Classification and ordination of the vegetation of Woodman Hollow, Iowa

by

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INTRODUCTION

> The sides of the valley are steep and well wooded from top to bottom. After ascending the slope, however, the climber finds himself at once on the level prairie where often for miles he can see the stream as it flows through its V shaped valley.

This is the nostalgic description of the Des Moines River valley in Webster County given by Wilder (1901). Such a gallery forest occurred along the rivers and larger streams of Iowa in presettlement times and followed the sloping land of the valleys deep into the tall grass prairie. The grandeur of Iowa as described by Wilder disappeared long ago, but there are still a few nearly intact remnants of the gallery forest he described. Woodman Hollow State Preserve is one such remnant which is the object of this study.

At the present time much of the original forest vegetation, which covered 16% of Iowa in presettlement times (Sanders, 1969), has been altered through introduced diseases, selective cutting, grazing, and to a certain extent by recreation. Forested land which closely resembles the type found by the original land surveyors and settlers in Iowa is rare, and completely natural stands probably no longer exist. Nevertheless, Woodman Hollow represents a close approximation to the original gallery forest, and for this reason it was chosen as the study area.

Woodman Hollow State Preserve is located on the west side of the Des Moines River in the southern ½ of the northern ½ of

Section 22 in Otho Township, T88N, R28W in Webster County, Iowa. This region of the state was glaciated about 14,000 years ago by the Cary lobe of the Wisconsin continental glaciation (Ruhe, 1969). The preserve lies within the Clarion-Nicollet-Webster soil association area (Oschwald et al., 1965).

A small unnamed intermittent stream enters the preserve at its western boundary and drains into the Des Moines River at the eastern end of the preserve after dropping approximately 27.5 meters (90 feet). The stream is confined in a deep canyon cut through the successive glacial tills and into the underlying soft Pennsylvanian sandstone. The local relief in the preserve is about 52 meters (170 feet).

The local relief within the preserve offers a continuous variation in habitats. Some places are exposed to a vertical sun during the growing season while others have never been exposed to direct sunlight since they were formed. This variation of habitats combined with the relatively undisturbed nature of Woodman Hollow makes it an ideal place in which to study the natural distribution of plants across an environmental gradient.

is the [illegible]?

[illegible] or a physiographic gradient?

The vegetation of the preserve may be subdivided generally according to habitat. The upland forest on the north side is dominated by Quercus alba with Carya ovata and Quercus rubra having less dominance. The upland on the south side of the preserve has less Quercus alba and is dominated by Quercus rubra and Carya ovata with some Populus grandidentata. Ribes *cynosbati* and *Parthenocissus quinquefolia* are almost ubiquitous in the ground layer while *Ostrya virginiana* is the major understory tree of both upland habitats. The north-facing slopes have mainly *Tilia americana* and *Acer nigrum*. *Ostrya virginiana* and *Carpinus caroliniana* are the predominant understory trees. *Mitella diphylla* is a characteristic herb on the north-facing slopes. The lower south-facing slopes possess an arborescent vegetation similar to that of the north-facing slope. Near the slope break, however, *Quercus alba* and *Q. rubra* again become dominant. The stream bottom is narrow and supports a number of species including *Ulmus americana*, *Acer nigrum*, *Fraxinus americana* and *Juglans cinerea*. *Laportea canadensis* is the predominant herb. South and southwest-facing shoulder slopes possess relict tall grass prairie openings which Shimek (1909, 1910) described from central and western Iowa. These xeric openings are dominated by *Andropogon gerardii* and *A. scoparius*, but also include a number of other prairie grasses and forbs. Special habitats can be described throughout the area, especially along the steep and undercut slopes (e.g., north-facing sandstone supports a few plants of the rare *Cryptogramma stelleri*); however, none of these habitats will be described in this study.

This study is an attempt to describe the vegetation of Woodman Hollow. A major purpose of this paper is to investigate the individualistic behavior of species across an environmental gradient in a central Iowa forest. Further objectives include the use of several methods to subdivide a small portion of the preserve into recognizable communities. The prairie openings were sampled intensively to discover their species composition and to determine potential forest encroachment. Permanent plots were established in the upland forest to provide a baseline for future observations of succession. The work reported in this paper was carried out during the 1970 growing season.

REVIEW OF LITERATURE

General

The dominant vegetation of Woodman Hollow is classified as broadleaved deciduous forest, the form dominating the eastern third of the United States, which is centered around the species-rich mountains and hills of the lower Ohio River basin (Transeau, 1905). More specifically, Woodman Hollow lies near the western margin of the eastern deciduous forest formation. This marginal region is variously referred to as the Maple-Linden region (Braun, 1947), Maple-Basswood association (Oosting, 1956), Oak-Hickory forest (Küchler, 1964), and White Oak-Red Oak-Hickory type (Society of American Foresters, 1954). As Oosting (1956), Gleason (1922), and Gleason and Cronquist (1964) point out, Maple and Basswood occur on the better soil, while Oak and Hickory occur on the rocky or broken upland.

The earliest detailed written records of the vegetation of this part of the eastern deciduous forest may be found in the records of the original land surveyors of Webster County (Neely, 1849). The survey was completed on November 21, 1849. The surveyors were to note: 1) kind and diameter of all bearing trees, 2) name, diameter, and distance on the line of all trees on the line, and 3) the types of timber and undergrowth in the order in which they predominate (Lutz, 1930). Sears (1921) claimed that the Ohio surveyors were excellent woodsmen and were quite accurate in their knowledge of arborescent species. However, in other regions the surveyors may not have been so skilled. Gleason (1922) notes that the surveyors designated land with trees up to 2 feet in diameter as prairie. McComb and Loomis (1944) similarly note that in western Iowa the areas mapped as prairie probably consisted of both true prairie and Bur Oak savanna. Despite the inaccuracies and mistakes the surveyors may have been guilty of, their records still provide the most reliable early information about undisturbed vegetation. These records have been used by several workers to reconstruct the vegetation of counties and townships (Sears, 1921; Kenoyer, 1929, 1933; Dick, 1936; Dick-Peddie, 1955).

Although the surveys are more useful for the reconstruction of vegetation of large areas such as counties, they are also of some value for an area as small as Woodman Hollow. The surveyors passed the western boundary of the preserve and described the vegetation as follows: "Land rolling prairie first rate timber Bur and blk. oak - Aspen Lynn Elm and Hickory. Undergrowth Hazel." Lynn refers to _Tilia americana_, and the Hickory is _Carya ovata_. The black oak is probably _Quercus rubra_. White Oak (_Quercus alba_) is not mentioned for this part of the survey. This may be due to a difficulty in distinguishing between _Quercus alba_ and _Q. macrocarpa_. Specimens which appear intermediate between these two species are abundant within the preserve. _Acer nigrum_ and _Juglans cinerea_ are also not mentioned for this part of the survey. They are restricted to the eastern portion of the preserve.

One other item of interest in the survey is the fact that the surveyors crossed the stream at the western boundary of the preserve but did not mention it, probably because it was likely to be dry in November. They did mention the point of timber which followed the stream. It was 61 meters (200 feet) in width. Now the entire western boundary of the preserve is forested.

Figure 1 is a copy of the map included with the survey. The survey notes were typed during the 1930's and the typed version was consulted. The map is presumably an electronically reproduced duplicate of the original. The map does not completely correspond to the descriptions in the survey. One especially noticeable error is the location of the stream in Woodman Hollow (Section 22) which should travel east-west and correspond to the point of timber described in the survey and noted on the map. The section lines on the map are also several decameters (hundreds of feet) in error.

The earliest specific mention of Woodman Hollow I was able to find is the statement by Hart (1919) that in 1855 wild cats and deer were seen in the area, attesting to the wildness of Iowa then. Deer still frequent the preserve. So do cows!!! Findlay (1919) comments on his experiences in Woodman Hollow in the 1880's. He mentions several plants not found in the current study including two orchids, Cypripedium pubescens and C. reginae.

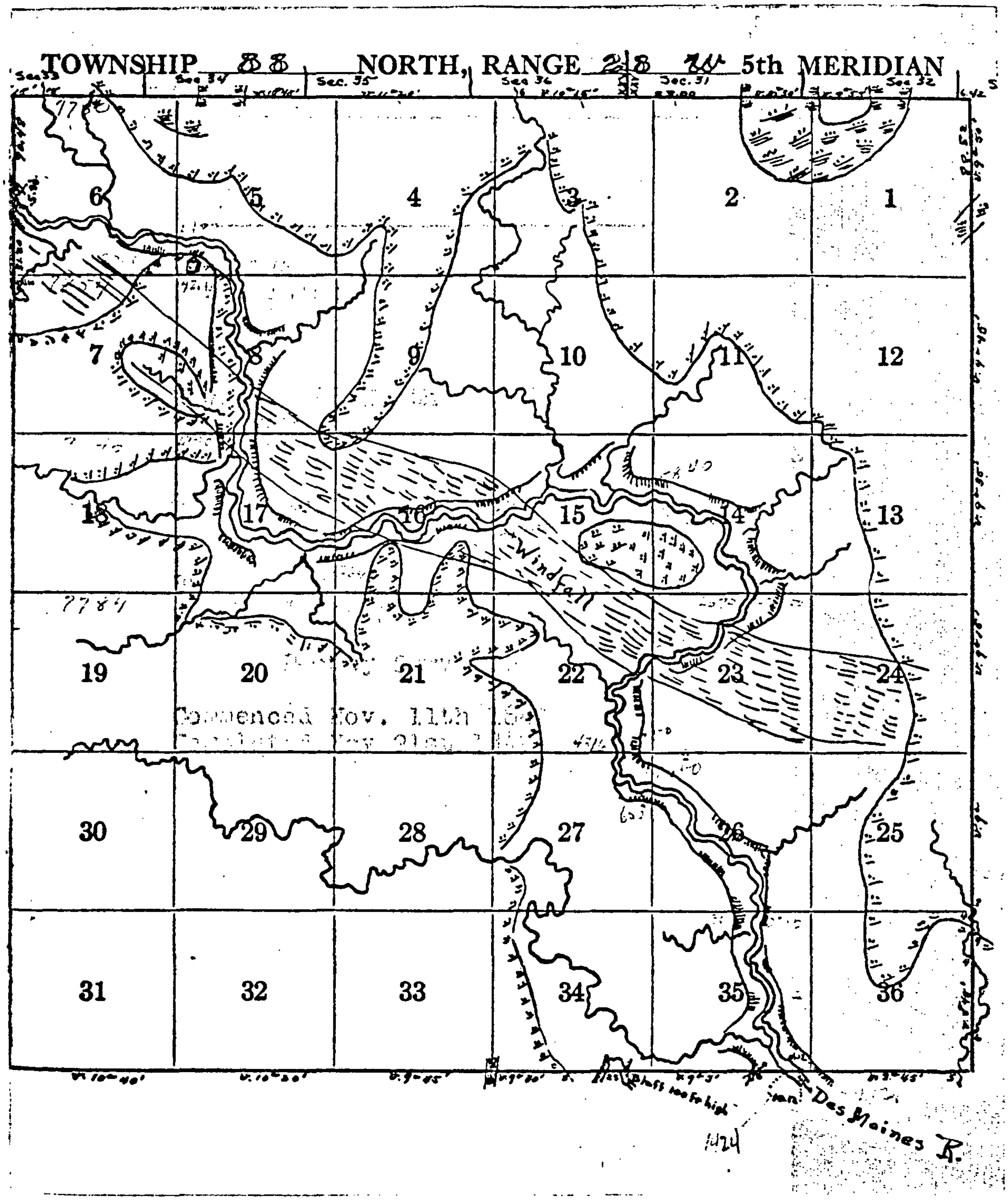

Figure 1. Copy of the map accompanying the original land survey of a part of Webster County, Iowa

His comments indicate considerable disturbance has taken place in the past, including pasturage, which he cites as the reason for the disappearance of the rarer species. He also states that for years the city of Otho selected its annual church Christmas tree from the junipers which occurred on the bluffs, where a few large stumps can still be seen in areas heavily forested over.

The land comprising the preserve was owned by a Mr. Woodman, and for years before the area became a park it was called Woodman Hollow. In 1927 the area was purchased by the state of Iowa and became a state park retaining the name given by the local residents (Stoneburner, 1970). In 1970 the status of Woodman Hollow was changed from that of a state park to that of a state preserve in order to assure its continued existence as a natural area.

No prior ecological research is known for Woodman Hollow. In Iowa and some surrounding states various aspects of the Maple-Basswood association have been studied. In central Iowa near Ames, the vegetation of the slopes varies with their aspect. North-facing slopes support Maple and Basswood, west-facing slopes support Oak and Hickory, and southeast-facing slopes are intermediate between the two types. Hazel, Dogwood and Sumac occupy hill summits. Maple-Basswood was considered the climax forest type in the region, limited in extent by periodic severe droughts (Aikman and Smelser, 1938). Similar effects of drought were observed in western Iowa and Nebraska by Albertson and Weaver (1945). In northern Wisconsin, however, drought does not seem to play such a role (Eggler, 1938).

The vegetational changes encountered in traveling northward along the Des Moines and Missouri Rivers were described by Aikman and Gilly (1948). Along the Des Moines River, _Acer saccharum_ drops out rapidly upstream and is replaced by _Acer nigrum_. There is a reduction in species number and size of trees westward, but in all cases, _Tilia americana_ is the dominant species on the most mesophytic north and northeast-facing slopes.

Comparisons of natural and grazed forests in central Iowa revealed that in most cases the grazed forests had a less favorable environment for the growth of trees (Kucera, 1950, 1952).

More recently Sanders (1967) studied the composition of slope forests along the Des Moines River in central Iowa in an attempt to provide information which would be useful in documenting changes which might occur due to flooding caused by the Saylorville Reservoir which was to be constructed. Later Sanders (1969) studied the growth patterns of herbaceous vegetation on forested slopes and found that species exhibited scales of pattern related to plant morphology and environmental factors. He suggested that plant distribution in central Iowa forests is probably not random, but rather systematically follows environmental patterns such as soil fertility which occur in random patterns (Sanders, 1969).

Outside Iowa, but still within the Maple-Basswood association, research has been carried out which shows that although the association is a distinguishable unit, it is not strictly uniform. In central Missouri, Kucera and McDermott (1955) found that *Acer nigrum*, *Tilia americana* and *Ulmus rubra* were the dominant arborescent species. They noted that *Ostrya virginiana* was the most prevalent understory tree, and *Celastrus scandens* was the most frequent vine. In addition to many species in common with Maple-Basswood forests in central Iowa, several southern species were found including *Asimina triloba*, *Cornus florida*, *Sassafras albidum*, and *Fraxinus quadrangulata*.

In Minnesota, Daubenmire (1936) studied nearly natural remnants of a large Maple-Basswood forest. He listed the important tree species in order of dominance as *Acer saccharum*, *Tilia americana*, *Quercus rubra*, *Ulmus rubra*, and *Ostrya virginiana*. In a rather extensive herbaceous species list, almost all species listed are also present in Woodman Hollow except for a few rare species such as *Aplectrum hyemale*. Daubenmire felt that the Minnesota forest was expanding westward. He found large specimens of *Quercus macrocarpa* which, judging from their form, must have grown under rather open savanna conditions. The present forest of *Tilia americana* and *Ostrya virginiana*, which grew up around the old oaks, consisted of multiple-stemmed trees, indicating that occasional fires may have killed back the thin-barked species while allowing the

Quercus macrocarpa specimens to develop their open-grown form and large size.

In southern Wisconsin, Cottam (1949) studied a forest which had been an oak-opening prior to settlement. Large open-grown specimens of *Quercus alba*, which were the original trees of the oak-opening, still remained in the forest but were surrounded by taller yet younger trees. The younger, forest-grown trees all started growing at about the same time, 1860. The soil was classified as a forest soil, and he suggested that such a soil would probably not have developed under an oak-opening. He concluded that the old oaks were remnants of a forest which had been thinned of all its fire-sensitive species at some time in the past, and was maintained in that condition by the annual fires set by the Indians. After settlement, the annual fires ceased and the forest regenerated. He suggested that the presence of saplings of *Acer saccharum* and *Tilia americana*, as well as other more mesophytic tree species, may mean that in another century or two, portions of the woods may become typical Maple-Basswood forest. McIntosh (1957) studied a forest in the same region of Wisconsin and concluded that Maple seemed to be expanding into an Oak-Hickory area.

Potzger (1935) studied the Beech-Maple woods of central Indiana which, despite the distance from central Iowa, show some remarkable similarities. He noted that *Ostrya virginiana* was the predominant understory tree. In studying the effects of slope aspect, he found that north-facing slopes supported

Beech-Maple while south-facing slopes supported a more xeric community dominated by Oak and Hickory. The number of species present on the south slope was only 50% of that present on the north slope. He also noted the barren appearance of the south slope with abundant exposed rocks. He concluded that the difference in vegetation was controlled by edaphic differences, chiefly soil moisture as influenced by differences in insolation and soil depth.

Literature Concerning Data Analysis

The classification and ordination of vegetation have become more important in ecological investigations in recent years. Whether one chooses to classify or ordinate vegetation depends partly on the vegetation and partly on the worker's concept of vegetation. In any case, both methods have seldom been applied to a single unit of vegetation by a worker.

Some early ecologists such as Sukachev (1928) concluded from visual observations that vegetation consisted of discrete types based on habitat and understory. On this basis, Sukachev classified the species-poor Spruce forests of European Russia.

Daubenmire (1952) and Daubenmire and Daubenmire (1968) adopted a very similar system of classification for the conifer forests of Washington and Idaho. They felt that such a classification was useful because it permitted general land use recommendations to be made. Their system of classification is subjective, like that of Sukachev, but it is based on detailed quadrat analysis.

Recently some very complex methods of classification have been developed. They are discussed by Kershaw (1964) and Greig-Smith (1964). One of the methods utilizes chi-square values to determine the one species which accounts for the greatest positive and negative associations. The method is discussed in the next chapter.

In contrast to the concept of discrete associations is the individualistic concept of the association. This concept of deciduous forest vegetation of Wisconsin was expressed as early as 1877 by Chamberlain. He described the forest types of this region as merging almost imperceptibly into one another (Curtis and McIntosh, 1951). Jaccard (1912) stated basically the same belief for the alpine vegetation of Switzerland. He said that a superficial examination of such meadows might lead one to believe that they are all very similar. A quantitative study using meter square quadrats showed, however, that all the sites sampled were distinct in species composition. This led him to state that probably nowhere in the Alps could one find 2 square meters of vegetation with the same composition.

This concept was clarified by Gleason (1926) as well as by others who apparently arrived at the same conclusion at about the same time (McIntosh, 1967). Gleason concluded his discussion of the individualistic nature of the association with this statement:

> In conclusion, it may be said that every species of plant is a law unto itself, the distribution of which in space depends upon its individual properties of migration and environmental requirements.

McIntosh (1967) has thoroughly reviewed the individualistic concept of plant communities.

Curtis and McIntosh (1951) developed a method of linear ordination to demonstrate the continuous variation of the forests of Wisconsin. Using relative frequency, relative density, and relative dominance as well as a climax adaptation number for each species they were able to ordinate stands of vegetation in such a way that their position in the ordination related to their successional status. The location of any stand in the linear ordination could also be related to other factors which change with succession, such as organic matter content of the soil.

The Curtis system of ordination was criticized because it was said that attempts to ordinate vegetation on the basis of one dimension failed to show the effects of many other environmental factors of importance. To determine if the use of additional dimensions could be of value to show the relationships of stands to other factors, Bray and Curtis (1957) developed a three-dimensional system of ordination. It was also discussed by Curtis (1959). This method was attacked by Austin and Orloci (1966) because they felt the community coefficient of Bray and Curtis (1957) was not a good measure of Euclidean distances between stands.

Other methods were developed which require electronic computers (Orloci, 1966; Crawford and Wishart, 1968; and Williams and Lambert, 1959, 1960, 1961). These methods can be used to ordinate species using stands as attributes or to ordinate stands using species as attributes. The Orloci method has been used by Sanders (1969) for deciduous forest vegetation in Iowa, and by Brotherson (1969) for prairie vegetation in Iowa. The results for forest vegetation are questionable, but the results for prairie often delimited groups of plots or species which were similar and thus confirmed the occurrence of rather discrete zones around potholes which were observed in the field.

MATERIALS AND METHODS

General

The field work reported in this paper was completed during the 1970 growing season. During this period of time, I visited the preserve at intervals no greater than 10 days in order to obtain flowering specimens of most of the species of flowering plants. The search for species was concentrated in the transect to be described later, but specimens were collected throughout the preserve. A set of these voucher specimens is on deposit in the herbarium of Iowa State University. The nomenclature for grasses follows Pohl (1966). All other vascular species follow the nomenclature of Fernald (1950).

Field Methods

The extreme variation of plant communities due to topographic features in Woodman Hollow can best be described by the use of a transect across the topographic gradient. The transect was located near the Des Moines River where the topographic variations are greatest. Subjective observations also revealed that this part of the preserve had the greatest variety of plant communities. In order to show the entire spectrum of habitats and communities, the transect had to run from the upland on one side of the stream valley down the slope to the stream bottom and then up the opposite slope to the upland on the other side of the stream. This transect crossed the main south-facing prairie opening in the preserve.

The plot size and number were determined through the use of species-area curves. Four rather distinct plant communities were chosen. These were defined according to their topographic position as: 1) north upland; 2) prairie opening; 3) south-facing slope; and 4) stream bottom. In each of these communities, plots of the following areas were laid out: 1, 2, 4, 8, 16, 32, and 64 square meters. The plots were nested; that is, the smaller plots were all included within the largest one. Within each plot, the total number of species was recorded. The number of species was then plotted versus plot size, and the resulting species-area curves are shown in Figure 2.

Cain (1932) felt that one could determine the proper quadrat size to use in a particular habitat by examining the species-area curve. He concluded that 100 square meters was the proper size to use for arborescent vegetation. Later Cain (1934) decided that an area of 4 square meters was good for general use in deciduous forest, but as Hopkins (1957) pointed out, the break in the species-area curve depends on the ratio of the axes of the plot. Cain (1938) concluded that species-area curves can still be useful in determining plot size if one uses a plot size such that a 10% increase in plot size yields a 10% increase in species encountered. If greater accuracy is desired, he suggested choosing a plot size for which a 10% increase in area yields a 5% increase in species encountered.

