopy which is tolerant of periodic drought and the exposure associated with these sites.

Succession in the mesic vegetation types (QR, QRTA, TA, QARS) appears to be toward a maple-basswood forest. Here maple and basswood clearly are reproducing and surviving as understory trees. In all vegetation types red oak will probably be a minor but important component, especially on the drier sites.

The present forest composition is probably in part a result of the logging activities of the late 1800's and early 1900's. Selective logging likely created gaps in the canopy which enhanced *Quercus* reproduction. In the past, fire may have also helped to maintain oak forests. Nigh et al. (in press) found that oaks in the Missouri Ozarks regenerated successfully only on exposed dry sites and concluded that oak upland forests in Missouri may have been maintained by prairie fires which also burned through the forest floor killing less fire tolerant species.

It is interesting to note changes in *Fraxinus* spp. populations from sapling to canopy. *Fraxinus* has a very high sapling count and is a major component of the understory of all vegetation types, but few ash are present in the canopy. Similar sapling mortalities are not demonstrated by the other canopy species. The cause of mortality is unknown, but may relate to a decrease in shade tolerance as the ash saplings mature into understory trees. Thus they survive to the understory and canopy stages only when they occur in gaps where sunlight penetrates the canopy.

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