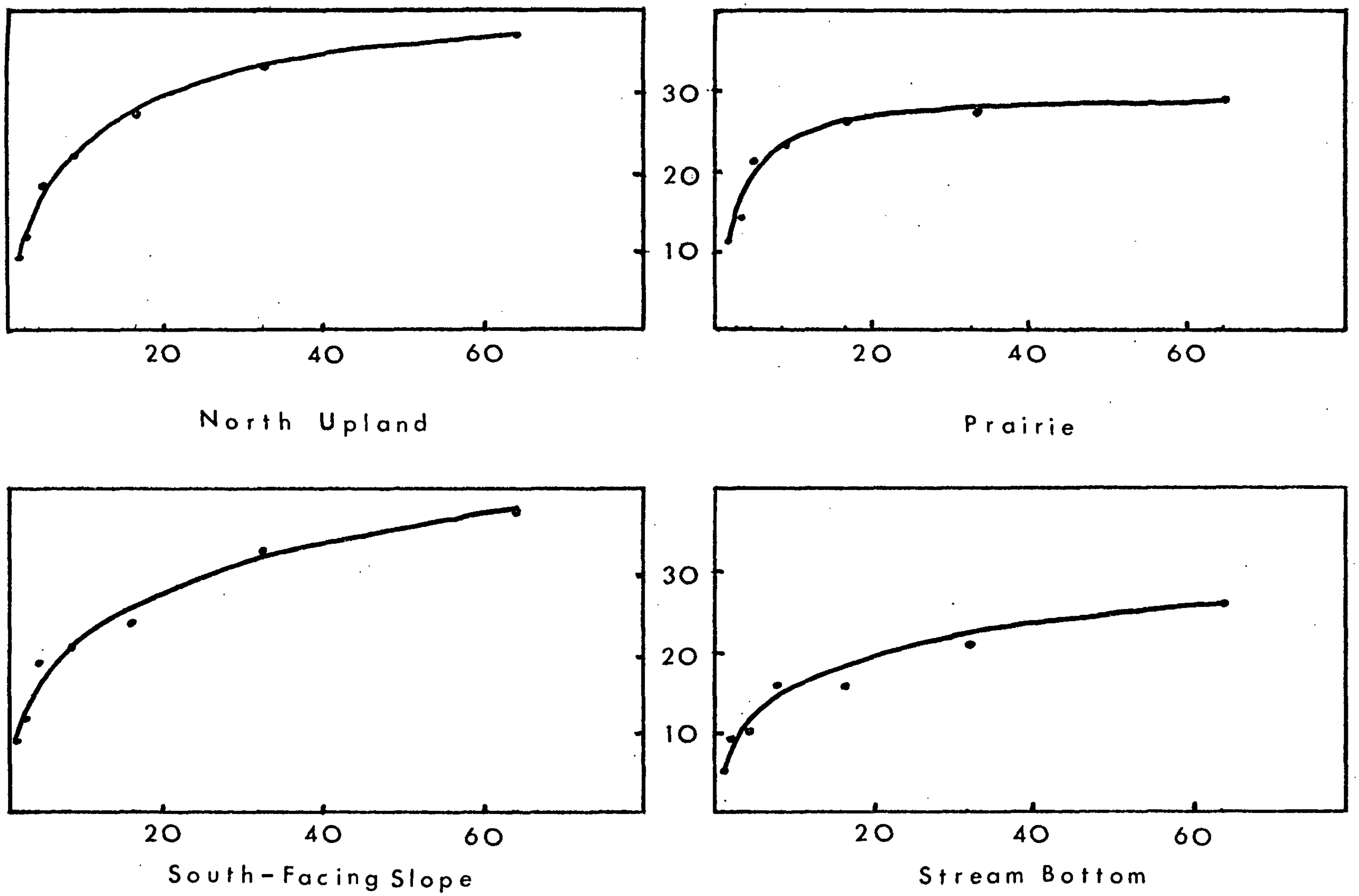

Figure 2. Species-area curves. The abscissa indicates the area in square meters and the ordinate indicates the number of species encountered

The species-area curves show that three of the four habitats may be represented fairly well with plot sizes of 16 or 32 square meters. The prairie may be equally well represented by plot sizes of 8 or 16 square meters. These may be regarded as minimum plot sizes. I wished to have the arborescent layer well represented in each plot, so I decided to choose a plot size larger than 32 square meters. Also, if a plot size of 32 square meters were used, an unmanageably large number of plots would have been required. For these reasons a plot size of 100 square meters was chosen. This conforms with Cain (1932) and is nearly the same as the 30x30-foot plots used by Brotherson in a prairie study (1969).

With the plot size determined, the number of plots was set at 200. Kershaw (1968) found this number entirely satisfactory for a similar study of forest vegetation. The transect was then laid out perpendicular to the contour intervals near the eastern edge of the preserve (Figure 3). Figure 4 is an aerial photograph of the eastern portion of the preserve, including the transect area. The 200 plots were arranged in a grid 80 meters wide and 250 meters long. This transect covered the desired area without being unmanageably large.

Field work in the transect was begun during the first week in June, 1970. The 10x10-meter plots were laid out using a compass and measuring tape. The plots were taken along the contours, i.e., roughly east-west beginning on the south side of the transect working toward the north when a tier of plots

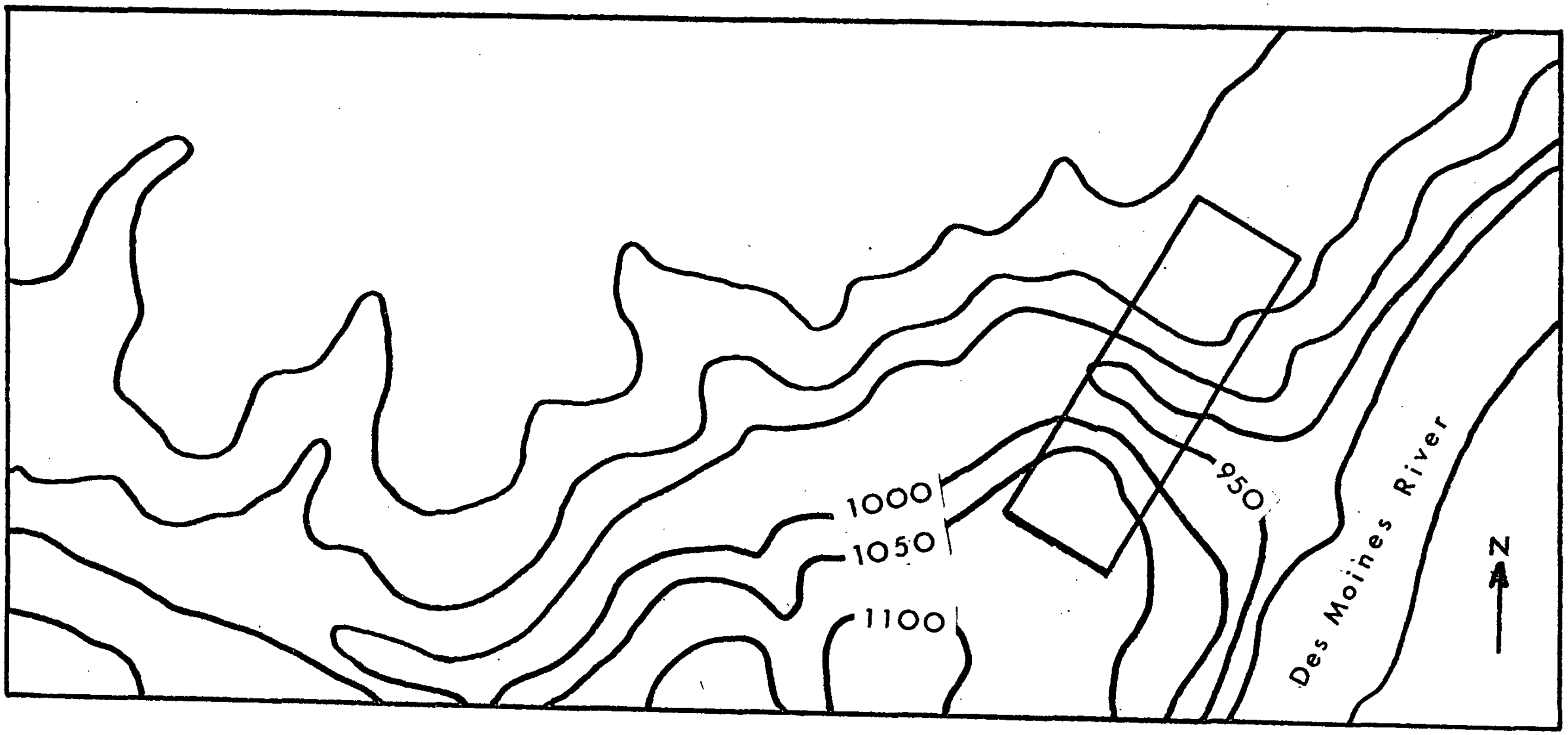

Figure 3. Topographic map of Woodman Hollow showing the location of the intensive study transect. Elevations are feet above sea level

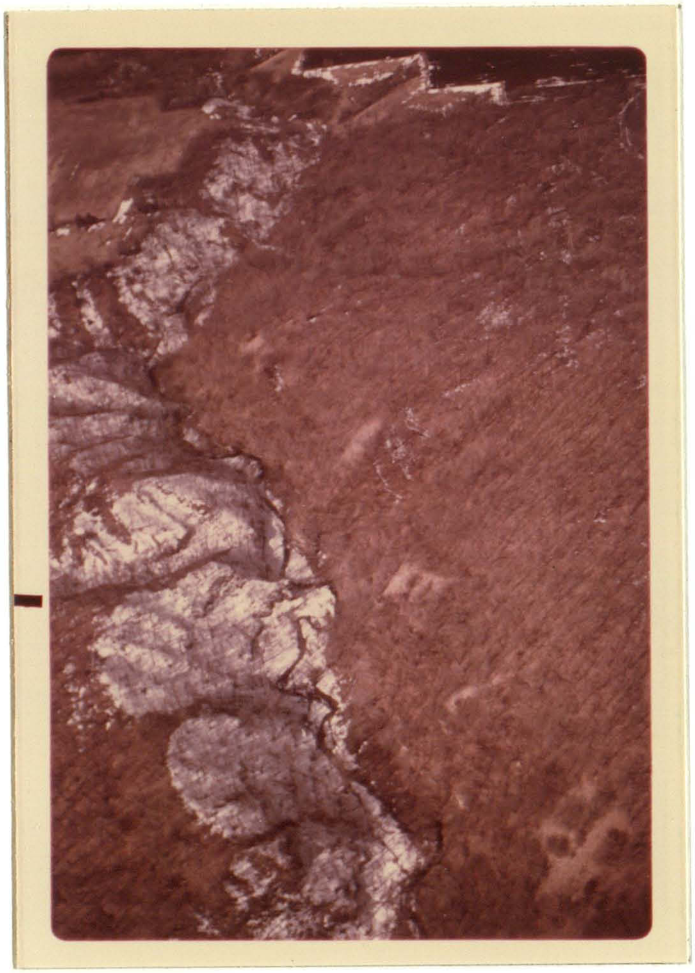

Figure 4. Aerial photograph of Woodman Hollow taken on April 3, 1970. Snow cover is retained on the north-facing slopes, and several prairie openings are visible on the upper south-facing slope

was completed. The corners of each plot were marked with wooden stakes. The stakes on the south side of the plot were removed after the data were taken, but the stakes on the north side remained to mark the corners of the next tier of plots. In this manner a 10x10-meter plot could be laid out in about 10 minutes even in difficult terrain. The plot size was not strictly uniform, but this probably had little effect on the results because of the wide variations in species composition among plots.

Within the large 10x10-meter plot, only presence data were taken. Any vascular plant with some or all foliage within the plot was counted as present. Thus, a single large tree near a corner post would be counted as present in at least four plots. This seems reasonable because the influence of the tree does extend over four plots in the form of shading and root competition. A disadvantage of the presence method is that a species is counted as present whether it is a first year seedling or a mature plant. Large arborescent species were divided into two classes with regard to presence: those over 10 cm in diameter at breast height and those under 10 cm in diameter. To further subdivide shrubby or arborescent species would make computations more difficult. Another disadvantage of presence data is the single tally for presence of a species regardless of number of individuals. This could be overcome if some estimate of numbers of individuals or percentage cover could be made. However, since I desired to classify the plots of the transect according to the ecological amplitude of the species present, no weighting of species according to numbers or percentage cover was considered.

In order to determine which species were present in a specific plot, I walked along the perimeter of the plot, then back and forth within the plot several times, collecting a leaf or twig of each species encountered. When a further search revealed no further species, the species collected were recorded in a notebook. Using this method, a 10x10-meter plot could be set up and the data taken in about a half hour. Some plots on extremely steep slopes required considerably longer while a few stream bottom plots were so species-poor that data could be taken in about 20 minutes.

Within Woodman Hollow are several prairie openings. These are small remnants of original tall grass prairie which occupied most of Iowa prior to settlement. Now forest appears to be closing in on these small remnants. In order to compare openings of different sizes and under different conditions, 20x50-cm plots were used to obtain data. The individual opening was measured, and a rectangular grid system was set up in such a manner that it included the greatest possible area of the opening. Then 100 plots were laid out within this rectangle at a regular spacing which depended on the size of the particular rectangle. For each plot the percentage cover and number of flowering stalks were recorded. The four largest openings were sampled, including one which had burned during

April, 1970. Figure 5 shows the approximate location of some of the prairie openings.

Four permanent 10x10-meter plots were placed in the forest of the north upland. Their locations are shown in Figure 5. Within each plot the arborescent species and their seedlings were measured. Small plants were divided into the following classes: 1) less than 25 cm tall; 2) more than 25 cm tall, but less than 2 meters tall; 3) more than 2 meters tall but less than 2.5 cm in diameter at breast height. The diameter of all plants over 2.5 cm was recorded. In order to determine what changes are occurring, the location of each specimen was recorded to the nearest meter. This was accomplished by laying out the plot, then setting off 100 one-meter square plots with string.

A subjective impression of successional trends within the transect developed as I took data. To make a more objective determination of the stability of communities within the transect, I decided to use the diversity index described by MacArthur and MacArthur (1961). Margalef (1958) stated that in advanced stages of plankton succession and during stable water conditions, there is always greater heterogeneity. Commenting further on stability and succession he stated that:

> In this sense, stability means basically, complexity. A natural forest, with its complete complement of species, is much more stable as a biological system than a forest regulated by man, forceably pre-climactic, subject to violent oscillation through the effects of disease. . .

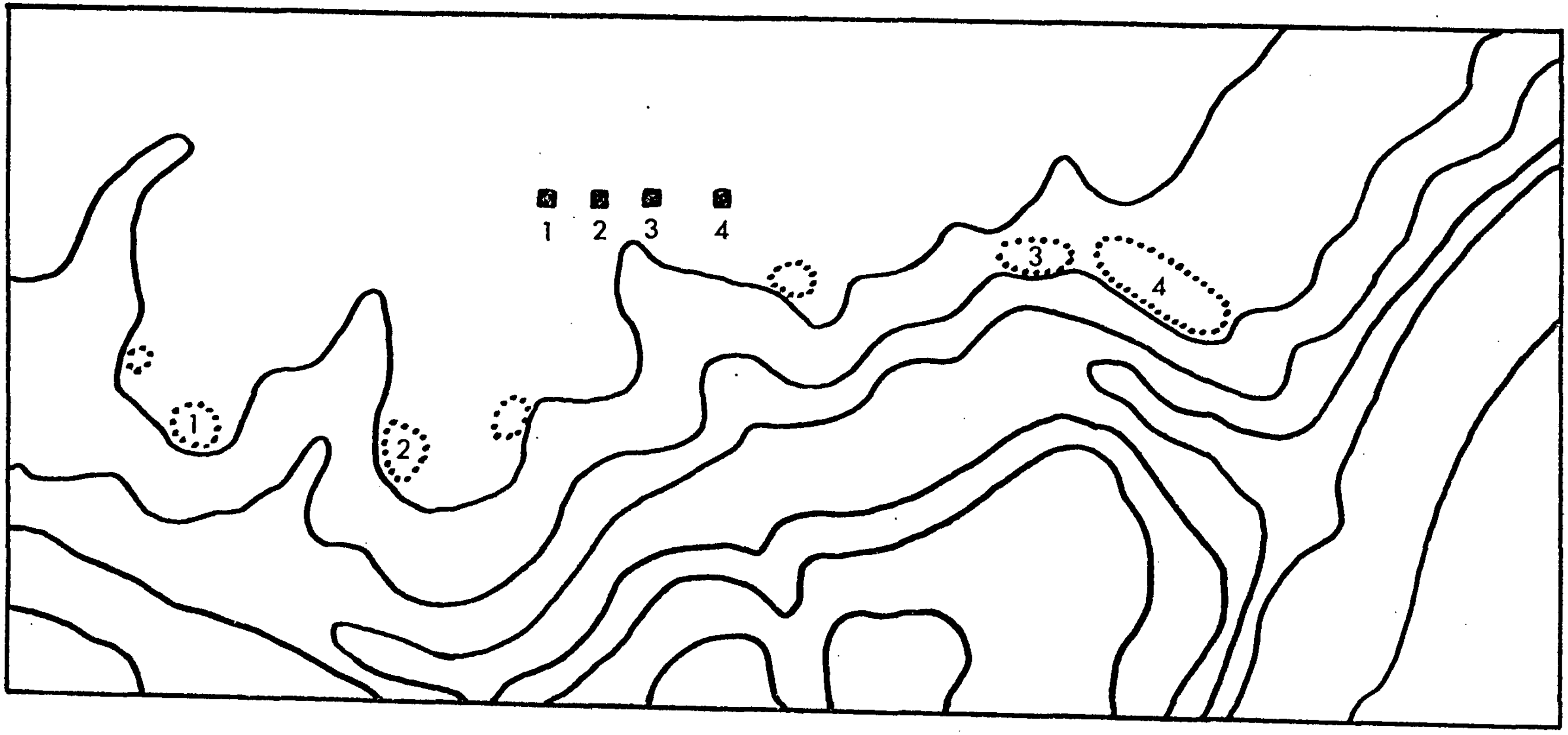

Figure 5. Map of Woodman Hollow showing the location of the four 10x10-meter permanent upland plots and some of the prominent prairie openings including the four which were studied

MacArthur and MacArthur (1961) stated that the sample size for different sites must be equal in size, but in a later paper MacArthur (1964) stated that sample sizes need not be identical. He used 20-25 bird pairs for a species diversity index. Margalef suggested a sample size of 50 individuals may be adequate for algae. This is much more reasonable than the thousands of individuals needed for a log normal curve estimate of diversity as discussed by Preston (1948) and Shobe (1967). I decided to use a sample size of 200 individuals. The samples were taken by laying out a transect using a tape measure. All species whose foliage or stems extended over the transect were counted until 200 individuals were counted. Samples were taken within subjectively determined communities. These were: 1) north upland; 2) upper south-facing slope; 3) stream bottom; 4) lower and middle north-facing slope; and 5) south upland.

Statistical Methods

The data of the transect were collected for two specific methods of analysis. The first was the ordination of plots using species as attributes, and the second was the binary system of community classification described by Williams and Lambert (1959, 1960, 1961).

The ordination of plots as individuals using species as attributes is discussed by Orloci (1966). The brief summary of the method which follows was taken from an abstract of a seminar given by Dr. David Jowett in 1970.

> Orloci has proposed a method for ordination which depends on calculating the Euclidian distance between points in factor space. If we have a 2-dimensional space, the distance between two points (a,b) and (x,y) can be calculated from Pythagoras as
>
> $$D = \sqrt{(x-a)^2 + (y-b)^2}$$
>
> This extends immediately to a space in many dimensions. For Orloci's method of ordination, the distance between all stands is computed, and then the first or principal axis is determined as the line joining the two points (or vegetational sites) which are furthest apart in space defined by their species composition. Each other point is then projected onto this line, and thus takes up a position on this axis. The second axis is obtained by joining the two points which deviated furthest from the first. Subsequently we can obtain a third axis, but it is seldom advisable to go beyond this. These axes are, of course oblique, that is, they do not cross at right angles, although when we represent the results graphically, we show them as if they were orthogonal. (Jowett, 1970)

The technique involves the use of an electronic computer. The final result is a graphical representation of the stands based on their compositional similarity.

The other purpose of gathering the transect data was to classify the area into communities objectively using the binary classification system developed by Williams and Lambert (1959, 1960, 1961). Briefly, this method involves calculating chi-square values for all species pairs encountered in the transect. Then the individual chi-square values for each species are summed. The species with the highest summed chi-square value is used to divide the plots of the transect into two groups: one group which does possess the species with the highest value, and one group which does not possess that species. The same process is carried out within the groups which results in a number of small groups of plots which should correspond to the communities which an ecologist would determine subjectively. Subdivision of the transect can be carried out until some level of significance is reached for the summed chi-square values, but meaningful communities should emerge long before the summed chi-square values drop below significance. Unfortunately, this method was found to be unsuitable for analyzing data with such a large number of species involved.

The formula used to determine the diversity index as described by MacArthur and MacArthur (1961) is: $-\sum pi \log_e pi$, where pi is the proportion of all plant individuals which belong to the i-th species. This is a far better method of determining diversity than simply expressing the number of species present. It takes into account the proportion of each species. Thus, a community with 99 individuals of one species and one individual of another species has a diversity value nearly zero, while another community with two species represented by 50 individuals each has a considerably higher diversity value.

RESULTS AND DISCUSSION

Transect Study

The major purpose of the transect study area in the western portion of Woodman Hollow was to classify the vegetation of a small portion of the preserve into communities. When the study was completed, 213 species had been identified in the large 10x10-meter plots. Despite the large number of species found, it was possible to classify subjectively vegetation along the transect into communities. Some species seemed very characteristic of a certain habitat. When the study was completed, an attempt was made to classify the vegetation of the transect based only on field experience. Figure 6 shows the transect with elevations. The resulting classification is shown in Figure 7. Compare with Figures 8 and 9 based on less subjective approaches.

The first community determined by this purely subjective method was the south upland community. Some of the species which gave it character were *Populus grandidentata*, *Quercus alba*, *Q. rubra* and *Galium concinnum*. The ground was mostly bare or covered with dead leaves rather than with living vegetation.

Immediately upon leaving the flat upland traveling north, the upper north-facing slope community was encountered. The ground layer vegetation changed as abruptly as the topography, becoming dense and completely covering the ground. The

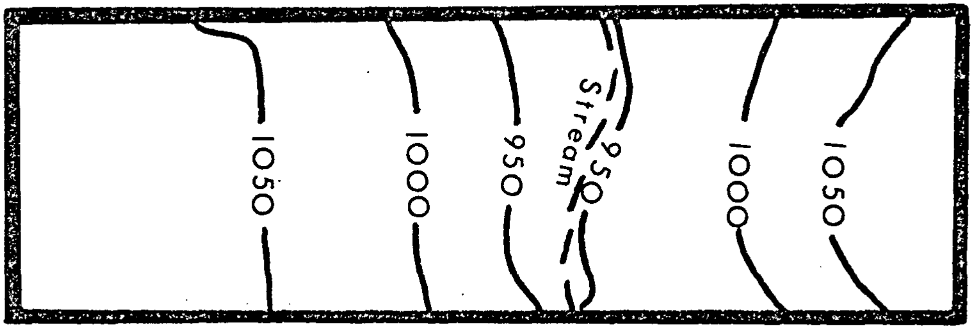

Figure 6. Intensive study transect with elevations in feet

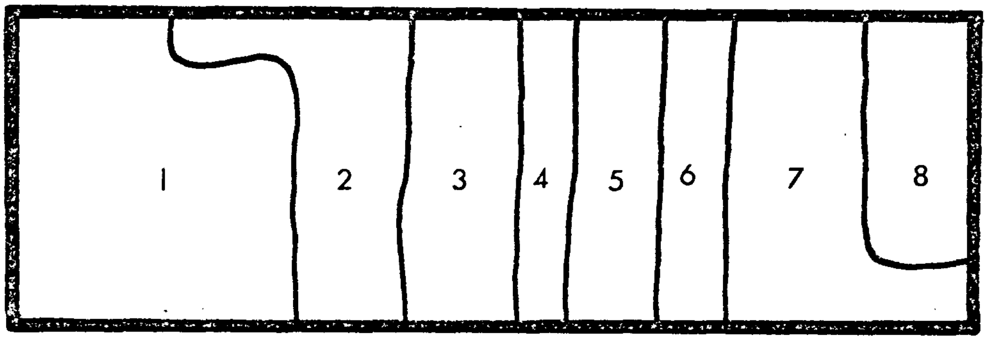

Figure 7. Classification of the intensive study transect based on subjective field experience. The communities were delimited as follows: 1 is the north upland community; 2 is the prairie opening community; 3 is the upper south-facing slope community; 4 is the lower south-facing slope community; 5 is the stream bottom community; 6 is the lower north slope community; 7 is the upper north-facing slope community; 8 is the south upland community

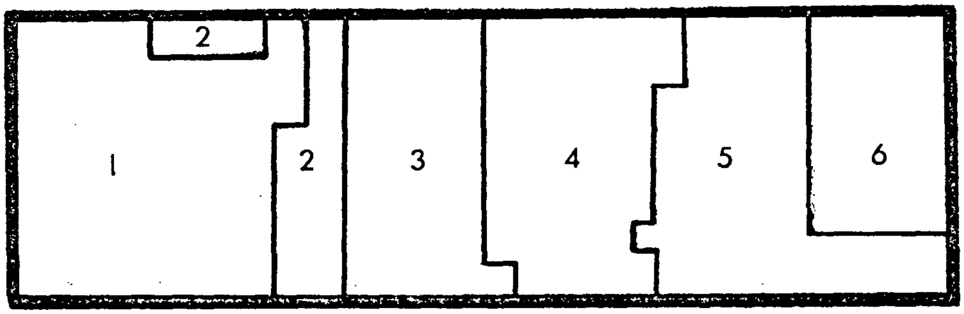

Figure 8. Classification of the intensive study transect based on species distribution patterns. The communities were delimited as follows: 1 is the north upland community; 2 is the prairie opening community; 3 is the south-facing slope community; 4 is the stream bottom community; 5 is the north-facing slope community; 6 is the south upland community

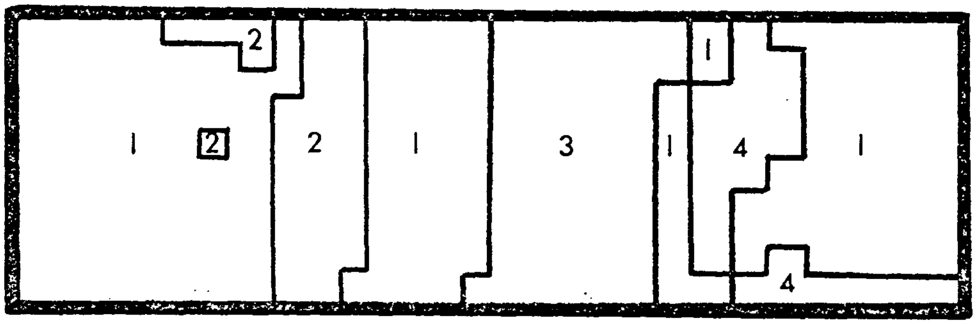

Figure 9. Classification of the intensive study transect based on the Orloci ordination of the plots (Orloci, 1966). The communities were delimited as follows: 1 represents the forested plots which were not distinguishable from one another, some being upland plots and some being from both the north and south-facing slopes; 2 represents the prairie opening community; 3 represents the stream bottom community; 4 represents the north-facing slope community

arborescent layer changed more slowly. In the ground layer, *Mitella diphylla* became the dominant herb, but it was accompanied by many others including *Adiantum pedatum*, *Arisaema atrorubens*, *Uvularia grandiflora*, *Asarum canadense*, *Thalictrum dioicum*, and *Panax quinquefolius*. The arborescent layer slowly lost *Quercus alba* and *Q. rubra* while *Tilia americana*, *Acer nigrum*, and *Carya cordiformis* gradually increased in importance.

Near the base of the north-facing slope, another rather distinct community seemed to be present. The arborescent layer included *Ulmus americana* as well as the species of the previous community. The ground layer, however, possessed several species not found elsewhere in the preserve. These were *Actaea rubra*, *Caulophyllum thalictroides*, and *Osmunda claytoniana*. None of these were represented by a large number of plants, but the few present lent a distinctive appearance to the community.

There was a rather abrupt topographic change from the sloping land to the flat alluvium. There was also an abrupt change in the appearance of the vegetation. *Laportea canadensis* became the dominant herb, and *Ulmus americana* was the dominant tree of the stream bottom community. Small individuals of *Fraxinus americana* were also present. Other abundant and conspicuous herbs included *Pteretis pensylvanica*, the Ostrich Fern, and *Impatiens pallida*. Many species conspicuous on the sloping land were also present in the stream bottom community, but they were inconspicuous and not very abundant.

The topographic change was again abrupt upon entering the lower south-facing slope. Again the vegetation changed abruptly at ground level but more gradually in the arborescent layer as one entered the lower south-facing slope community. On the ground some herbs characteristic of the north-facing slope again appeared including *Thalictrum dioicum* and *Arisaema atrorubens*. Notably missing were *Hepatica acutiloba* and *Mitella diphylla*. In the arborescent layer *Acer nigrum* and *Tilia americana* replaced *Ulmus americana*. The general aspect of the vegetation was one of less dense growth than that present on the north-facing slope. Eroding soil and bare rocks were evident.

Somewhat farther up the south-facing slope, *Acer nigrum* and *Tilia americana* were replaced by *Quercus alba* and *Carya ovata*. On the ground the species composition did not change much but the plants became less abundant. This was called the upper south-facing slope community.

Upon entering the shoulder position of the south-facing slope, the most abrupt change in vegetation was encountered. Within a distance of one meter one could step from the shade of Oak trees with *Thalictrum dioicum* beneath to full sunlight with *Andropogon gerardii*. This was the prairie opening community, the most distinct of them all. It was dominated by *Andropogon gerardii*, *A. scoparius*, *Amorpha canescens*, and *Ceanothus ovatus*. Seedlings of several tree species were also present among the prairie plants, but these were not conspicuous.

North of the prairie opening, a small ravine was crossed, then the relatively flat north upland was reached. The north upland community of the remainder of the transect was somewhat similar to the south upland community except that there were fewer species present. *Quercus alba* and *Carya ovata* were abundant but there were no specimens of *Populus grandidentata* in the transect. On the ground, *Galium concinnum* and *Carex pensylvanica* became abundant. Although quite similar to the south upland, I considered the north upland distinct enough to be a separate community.

Thus, the purely subjective classification based only on field observations revealed a total of eight relatively distinct communities. Habitats too small to be meaningful on a scale comparable to the other communities in the transect nevertheless should be mentioned briefly. The stream gravel supported a micro-community of *Pilea pumila* and *Glyceria striata*. Large sandstone rocks on the north-facing slope supported lichens and mosses as well as *Polypodium virginianum* and *Camptosorus rhyzophyllus*. Chinks in moist sandstone of the north-facing slope supported a few plants of a delicate fern, *Cryptogramma stelleri*. A densely shaded portion of the north-facing slope possessed *Maianthemum canadense* and *Diervilla lonicera*.

After delimiting the communities of the transect on a purely subjective assessment of species composition and habitat, species distribution maps of the transect were constructed. These maps represented the presence and absence of the species which occurred in at least 5% of the large 10x10-meter plots. Maps of 127 species were made (Figures 10-144). Euonymus atropurpureus and Hystrix patula occurred in more than 5% of the plots but were not mapped because of identification problems. Acer nigrum, Carya cordiformis, C. ovata, Celtis occidentalis, Fraxinus americana, F. pennsylvanica, Quercus alba, Q. rubra, and Tilia americana were mapped in two classes: those greater than 10 cm in diameter and those less than 10 cm in diameter. Most specimens were either mature trees 20 cm or more in diameter or were small seedlings less than 25 cm tall; therefore, the two classes represent fairly distinct groups of mature trees on the one hand and seedlings on the other.

The first thing which became apparent from an examination of the maps is that the species behave as individuals. No two species have identical distributions although groups of species tend to overlap over most of their distribution. It is these overlapping distributions which give one the impression of a distinctive community.

There were three general types of species distribution. One group of species occurred almost throughout the transect. This group included Carex pensylvanica, Ostrya virginiana, Parthenocissus quinquefolia, Polygonatum canaliculatum, and

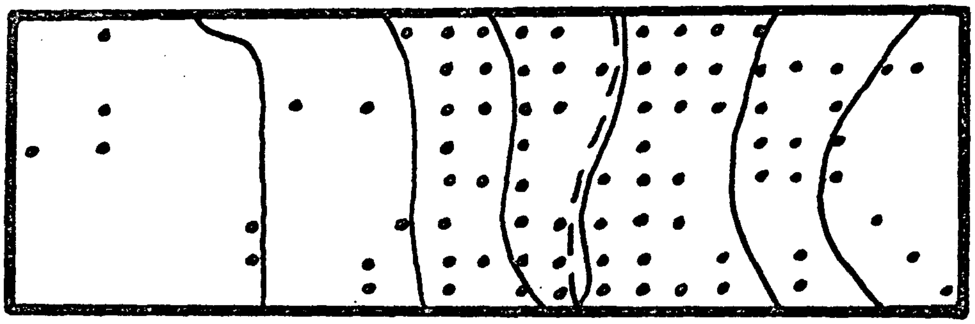

Figure 10. Distributional pattern of Acer nigrum specimens less than 10 cm in diameter in the intensive study transect

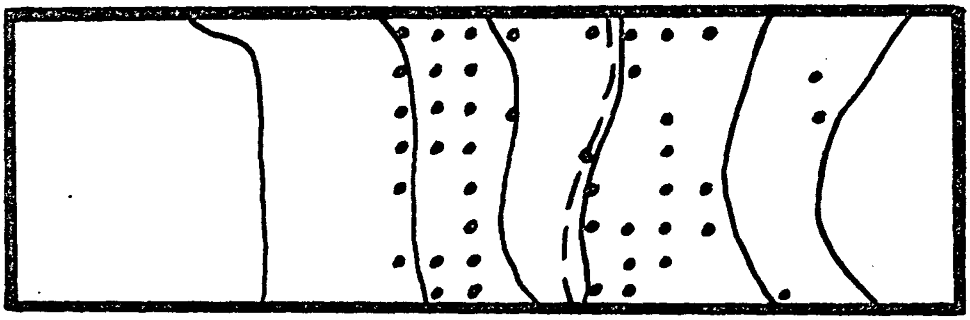

Figure 11. Distributional pattern of Acer nigrum specimens greater than 10 cm in diameter in the intensive study transect

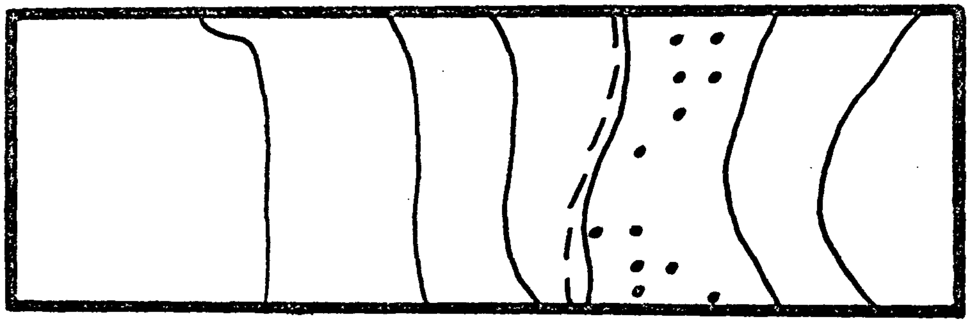

Figure 12. Distributional pattern of Actaea rubra in the intensive study transect

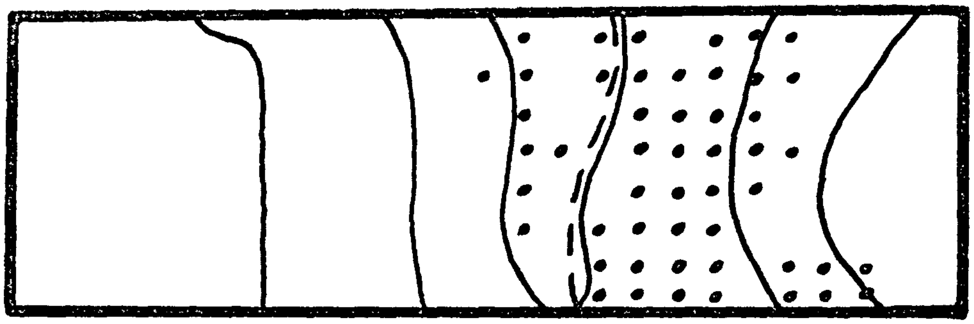

Figure 13. Distributional pattern of <u>Adiantum</u> <u>pedatum</u> in the intensive study transect

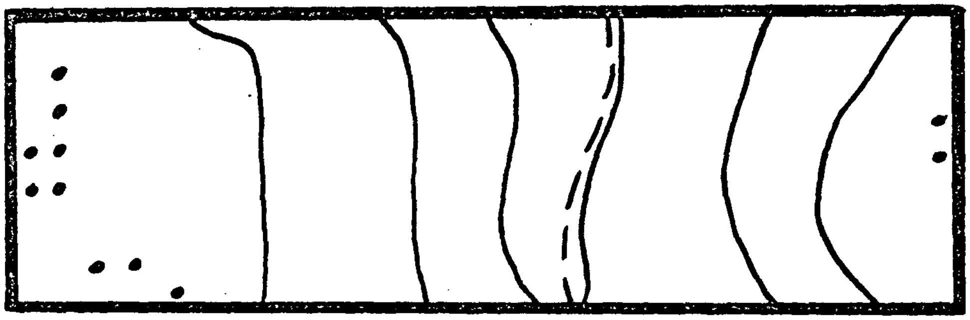

Figure 14. Distributional pattern of <u>Agrimonia</u> <u>gryposepala</u> in the intensive study transect

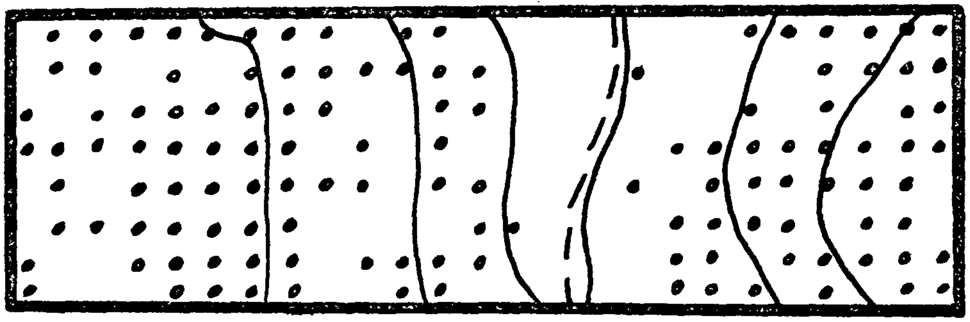

Figure 15. Distributional pattern of <u>Amelanchier</u> <u>arborea</u> in the intensive study transect

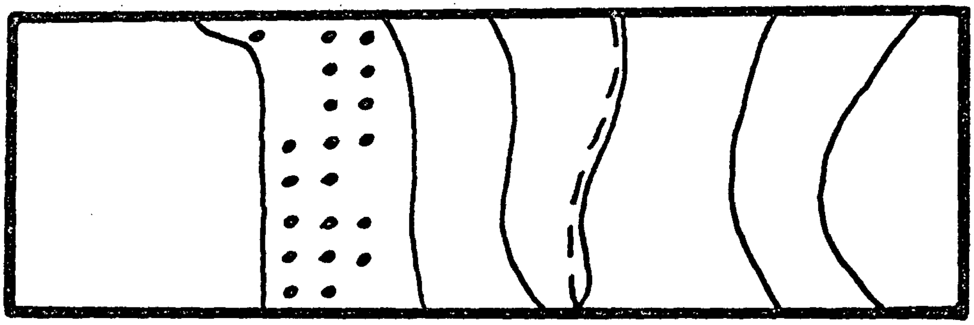

Figure 16. Distributional pattern of <u>Amorpha</u> <u>canescens</u> in the intensive study transect

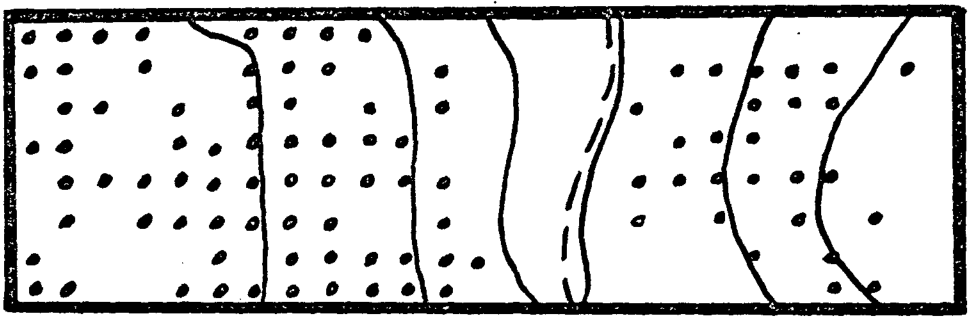

Figure 17. Distributional pattern of <u>Amphicarpa</u> <u>bracteata</u> in the intensive study transect

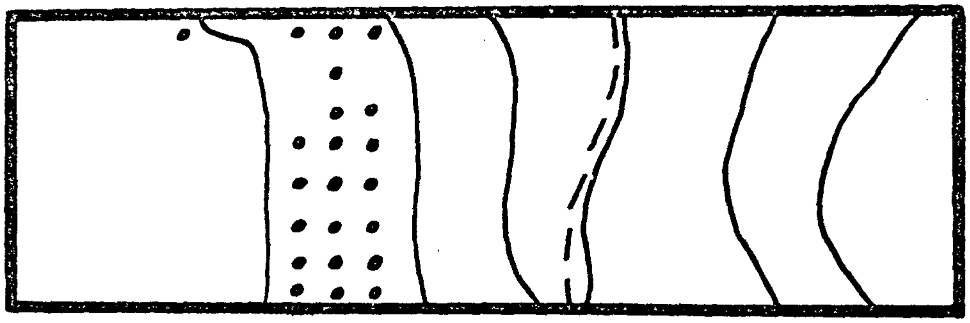

Figure 18. Distributional pattern of <u>Andropogon</u> <u>gerardii</u> in the intensive study transect

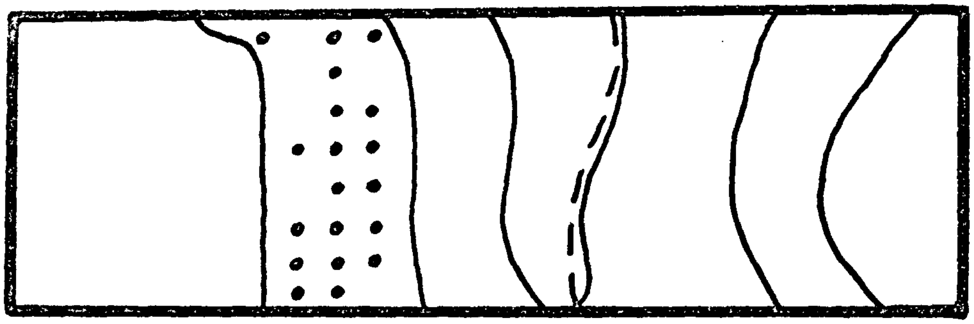

Figure 19. Distributional pattern of <u>Andropogon</u> <u>scoparius</u> in the intensive study transect

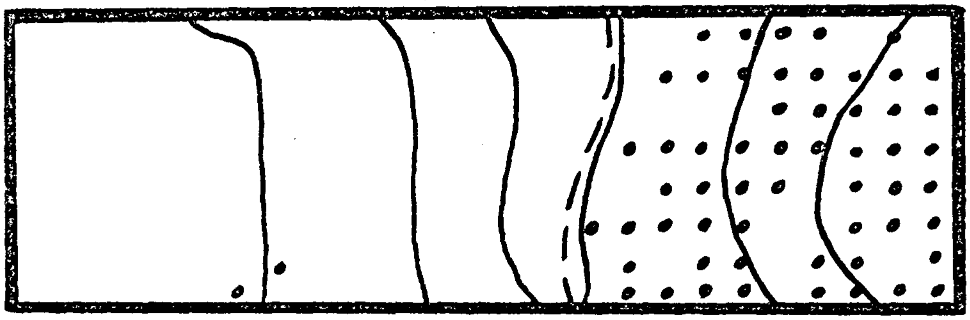

Figure 20. Distributional pattern of <u>Anemone</u> <u>quinquefolia</u> in the intensive study transect

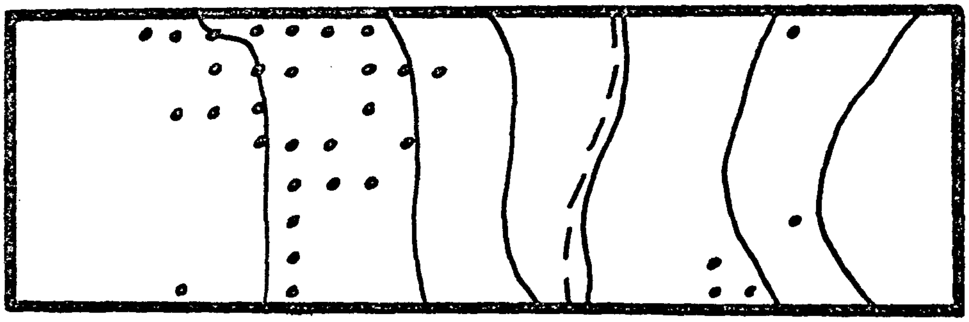

Figure 21. Distributional pattern of <u>Antennaria</u> <u>plantaginifolia</u> in the intensive study transect

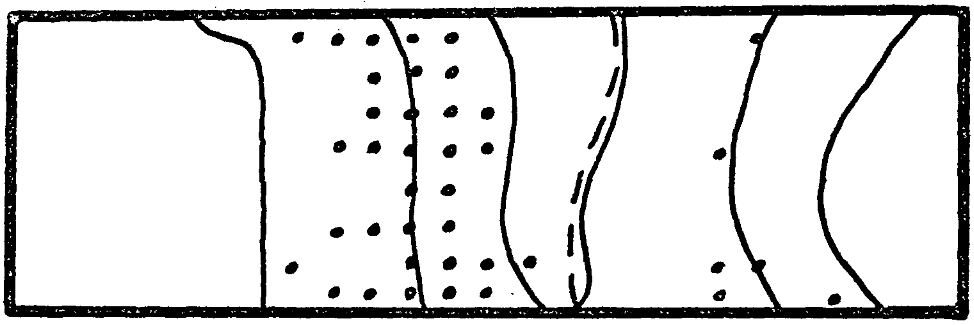

Figure 22. Distributional pattern of Aquilegia canadensis in the intensive study transect

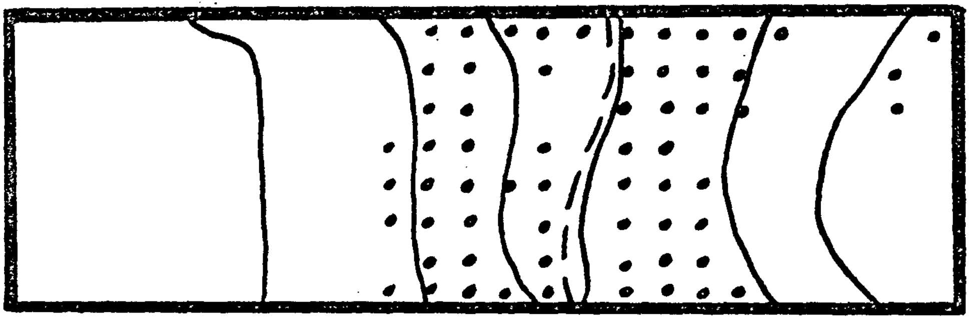

Figure 23. Distributional pattern of Arisaema atrorubens in the intensive study transect

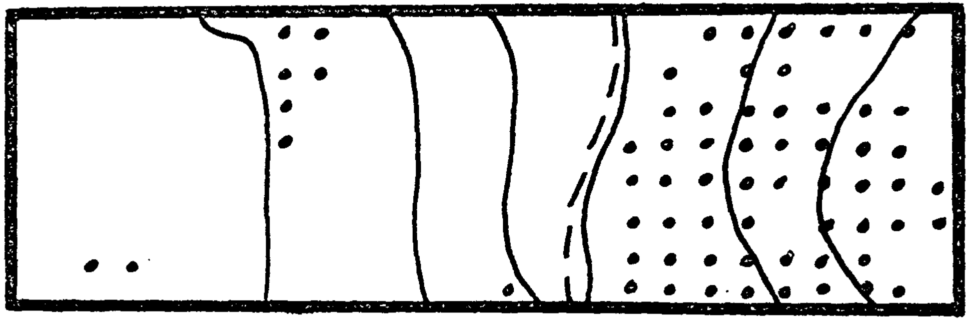

Figure 24. Distributional pattern of Aralia nudicaulis in the intensive study transect

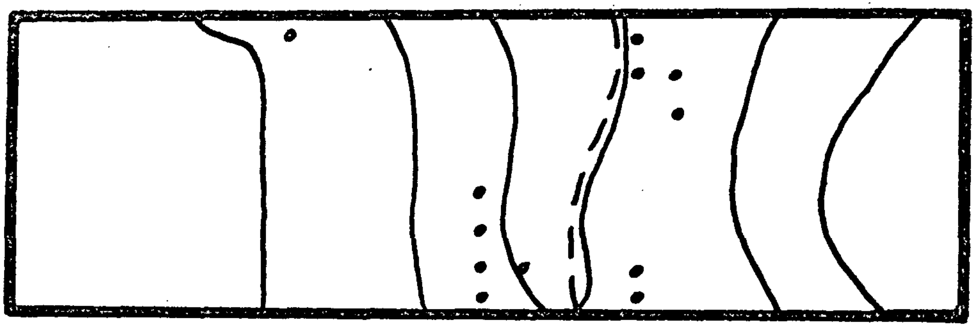

Figure 25. Distributional pattern of <u>Aralia</u> <u>racemosa</u> in the intensive study transect

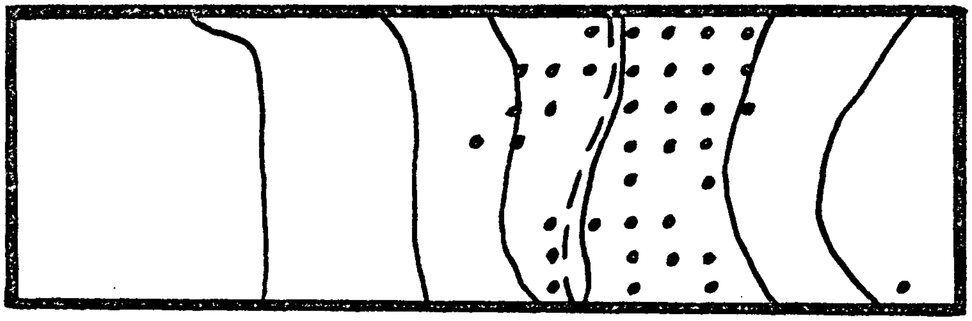

Figure 26. Distributional pattern of <u>Asarum</u> <u>canadense</u> in the intensive study transect

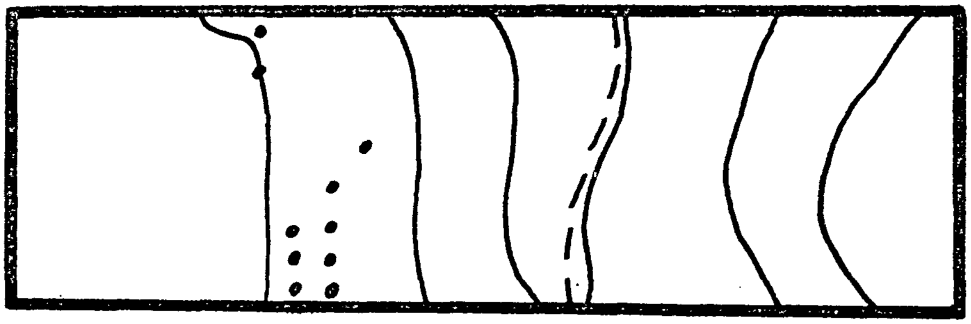

Figure 27. Distributional pattern of <u>Asclepias</u> <u>verticillata</u> in the intensive study transect

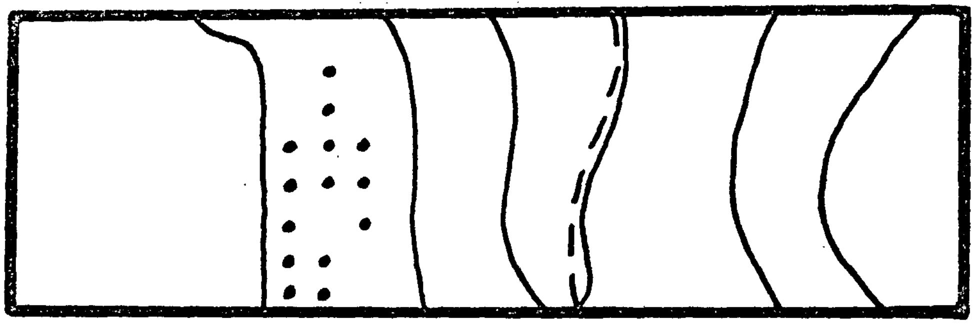

Figure 28. Distributional pattern of <u>Aster</u> <u>azureus</u> in the intensive study transect

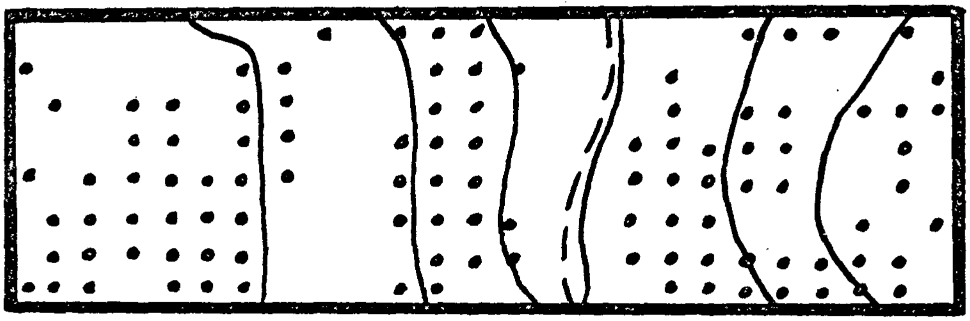

Figure 29. Distributional pattern of <u>Aster</u> <u>cordifolius</u> in the intensive study transect

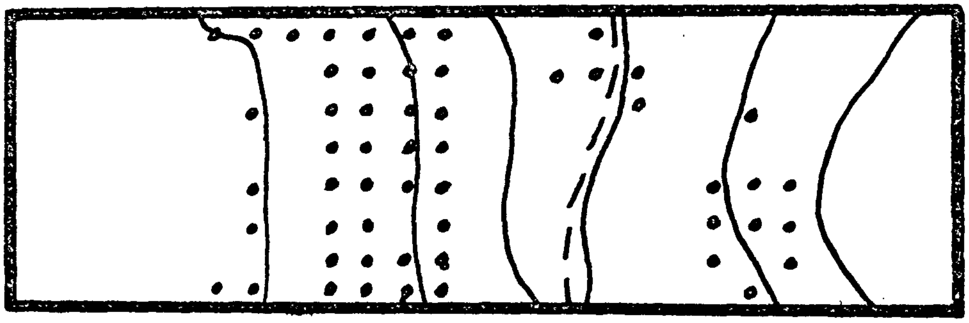

Figure 30. Distributional pattern of <u>Aster</u> <u>laevis</u> in the intensive study transect

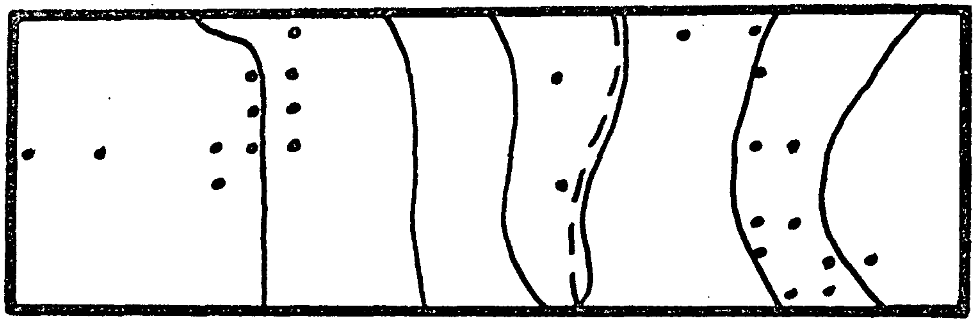

Figure 31. Distributional pattern of Aster parviceps in the intensive study transect

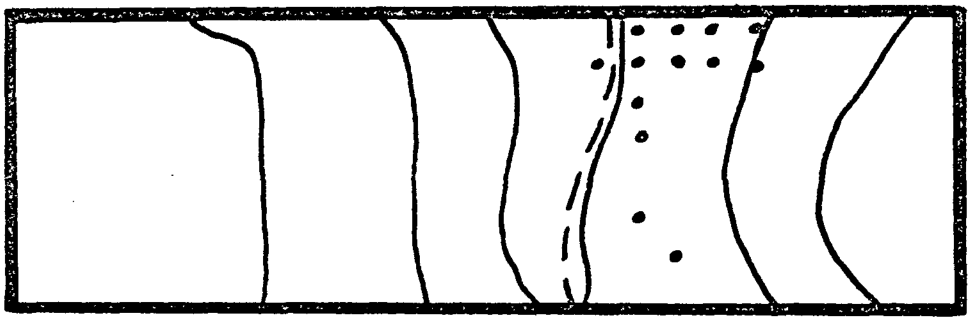

Figure 32. Distributional pattern of Athyrium felix-femina in the intensive study transect

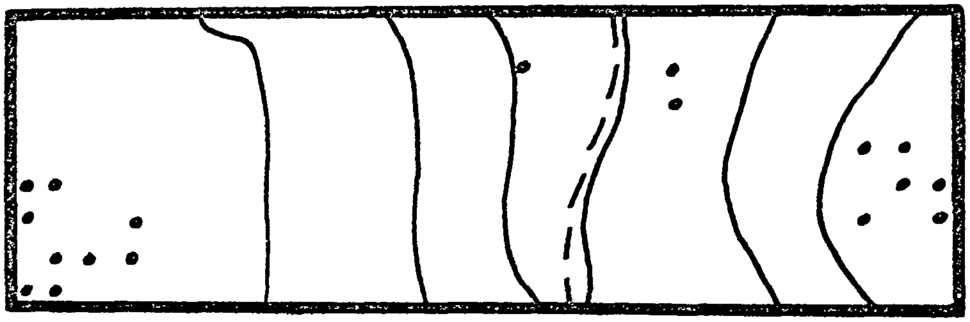

Figure 33. Distributional pattern of Botrychium virginianum in the intensive study transect

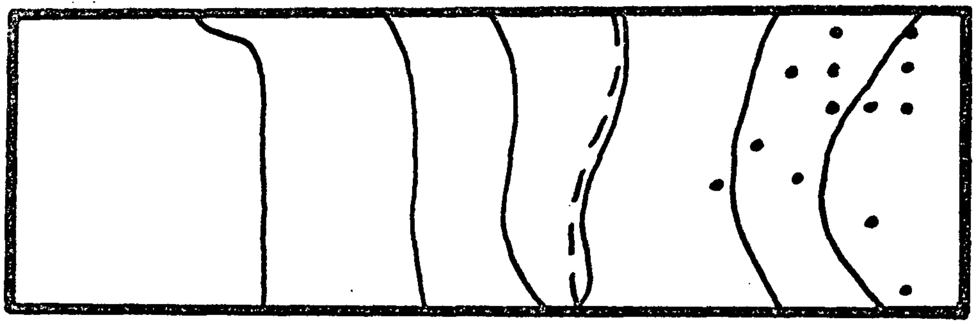

Figure 34. Distributional pattern of Bromus purgans in the intensive study transect

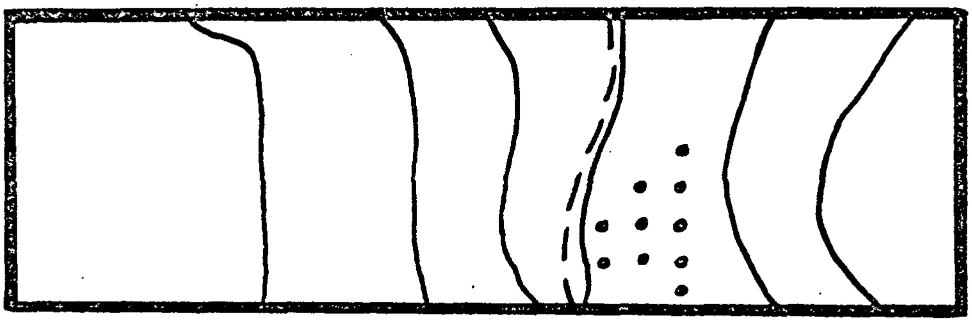

Figure 35. Distributional pattern of Camptosorus rhyzophyllus in the intensive study transect

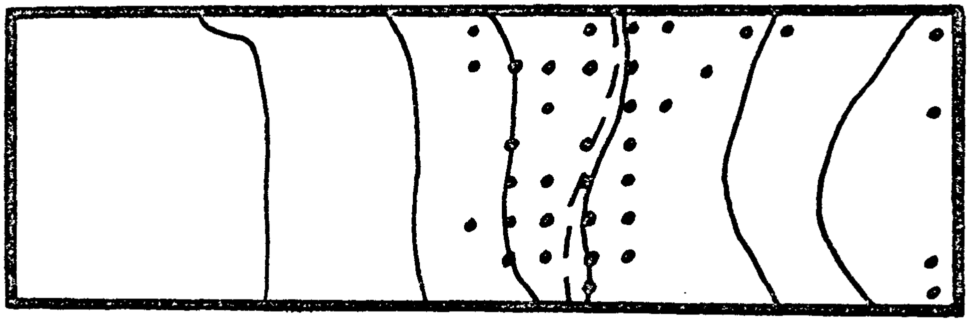

Figure 36. Distributional pattern of Carex albursina in the intensive study transect

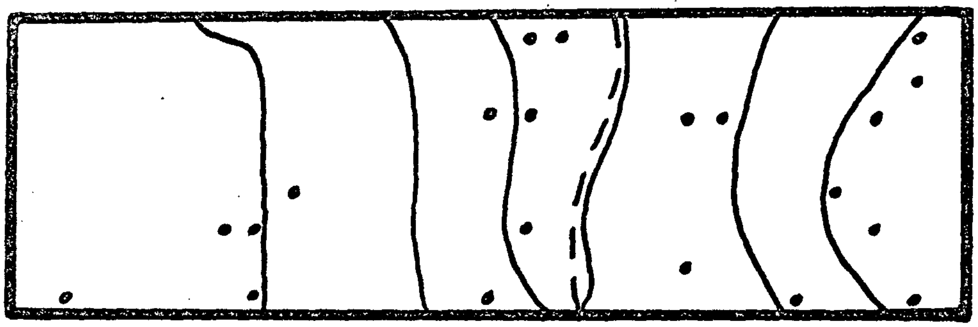

Figure 37. Distributional pattern of <u>Carex</u> <u>convoluta</u> in the intensive study transect

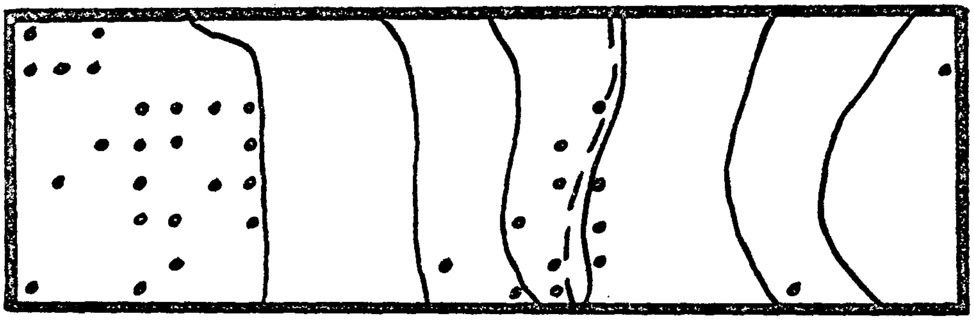

Figure 38. Distributional pattern of <u>Carex</u> <u>jamesii</u> in the intensive study transect

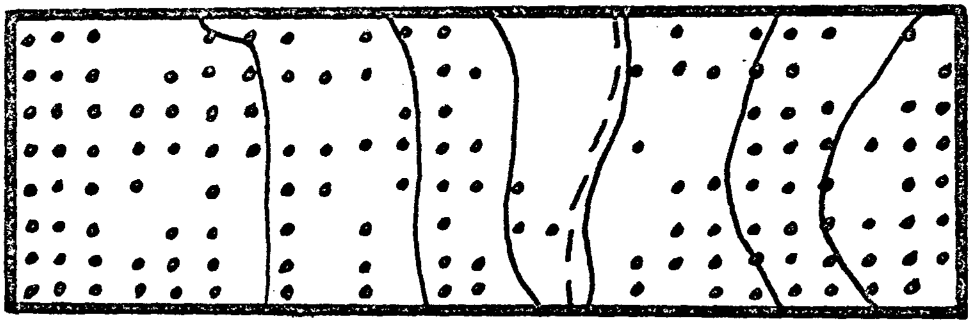

Figure 39. Distributional pattern of <u>Carex</u> <u>pensylvanica</u> in the intensive study transect

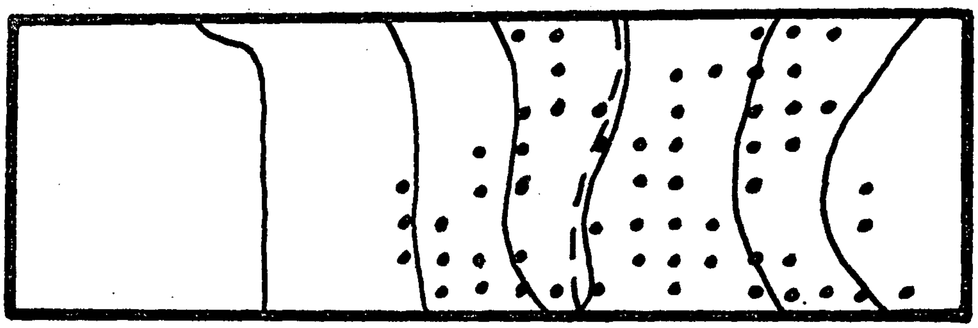

Figure 40. Distributional pattern of Carpinus caroliniana in the intensive study transect

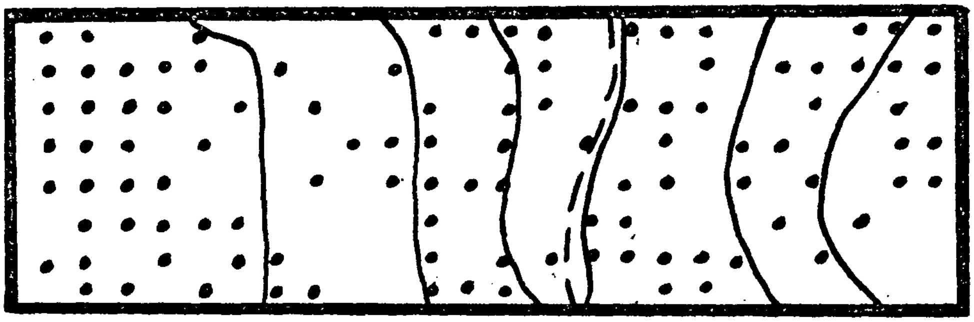

Figure 41. Distributional pattern of Carya cordiformis specimens less than 10 cm in diameter in the intensive study transect

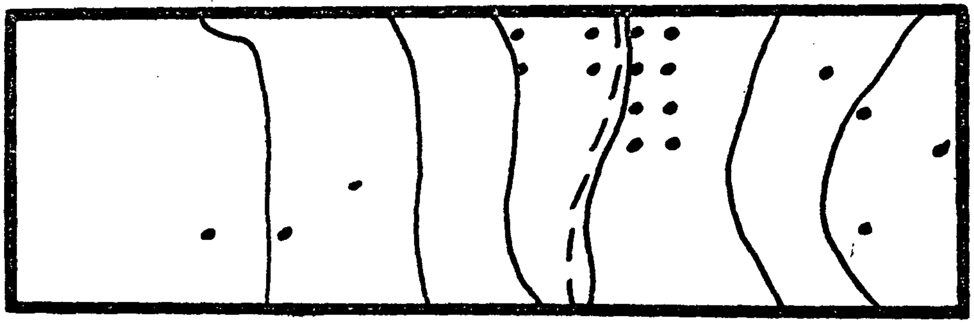

Figure 42. Distributional pattern of Carya cordiformis specimens greater than 10 cm in diameter in the intensive study transect

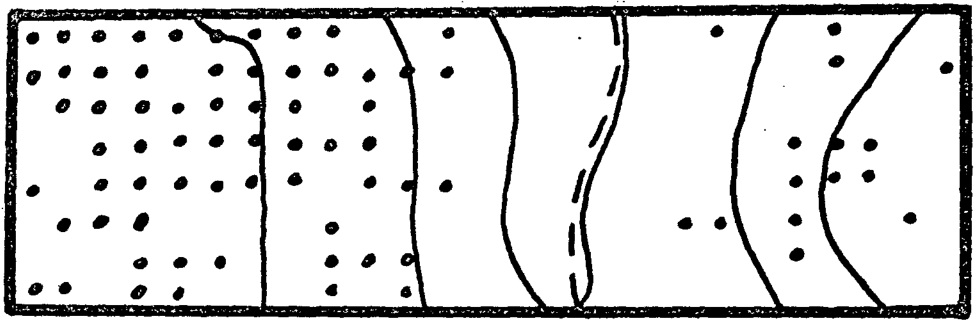

Figure 43. Distributional pattern of <u>Carya ovata</u> specimens less than 10 cm in diameter in the intensive study transect

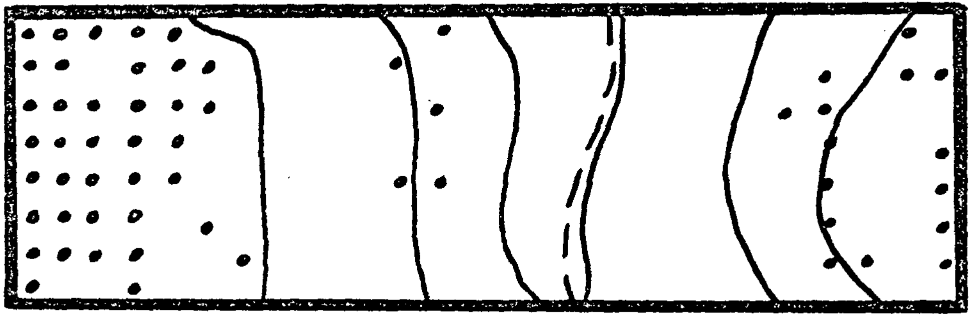

Figure 44. Distributional pattern of <u>Carya ovata</u> specimens greater than 10 cm in diameter in the intensive study transect

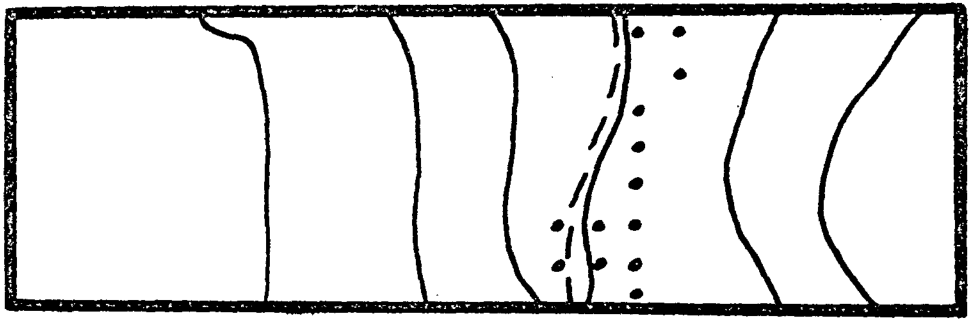

Figure 45. Distributional pattern of <u>Caulophyllum thalictroides</u> in the intensive study transect

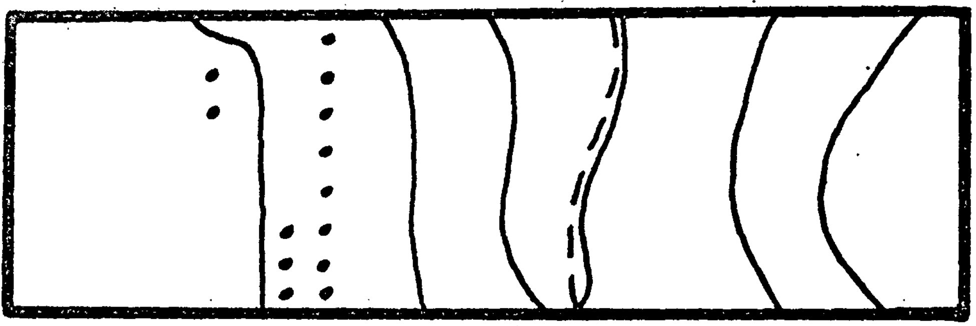

Figure 46. Distributional pattern of <u>Ceanothus</u> <u>ovatus</u> in the intensive study transect

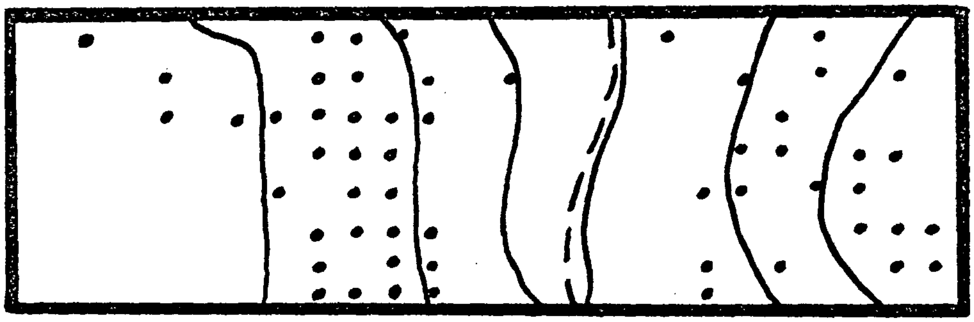

Figure 47. Distributional pattern of <u>Celastrus</u> <u>scandens</u> in the intensive study transect

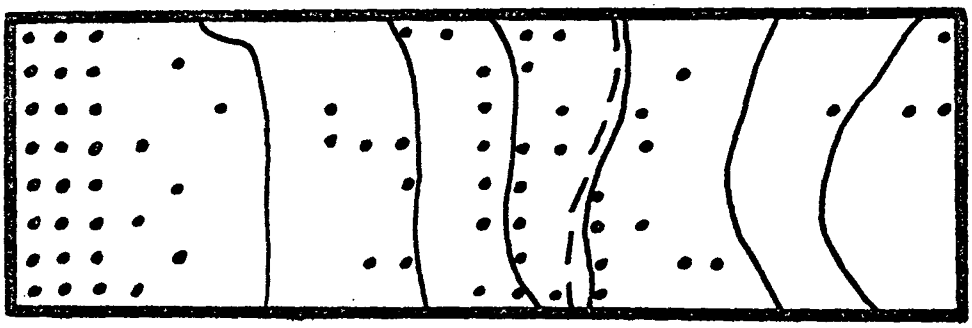

Figure 48. Distributional pattern of <u>Celtis</u> <u>occidentalis</u> specimens less than 10 cm in diameter in the intensive study transect

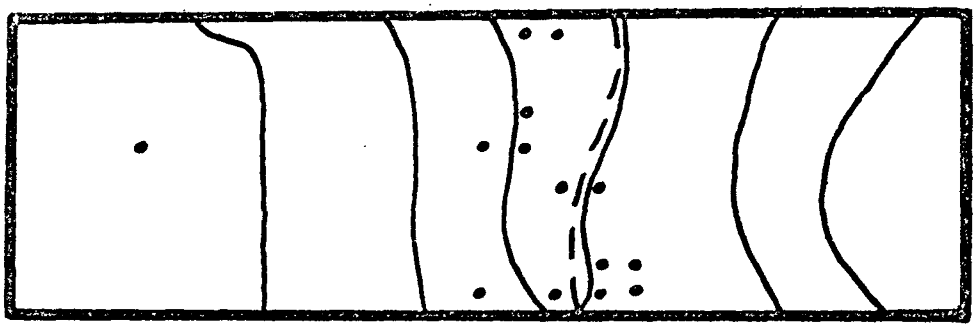

Figure 49. Distributional pattern of <u>Celtis occidentalis</u> specimens greater than 10 cm in diameter in the intensive study transect

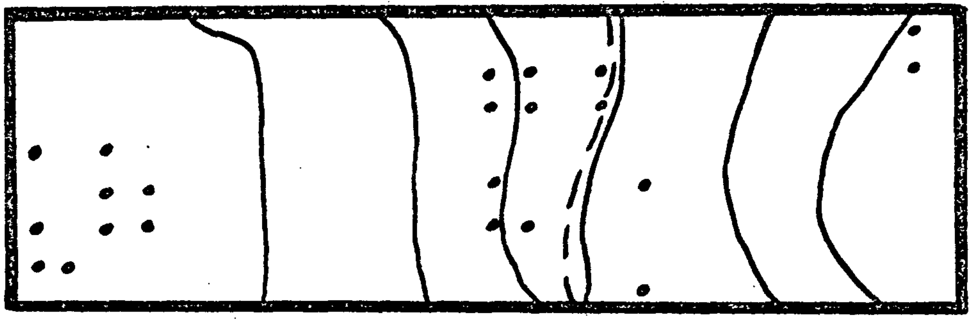

Figure 50. Distributional pattern of <u>Circaea quadrisulcata</u> in the intensive study transect

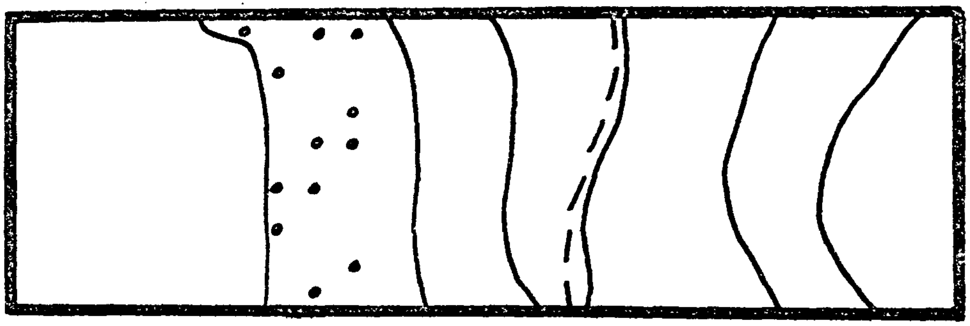

Figure 51. Distributional pattern of <u>Coreopsis palmata</u> in the intensive study transect

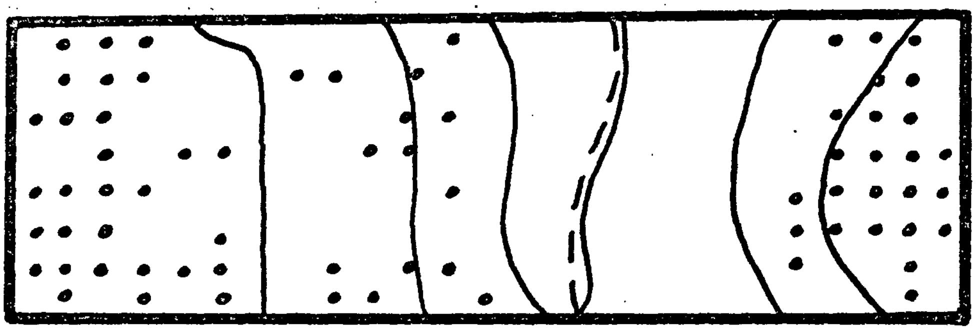

Figure 52. Distributional pattern of Cornus drummondi in the intensive study transect

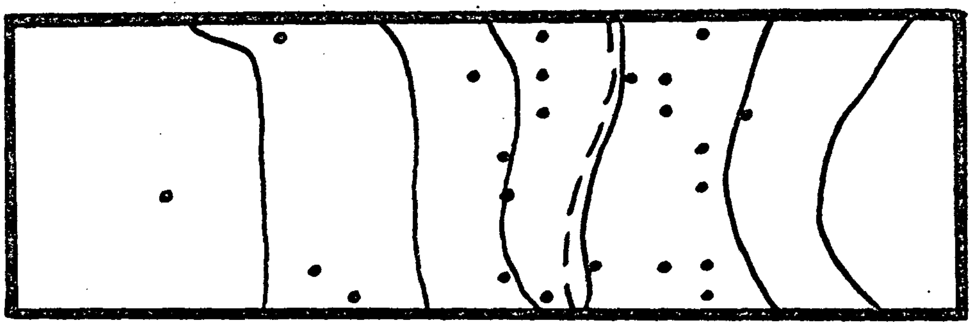

Figure 53. Distributional pattern of Cornus rugosa in the intensive study transect

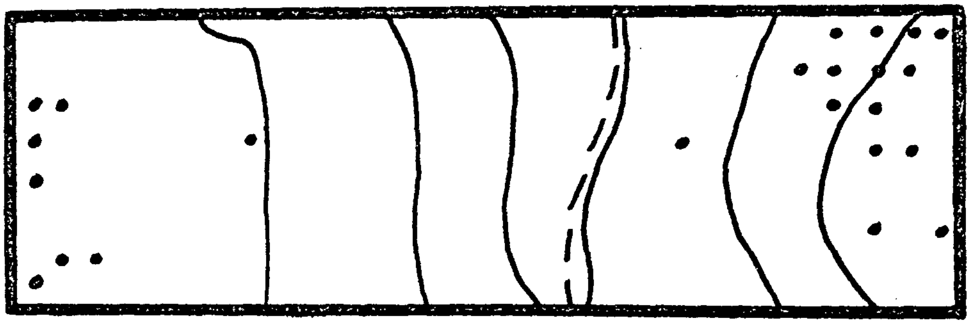

Figure 54. Distributional pattern of Corylus americana in the intensive study transect

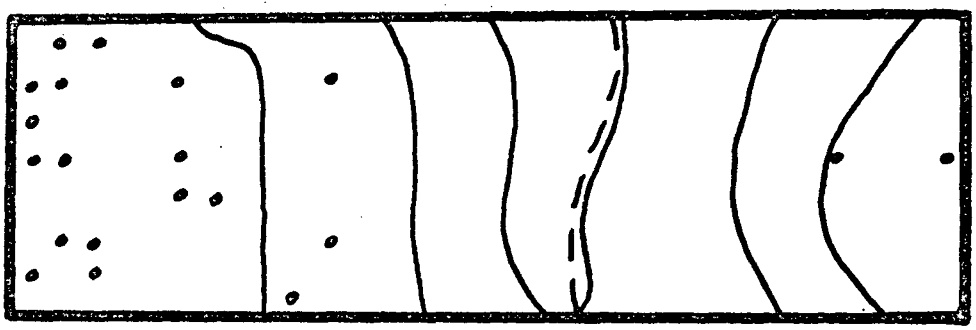

Figure 55. Distributional pattern of Crataegus mollis in the intensive study transect

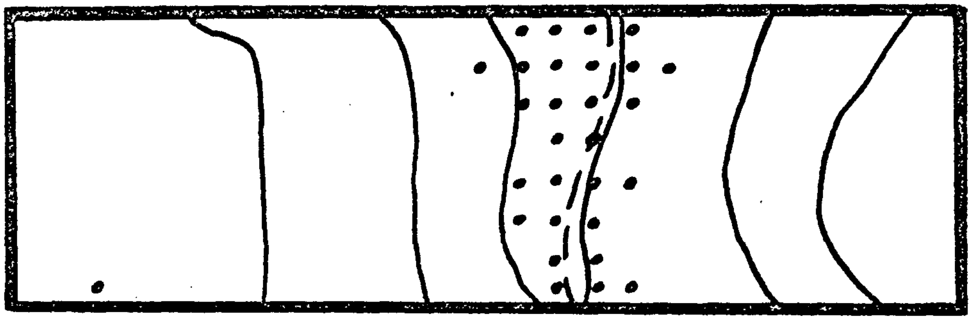

Figure 56. Distributional pattern of Cryptotaenia canadensis in the intensive study transect

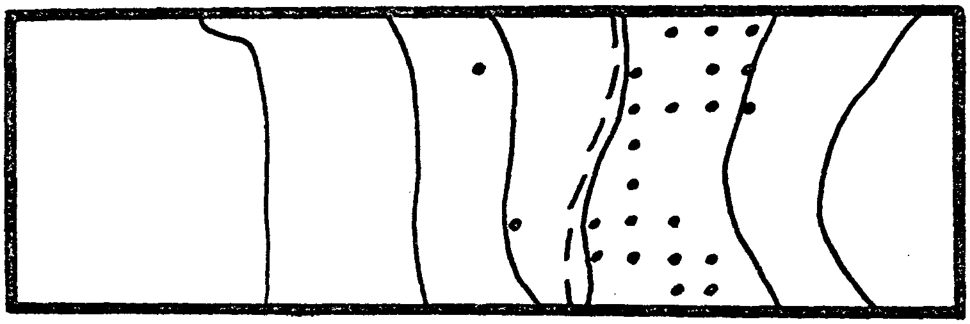

Figure 57. Distributional pattern of Cystopteris bulbifera in the intensive study transect

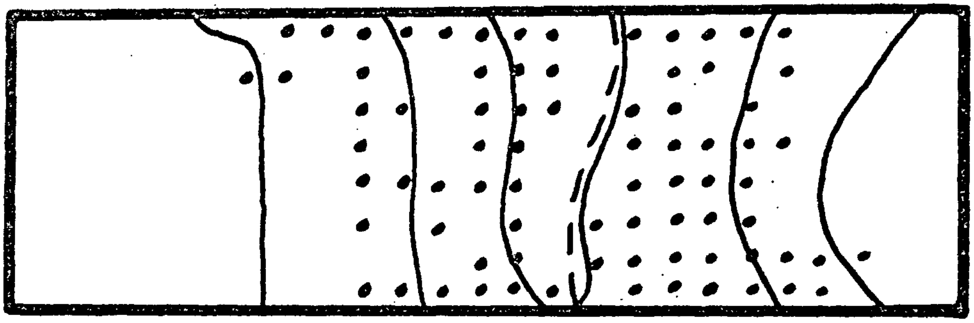

Figure 58. Distributional pattern of Cystopteris fragilis in the intensive study transect

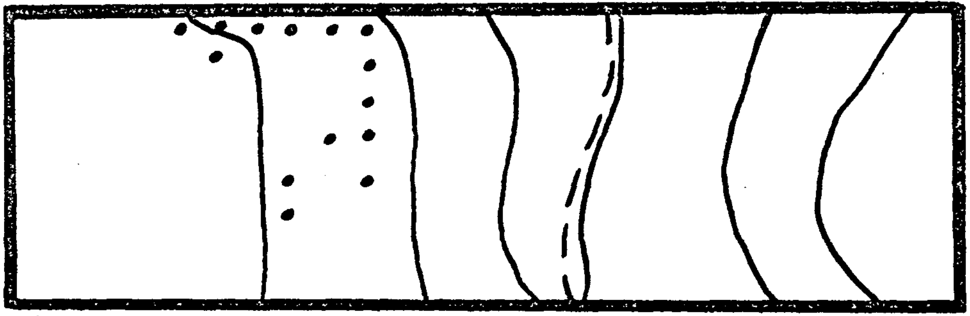

Figure 59. Distributional pattern of Danthonia spicata in the intensive study transect

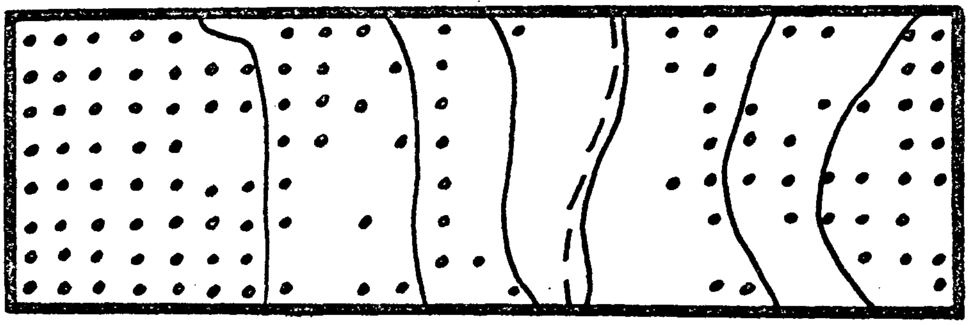

Figure 60. Distributional pattern of Desmodium glutinosum in the intensive study transect

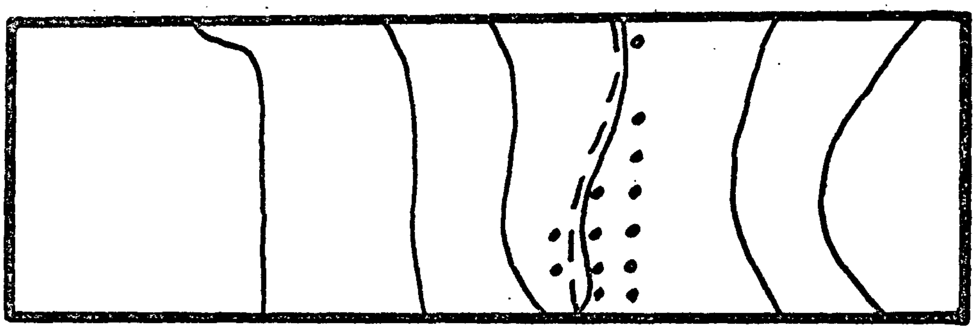

Figure 61. Distributional pattern of Dryopteris goldiana in the intensive study transect

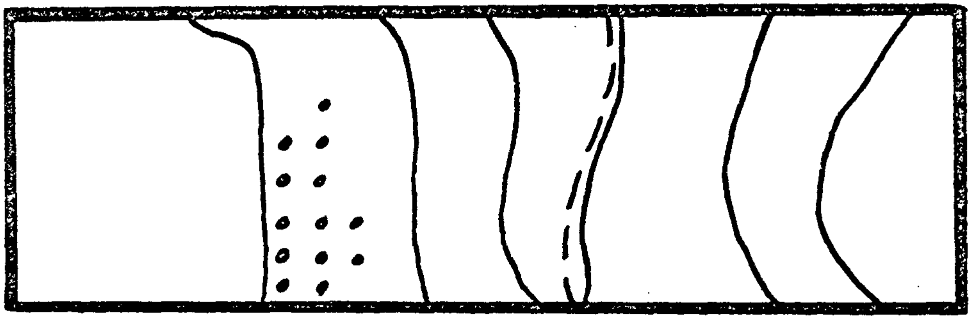

Figure 62. Distributional pattern of Echinacea pallida in the intensive study transect

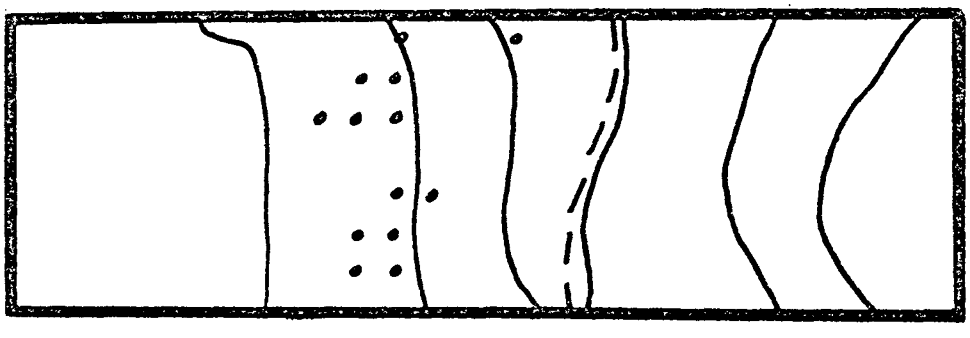

Figure 63. Distributional pattern of Elymus canadensis in the intensive study transect

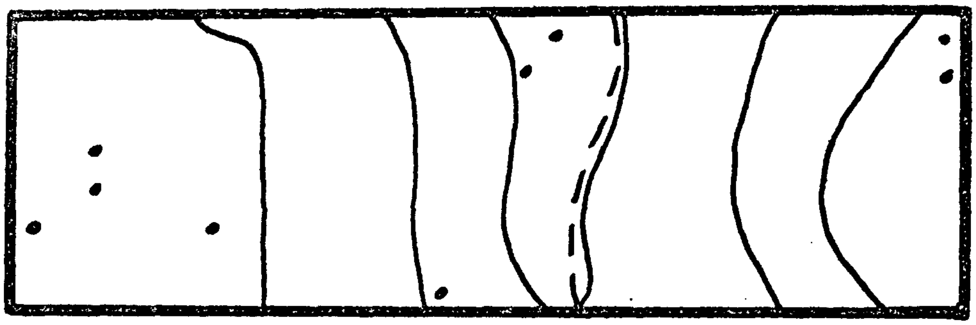

Figure 64. Distributional pattern of Eupatorium purpureum in the intensive study transect

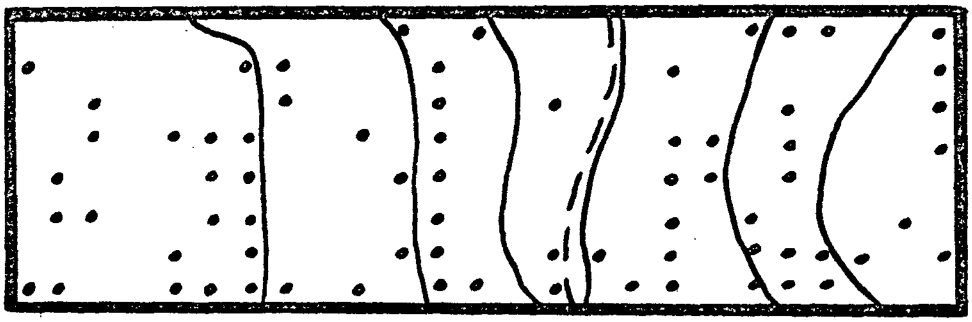

Figure 65. Distributional pattern of Festuca obtusa in the intensive study transect

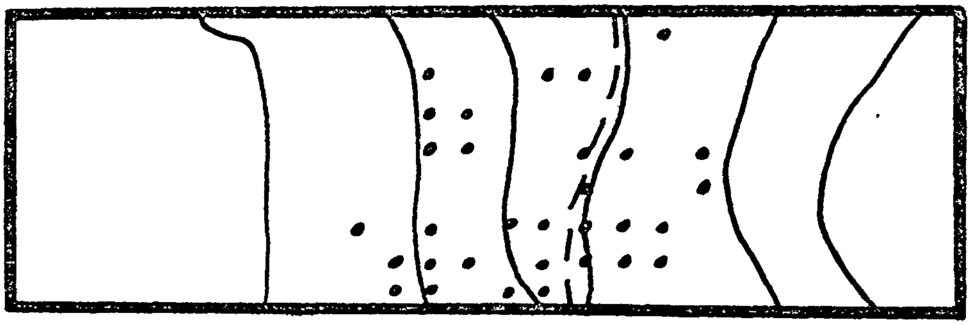

Figure 66. Distributional pattern of Fraxinus americana specimens less than 10 cm in diameter in the intensive study transect

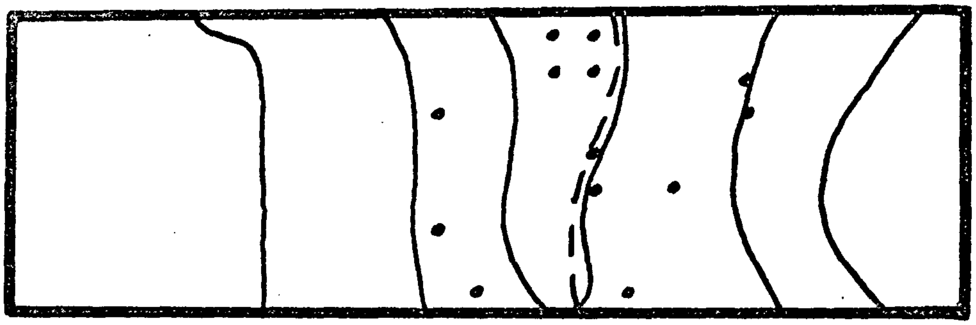

Figure 67. Distributional pattern of Fraxinus americana specimens greater than 10 cm in diameter in the intensive study transect

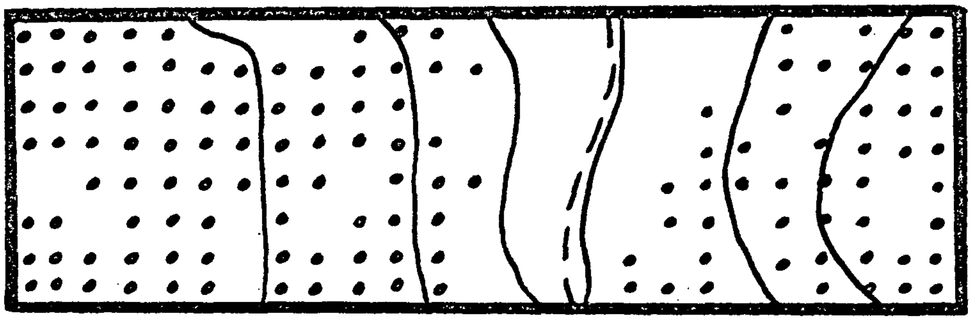

Figure 68. Distributional pattern of Fraxinus pennsylvanica specimens less than 10 cm in diameter in the intensive study transect

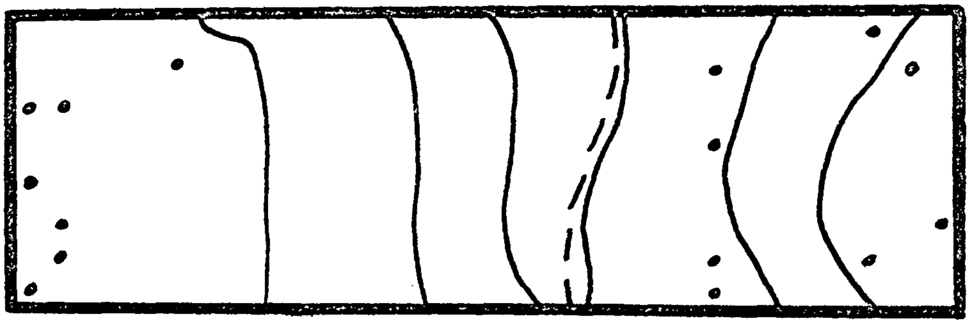

Figure 69. Distributional pattern of Fraxinus pennsylvanica specimens greater than 10 cm in diameter in the intensive study transect

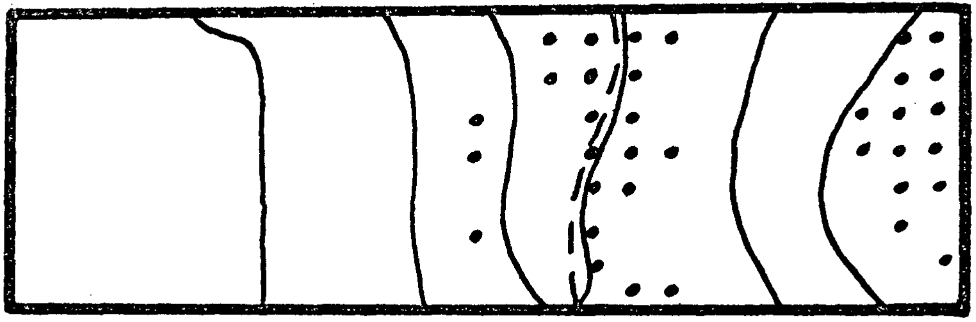

Figure 70. Distributional pattern of <u>Galium</u> <u>aparine</u> in the intensive study transect

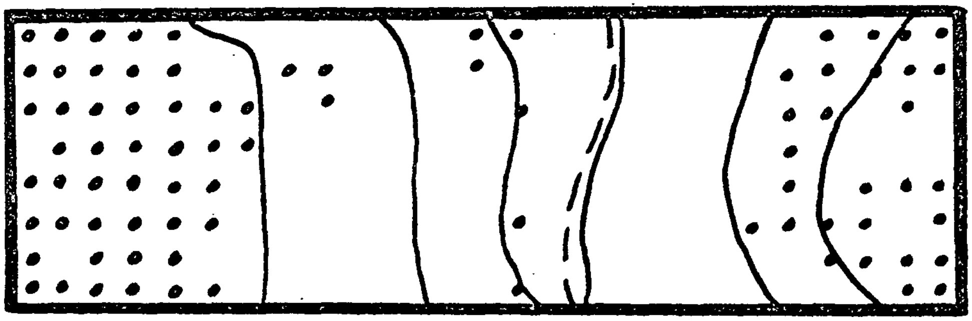

Figure 71. Distributional pattern of <u>Galium</u> <u>concinnum</u> in the intensive study transect

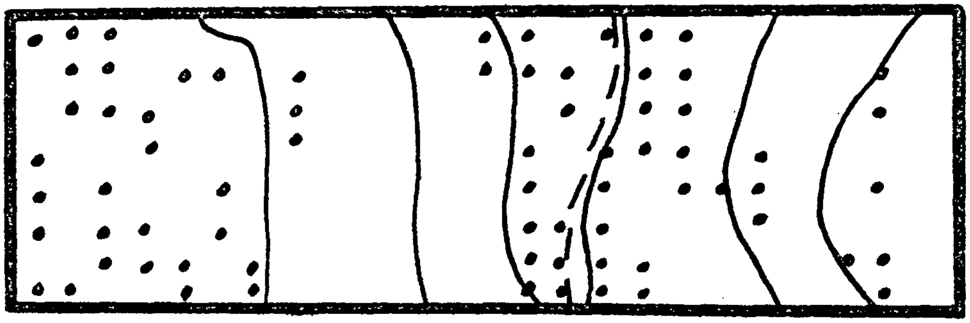

Figure 72. Distributional pattern of <u>Geum</u> <u>canadense</u> in the intensive study transect

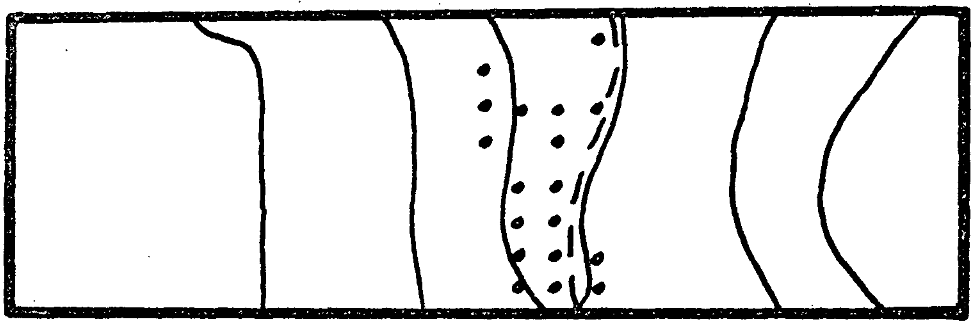

Figure 73. Distributional pattern of Glyceria striata in the intensive study transect

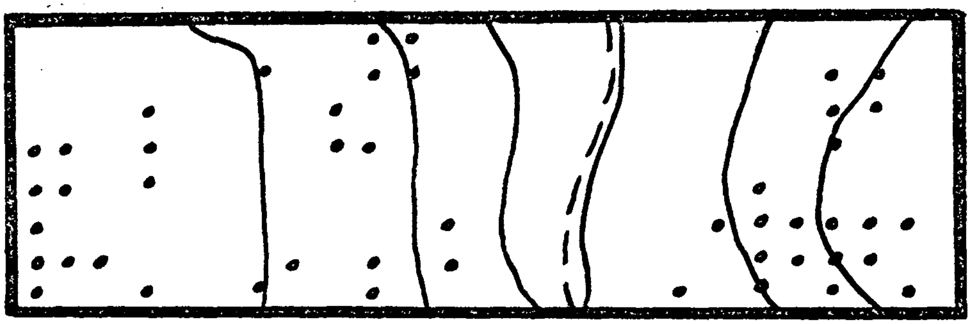

Figure 74. Distributional pattern of Helianthus strummosus in the intensive study transect

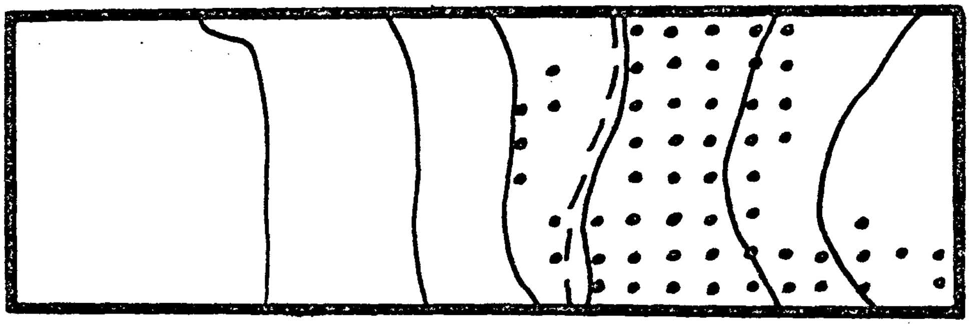

Figure 75. Distributional pattern of Hepatica acutiloba in the intensive study transect

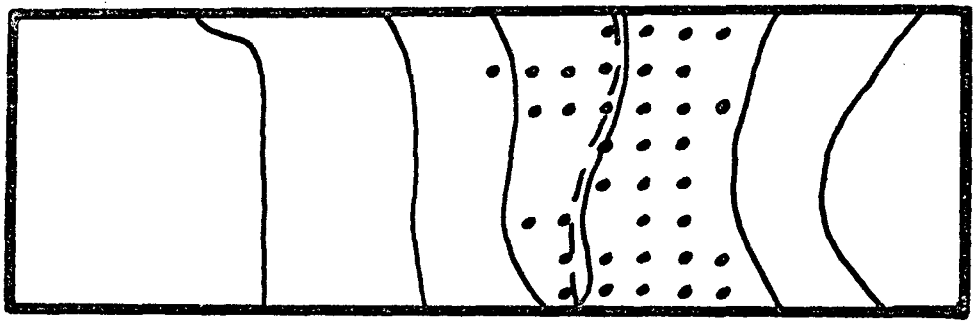

Figure 76. Distributional pattern of <u>Hydrophyllum</u> <u>virginianum</u> in the intensive study transect

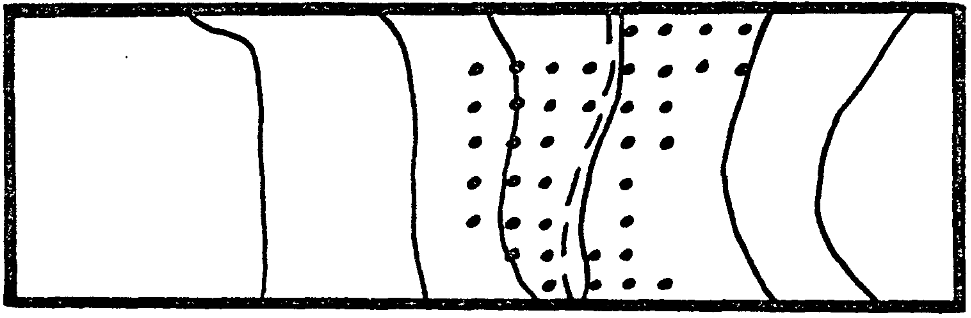

Figure 77. Distributional pattern of <u>Impatiens</u> <u>pallida</u> in the intensive study transect

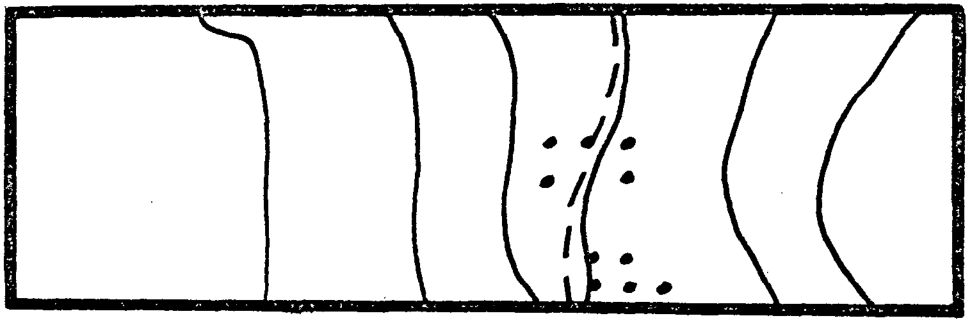

Figure 78. Distributional pattern of <u>Juglans</u> <u>cinerea</u> specimens greater than 10 cm in diameter in the intensive study transect

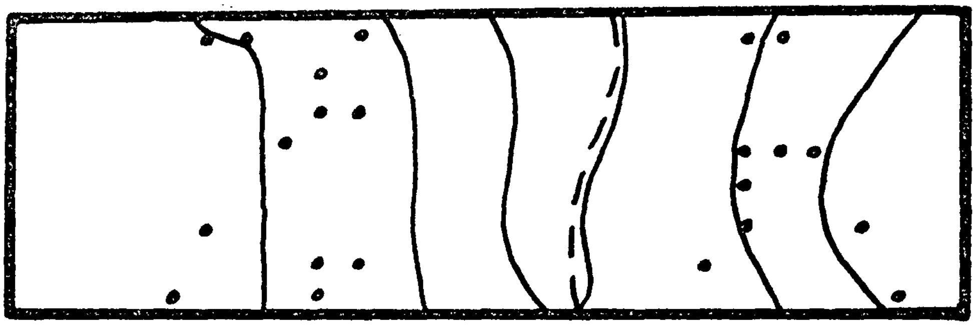

Figure 79. Distributional pattern of Juniperus virginiana in the intensive study transect

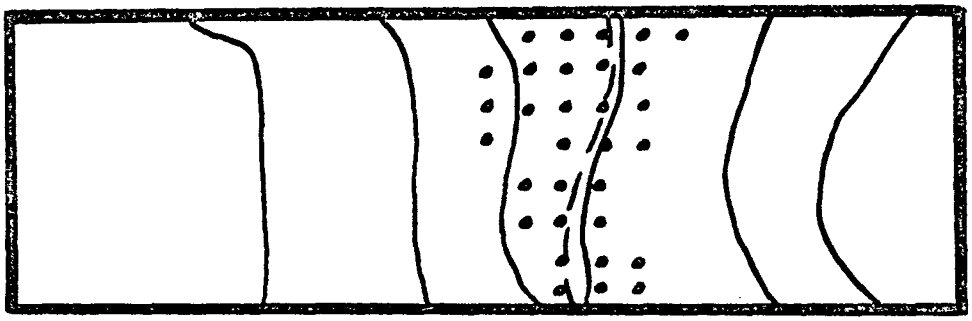

Figure 80. Distributional pattern of Laportea canadensis in the intensive study transect

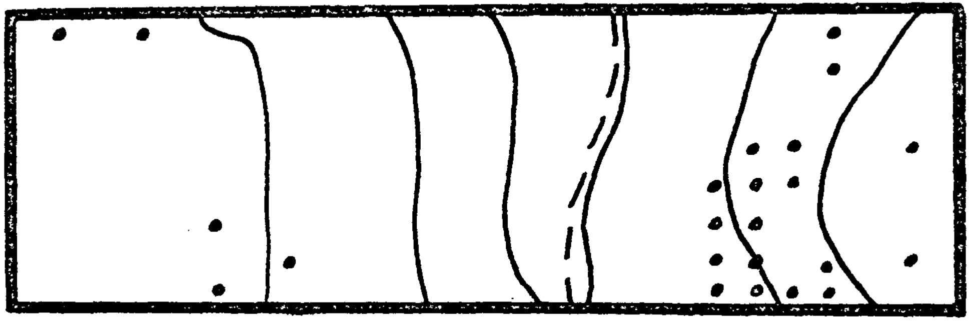

Figure 81. Distributional pattern of Lathyrus ochroleucus in the intensive study transect

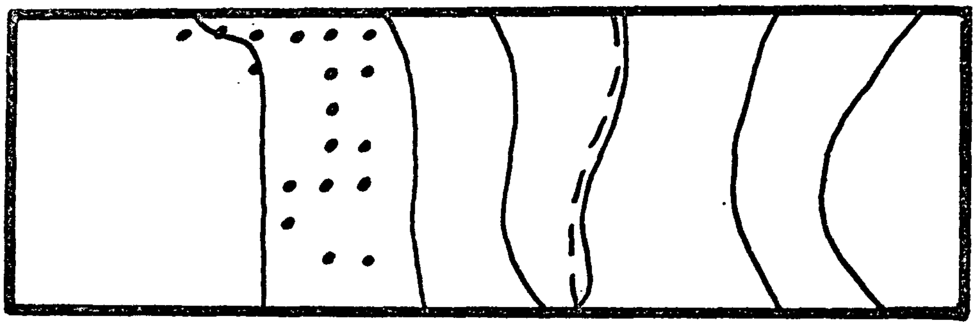

Figure 82. Distributional pattern of Lespedeza capitata in the intensive study transect

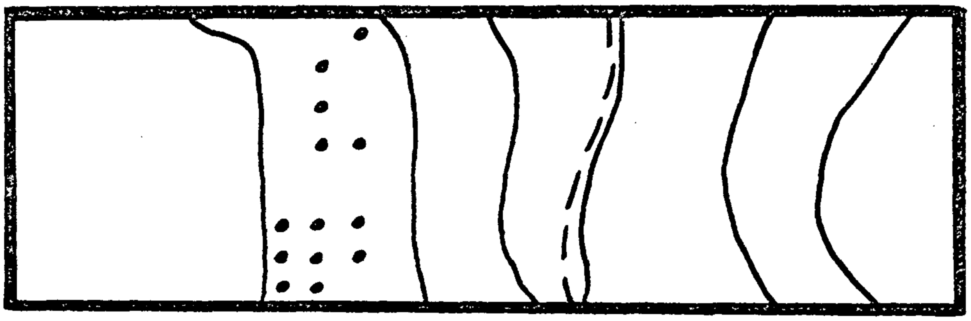

Figure 83. Distributional pattern of Lithospermum canescens in the intensive study transect

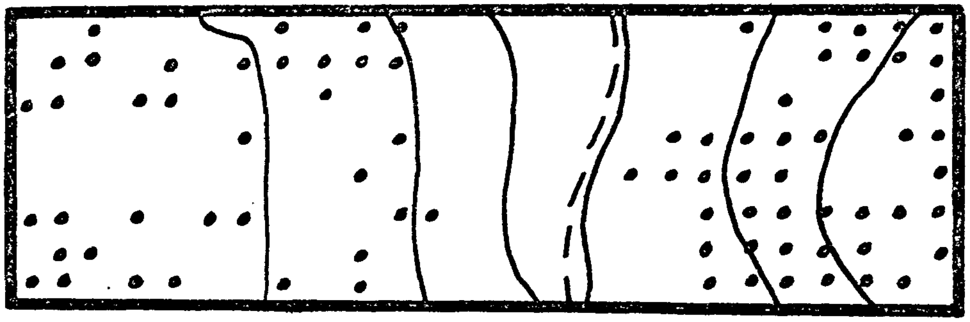

Figure 84. Distributional pattern of Lonicera dioica in the intensive study transect

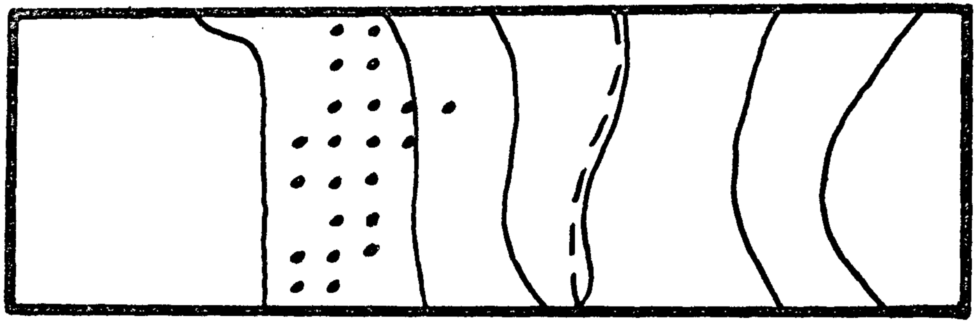

Figure 85. Distributional pattern of <u>Melilotus</u> <u>albus</u> in the intensive study transect

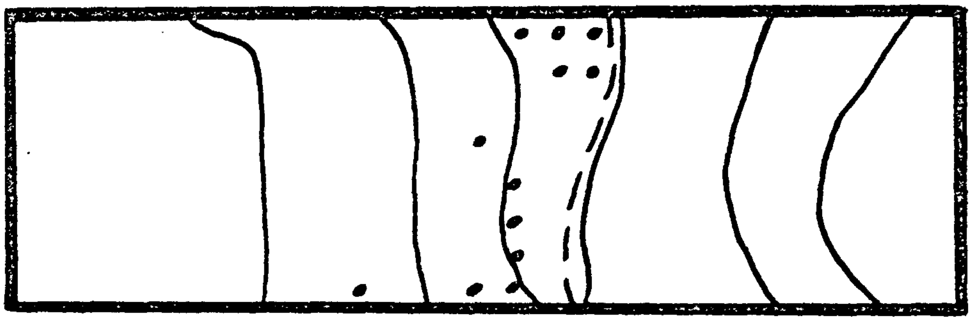

Figure 86. Distributional pattern of <u>Menispermum</u> <u>canadense</u> in the intensive study transect

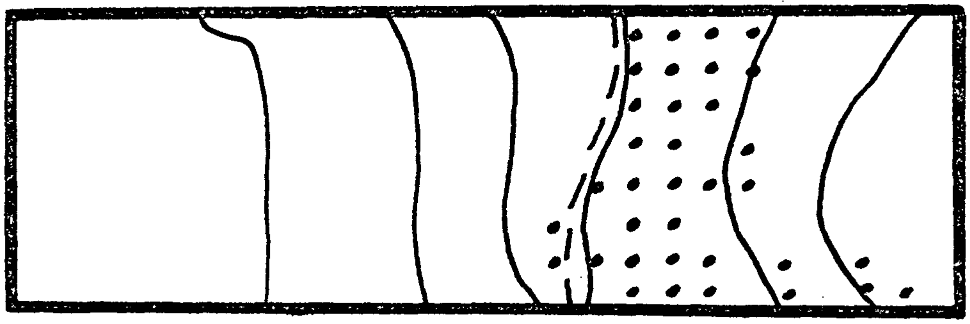

Figure 87. Distributional pattern of <u>Mitella</u> <u>diphylla</u> in the intensive study transect

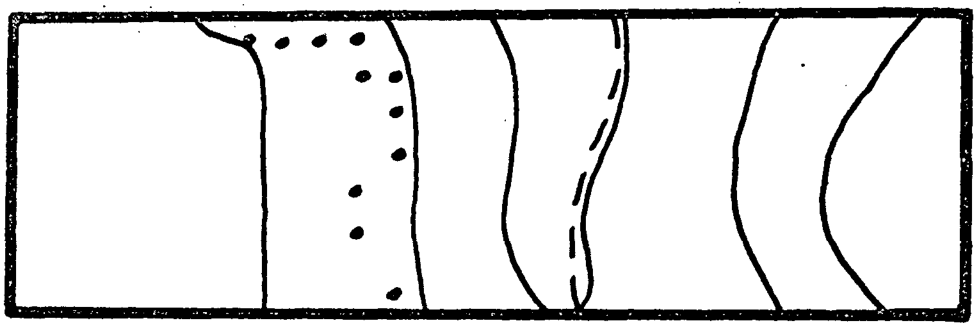

Figure 88. Distributional pattern of Muhlenbergia racemosa in the intensive study transect

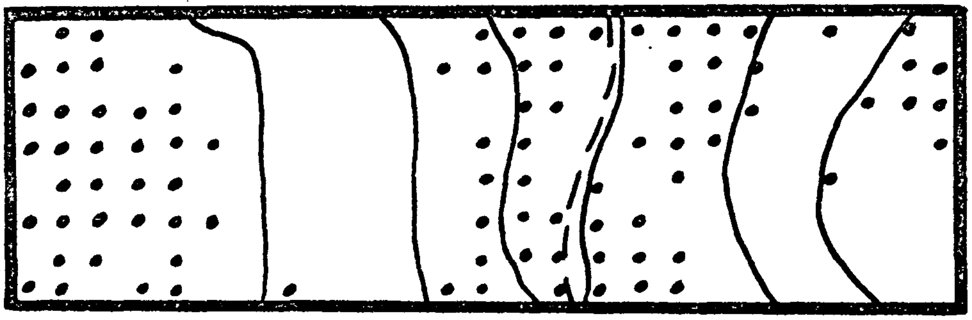

Figure 89. Distributional pattern of Osmorhiza claytoni in the intensive study transect

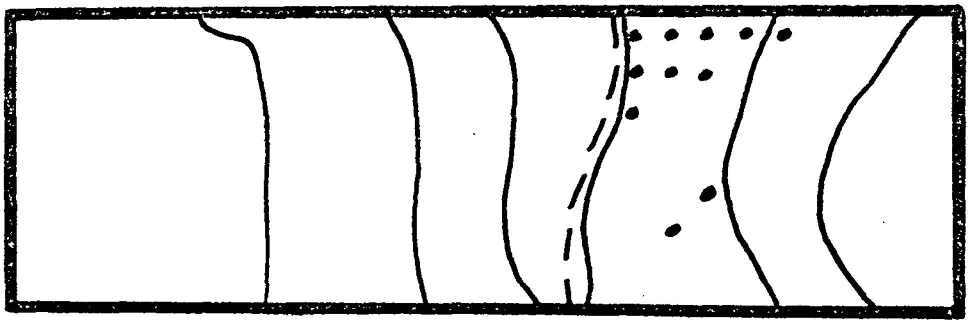

Figure 90. Distributional pattern of Osmunda claytoniana in the intensive study transect

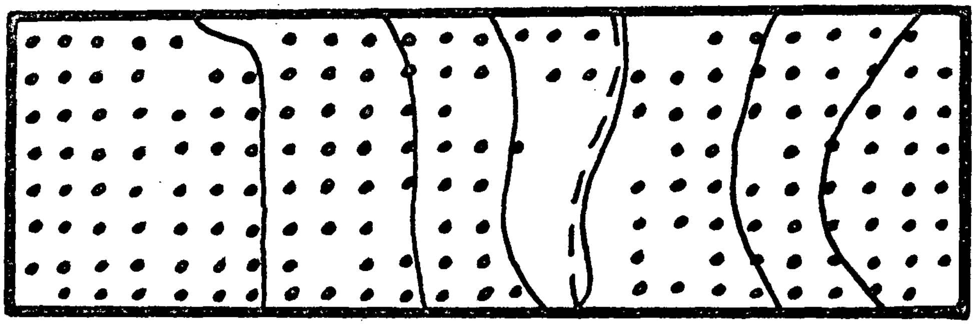

Figure 91. Distributional pattern of Ostrya virginiana in the intensive study transect

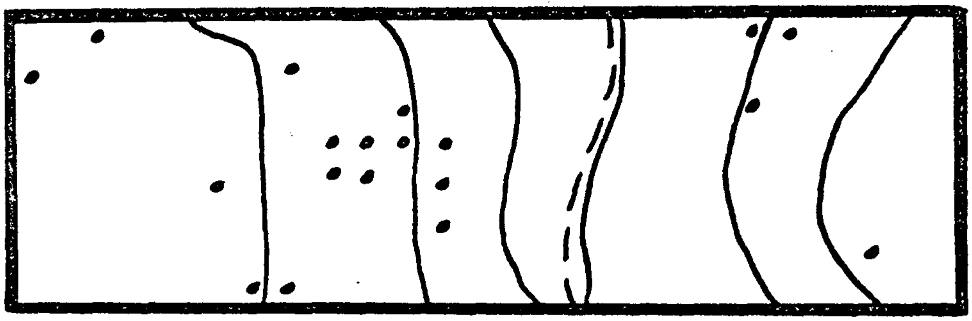

Figure 92. Distributional pattern of Oxalis stricta in the intensive study transect

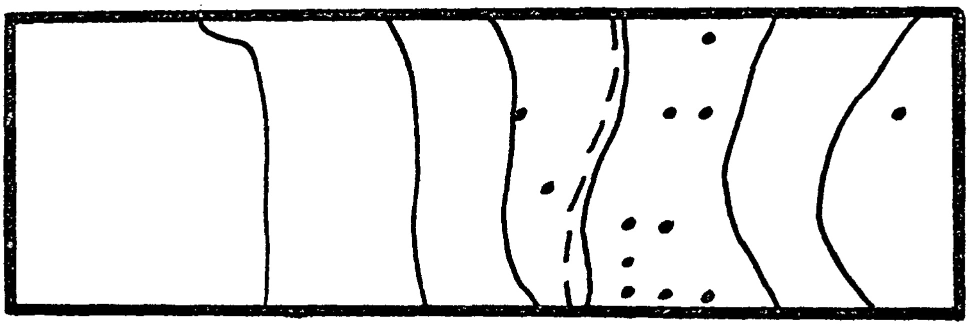

Figure 93. Distributional pattern of Panax quinquefolius in the intensive study transect

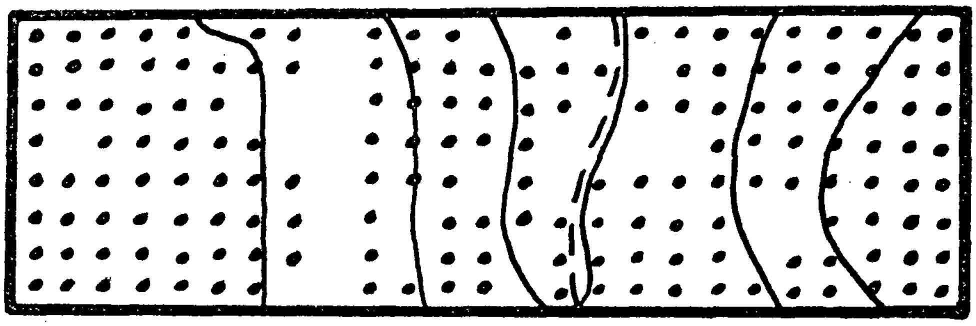

Figure 94. Distributional pattern of <u>Parthenocissus quinquefolia</u> in the intensive study transect

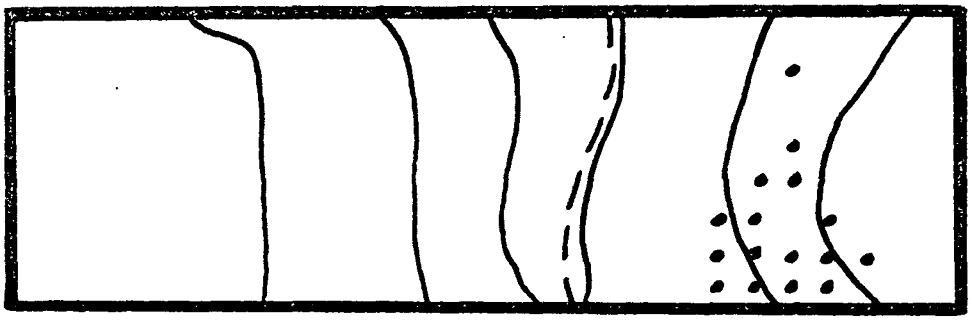

Figure 95. Distributional pattern of <u>Pedicularis canadensis</u> in the intensive study transect

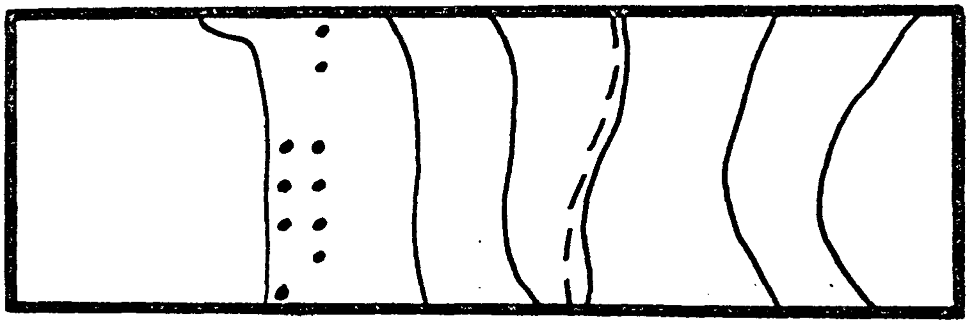

Figure 96. Distributional pattern of <u>Petalostemum candidum</u> in the intensive study transect

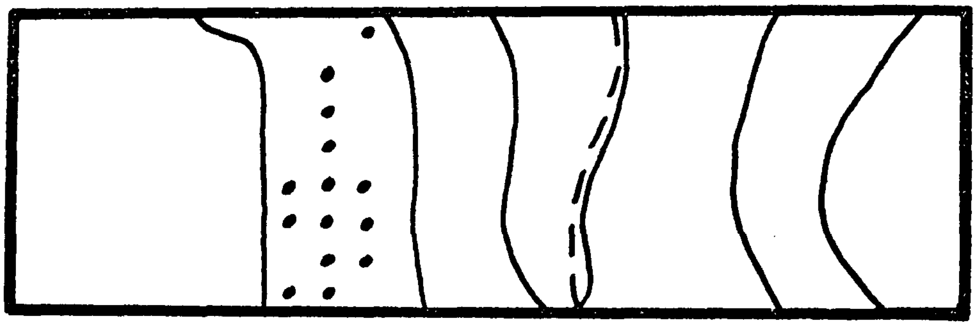

Figure 97. Distributional pattern of Petalostemum purpureum in the intensive study transect

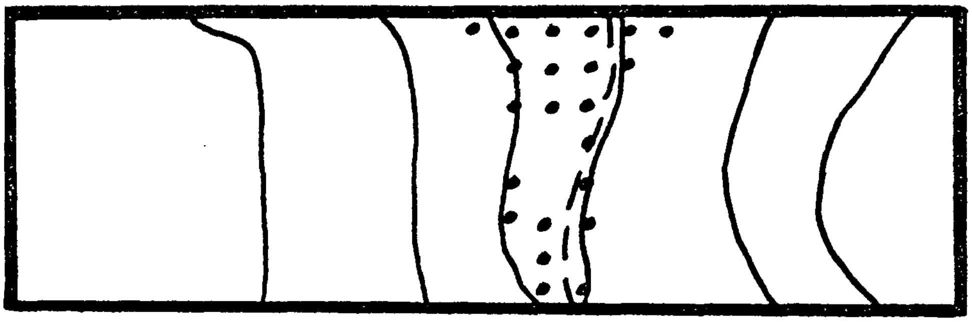

Figure 98. Distributional pattern of Phlox divaricata in the intensive study transect

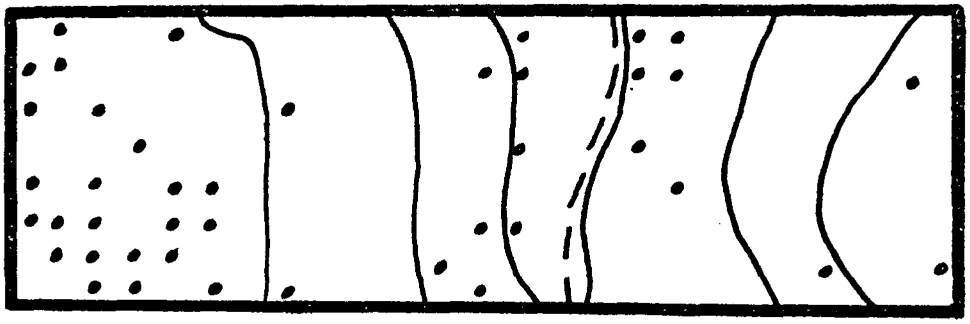

Figure 99. Distributional pattern of Phryma leptostachya in the intensive study transect

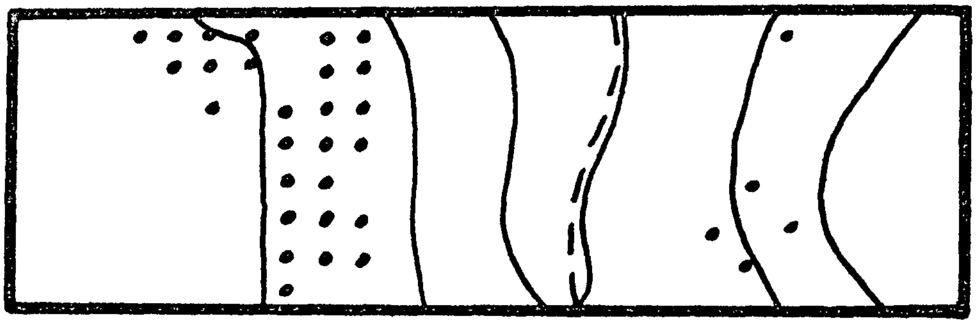

Figure 100. Distributional pattern of <u>Poa pratensis</u> in the intensive study transect

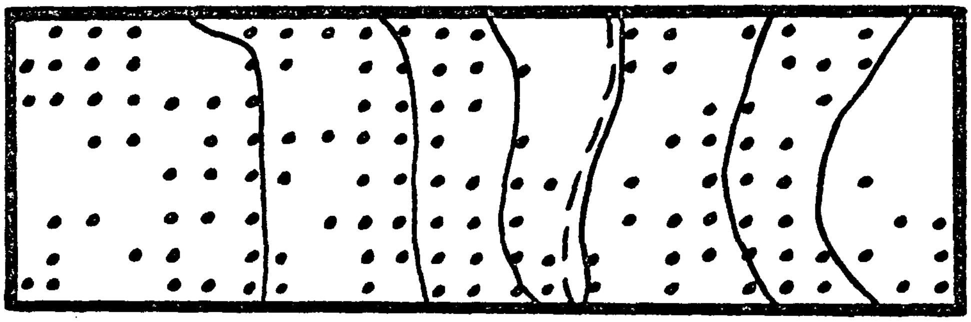

Figure 101. Distributional pattern of <u>Polygonatum canaliculatum</u> in the intensive study transect

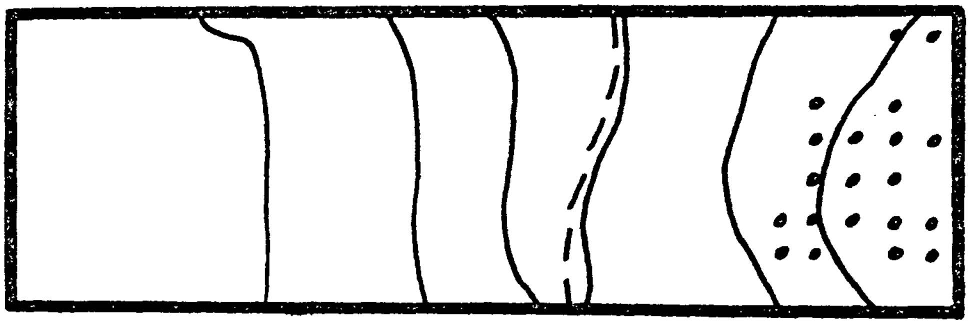

Figure 102. Distributional pattern of <u>Populus grandidentata</u> specimens less than 10 cm in diameter in the intensive study transect

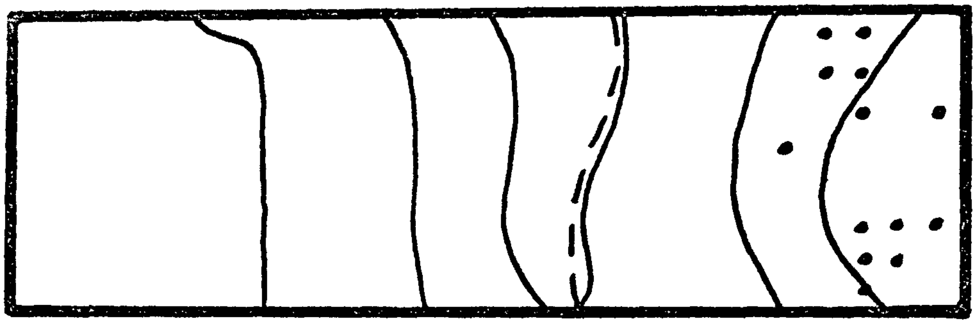

Figure 103. Distributional pattern of Populus grandidentata specimens greater than 10 cm in diameter in the intensive study transect

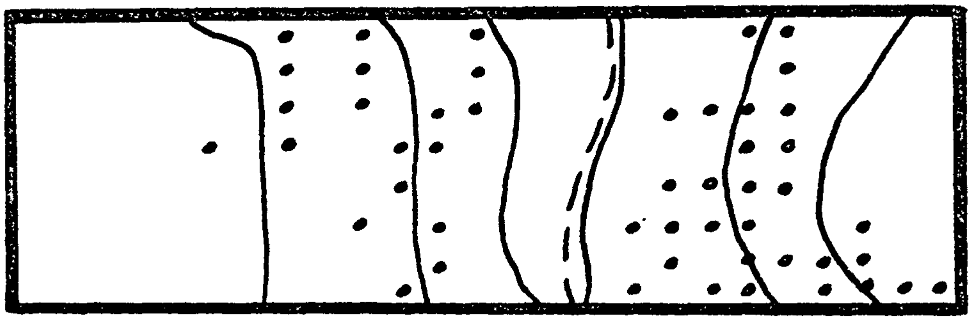

Figure 104. Distributional pattern of Prenanthes alba in the intensive study transect

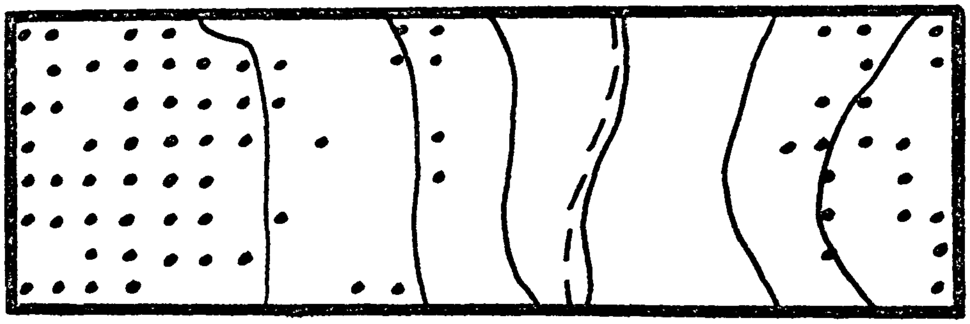

Figure 105. Distributional pattern of Prunus serotina specimens less than 10 cm in diameter in the intensive study transect

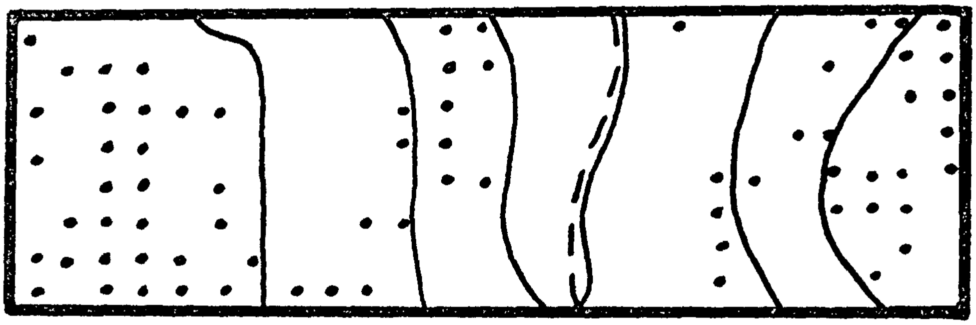

Figure 106. Distributional pattern of Prunus virginiana in the intensive study transect

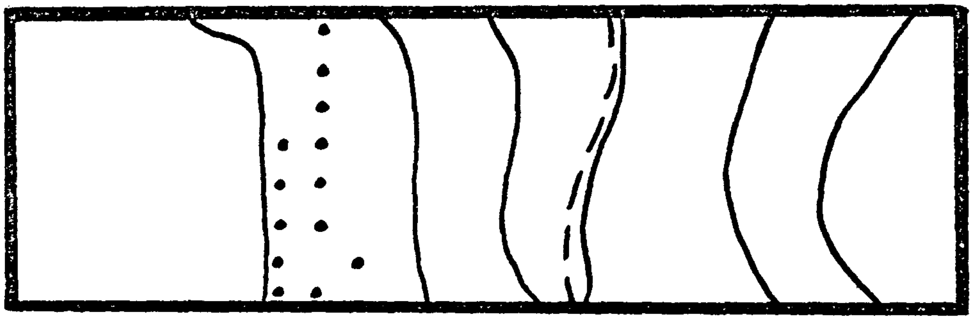

Figure 107. Distributional pattern of Psoralea tenuiflora in the intensive study transect

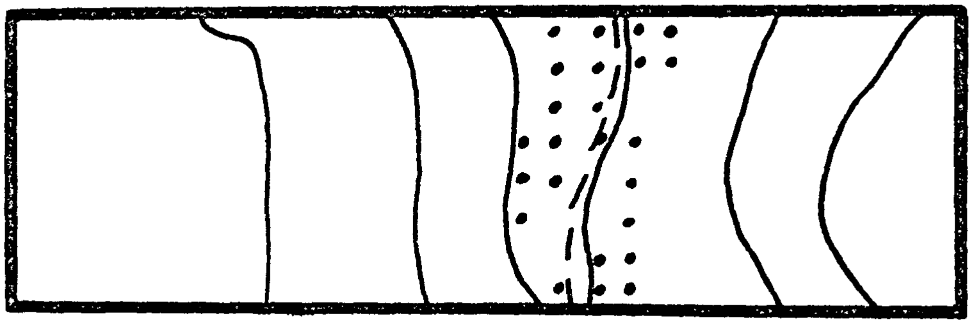

Figure 108. Distributional pattern of Pteretis pensylvanica in the intensive study transect

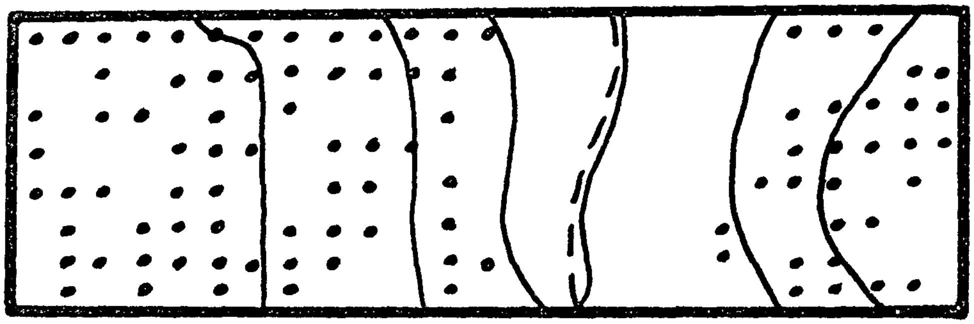

Figure 109. Distributional pattern of Quercus alba specimens less than 10 cm in diameter in the intensive study transect

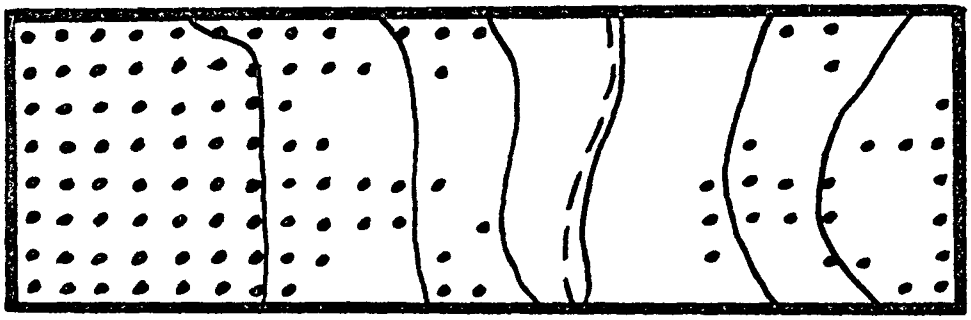

Figure 110. Distributional pattern of Quercus alba specimens greater than 10 cm in diameter in the intensive study transect

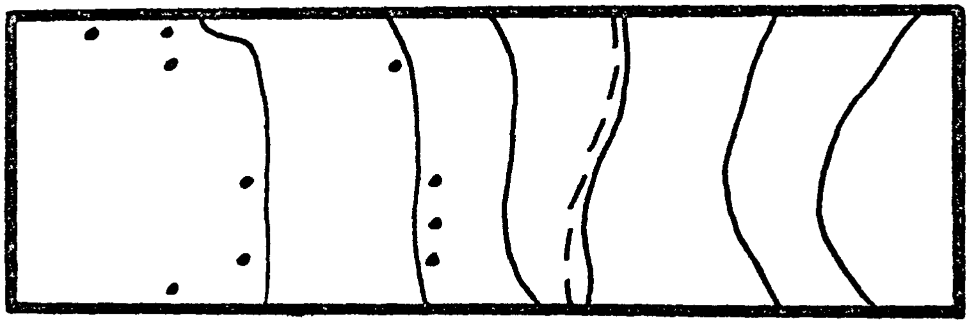

Figure 111. Distributional pattern of Quercus macrocarpa specimens greater than 10 cm in diameter in the intensive study transect

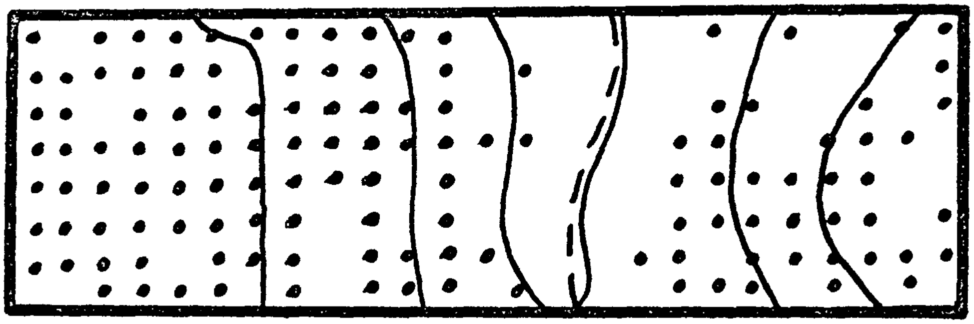

Figure 112. Distributional pattern of Quercus rubra specimens less than 10 cm in diameter in the intensive study transect

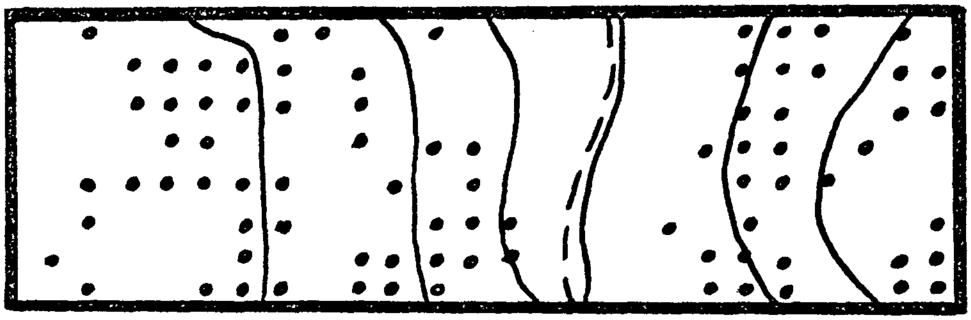

Figure 113. Distributional pattern of Quercus rubra specimens greater than 10 cm in diameter in the intensive study transect

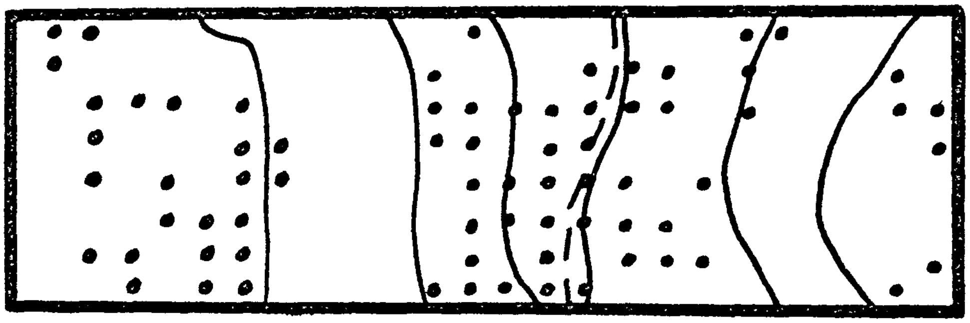

Figure 114. Distributional pattern of Ranunculus abortivus in the intensive study transect

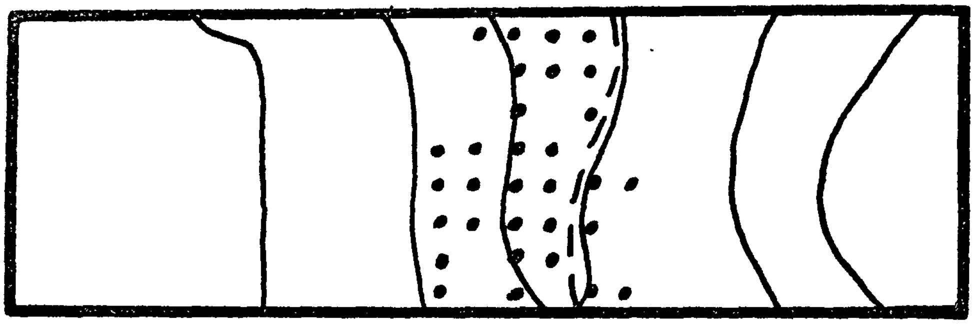

Figure 115. Distributional pattern of Ranunculus pensylvanicus in the intensive study transect

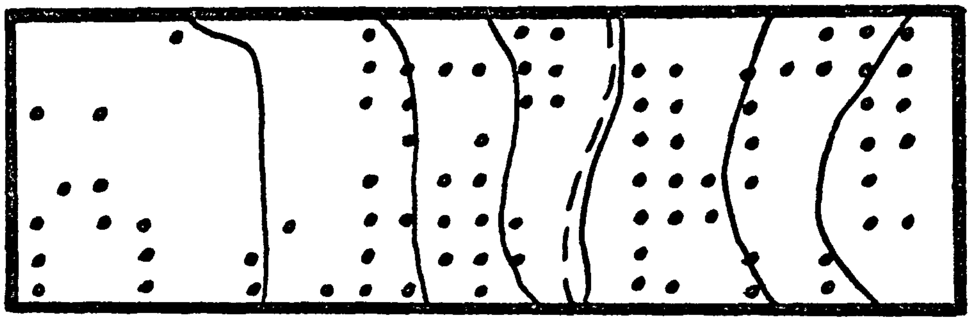

Figure 116. Distributional pattern of Rhus radicans in the intensive study transect

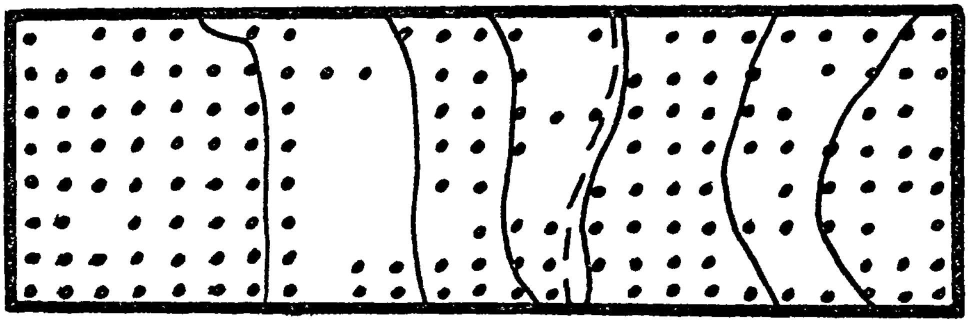

Figure 117. Distributional pattern of Ribes cynosbati in the intensive study transect

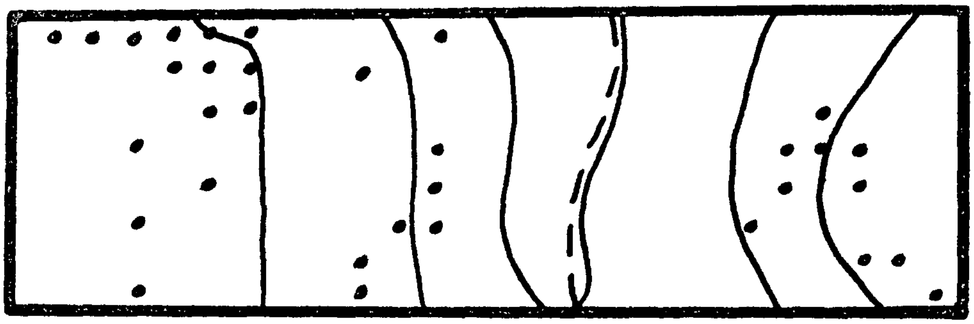

Figure 118. Distributional pattern of Rosa arkansana in the intensive study transect

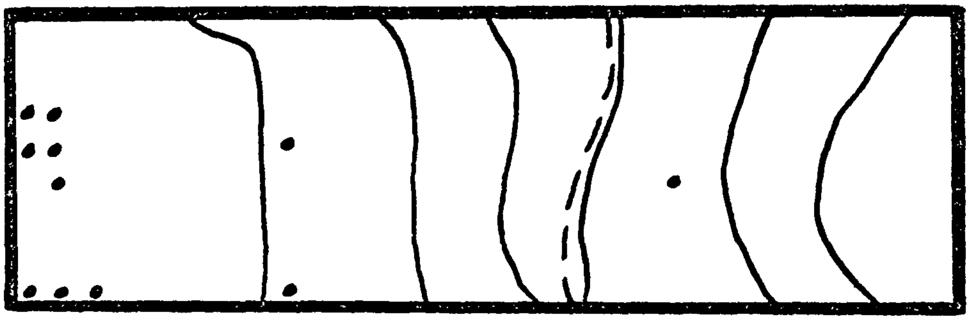

Figure 119. Distributional pattern of Rubus occidentalis in the intensive study transect

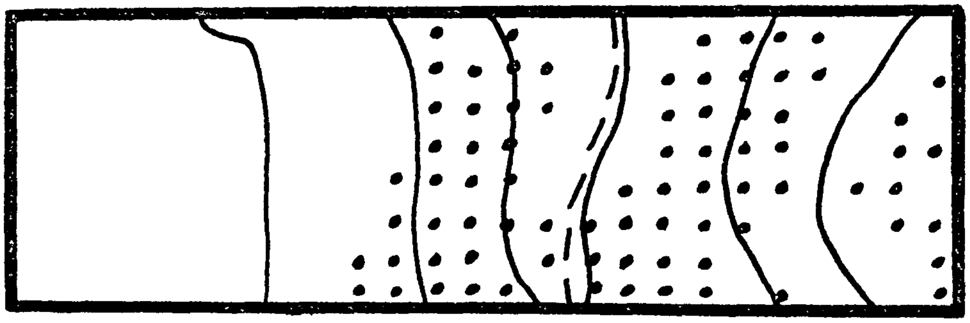

Figure 120. Distributional pattern of Sanguinaria canadensis in the intensive study transect

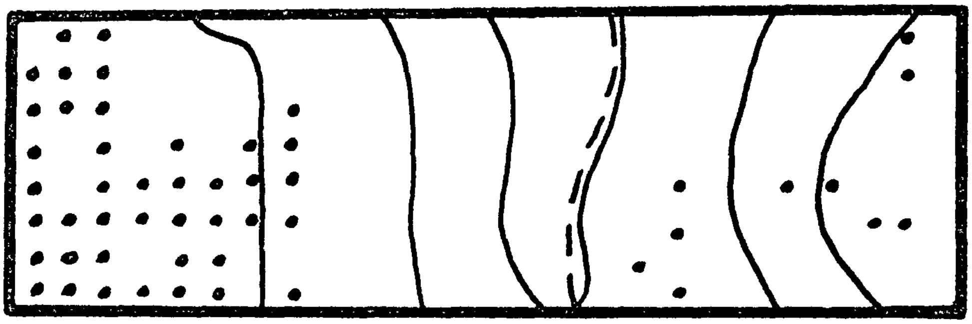

Figure 121. Distributional pattern of <u>Sanicula marilandica</u> in the intensive study transect

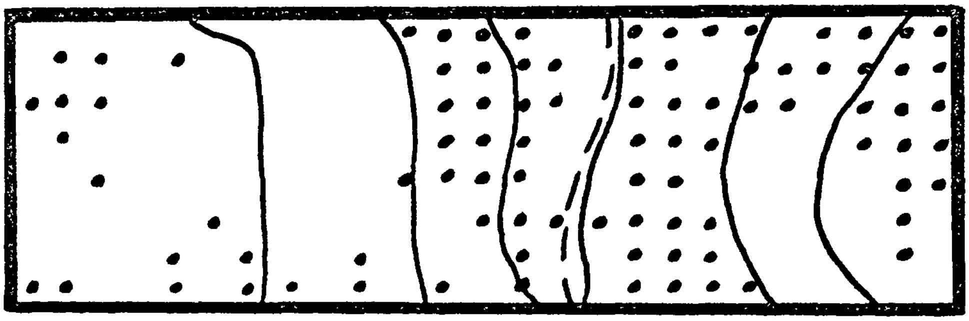

Figure 122. Distributional pattern of <u>Smilacina racemosa</u> in the intensive study transect

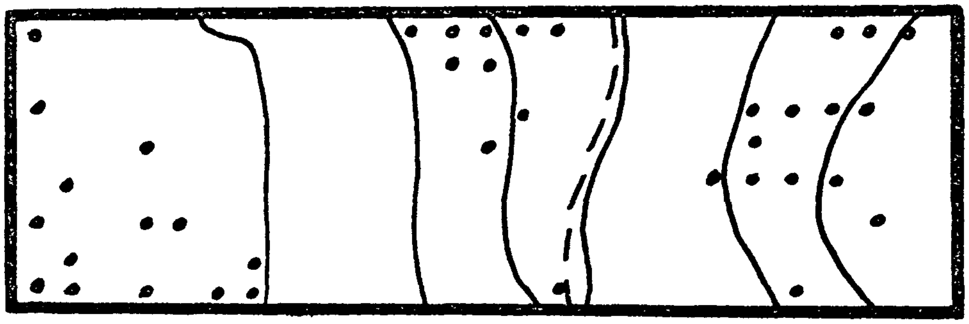

Figure 123. Distributional pattern of <u>Smilax ecirrhata</u> in the intensive study transect

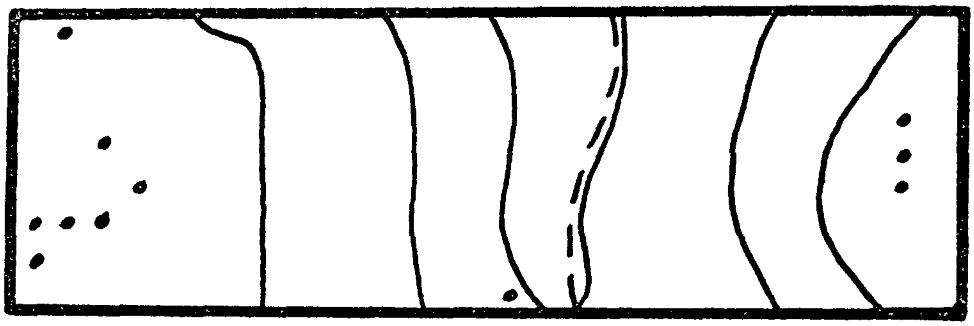

Figure 124. Distributional pattern of Smilax herbacea in the intensive study transect

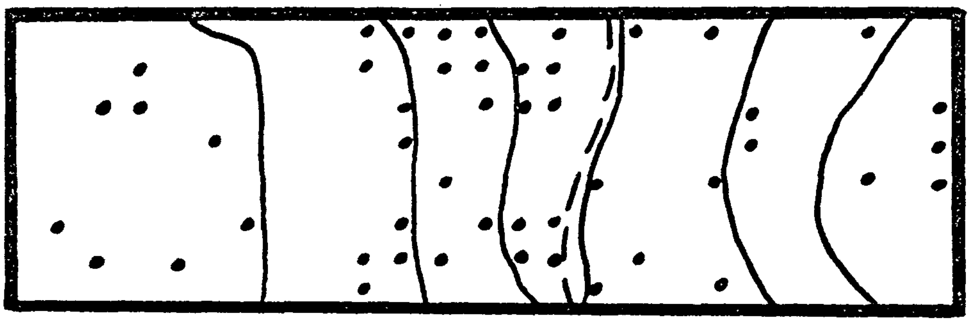

Figure 125. Distributional pattern of Smilax tamnoides in the intensive study transect

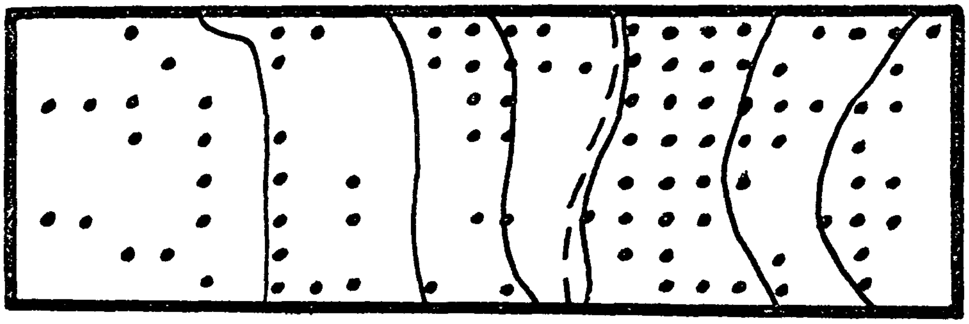

Figure 126. Distributional pattern of Solidago flexicaulis in the intensive study transect

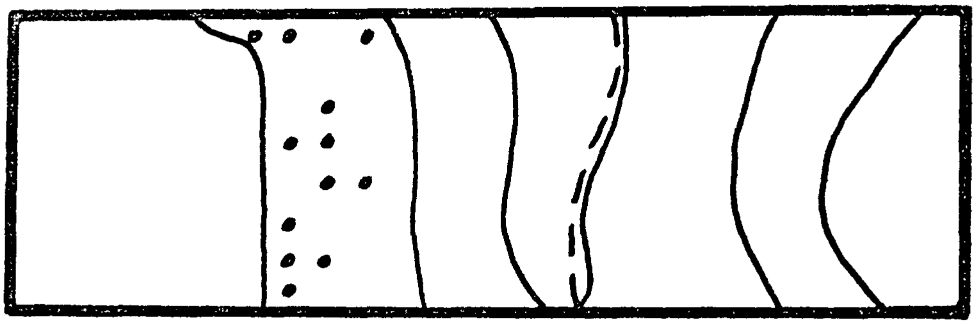

Figure 127. Distributional pattern of Solidago nemoralis in the intensive study transect

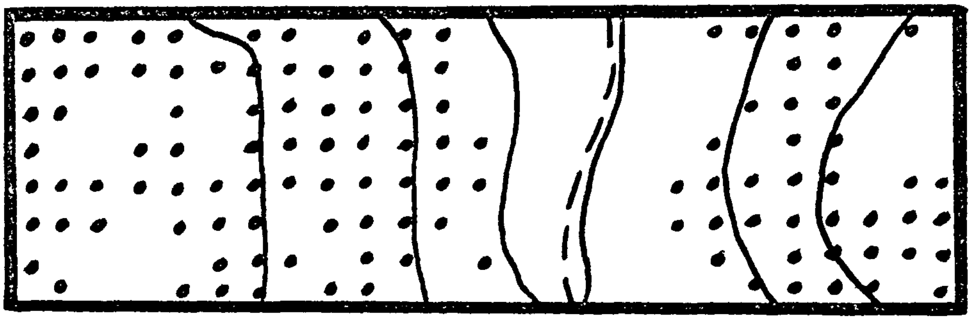

Figure 128. Distributional pattern of Solidago ulmifolia in the intensive study transect

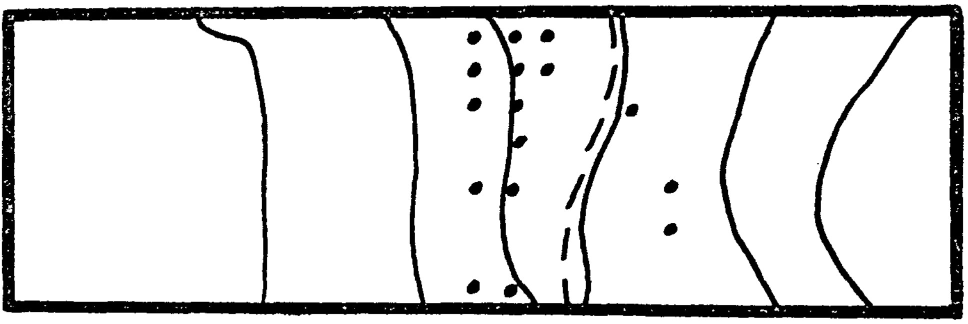

Figure 129. Distributional pattern of Staphylea trifolia in the intensive study transect

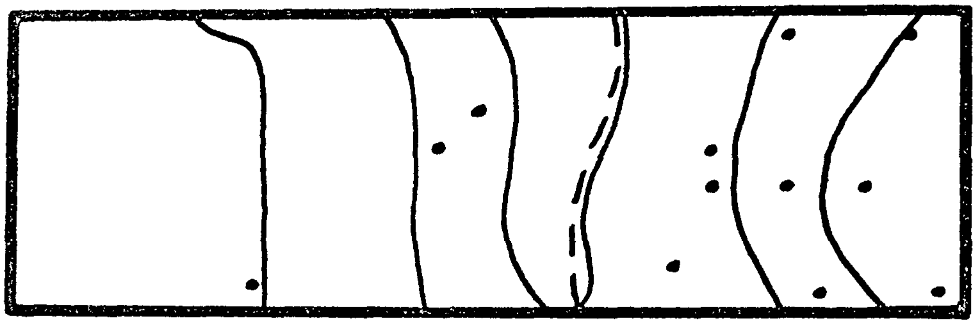

Figure 130. Distributional pattern of Taraxicum officinale in the intensive study transect

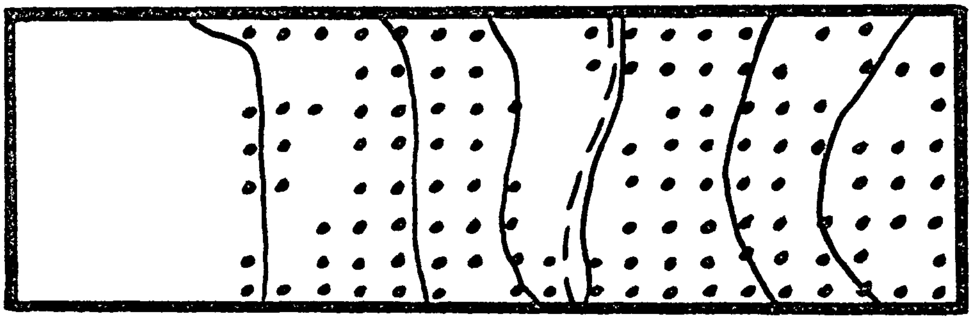

Figure 131. Distributional pattern of Thalictrum dioicum in the intensive study transect

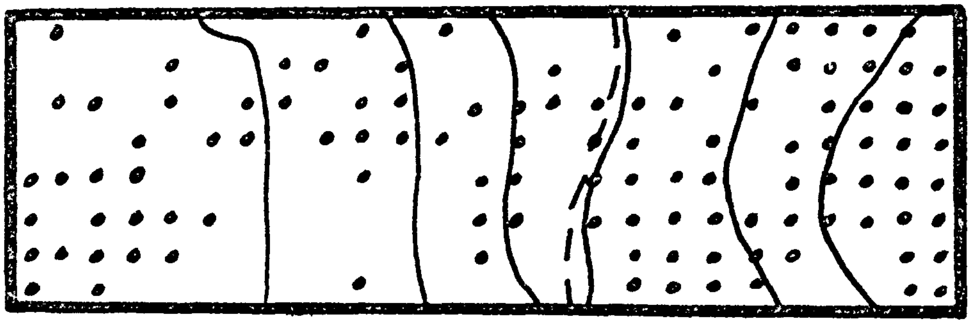

Figure 132. Distributional pattern of Tilia americana specimens less than 10 cm in diameter in the intensive study transect

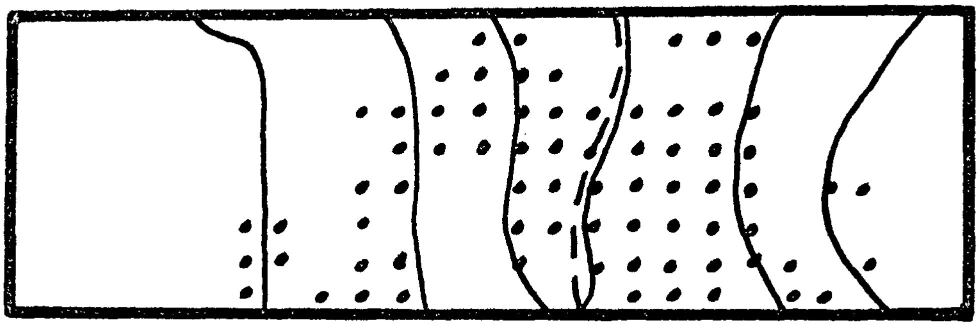

Figure 133. Distributional pattern of <u>Tilia</u> <u>americana</u> specimens greater than 10 cm in diameter in the intensive study transect

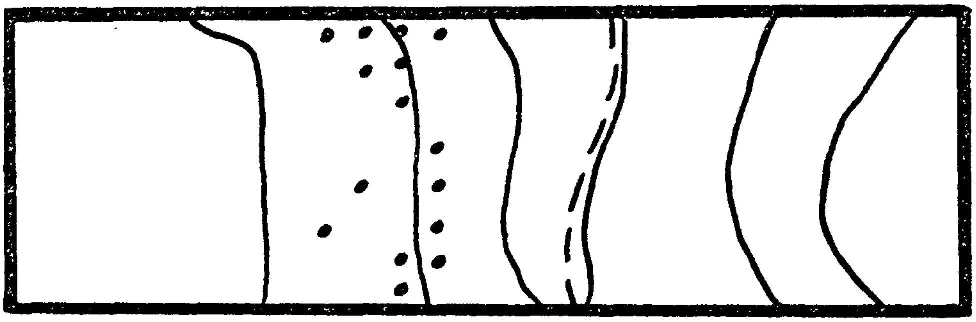

Figure 134. Distributional pattern of <u>Tradescantia</u> <u>virginiana</u> in the intensive study transect

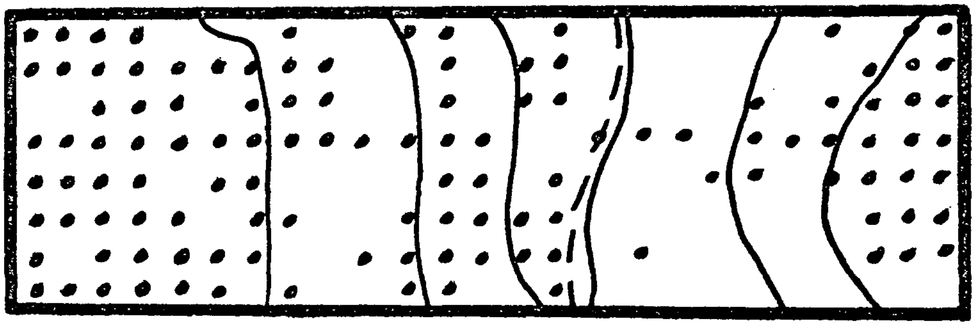

Figure 135. Distributional pattern of <u>Ulmus</u> <u>americana</u> specimens less than 10 cm in diameter in the intensive study transect

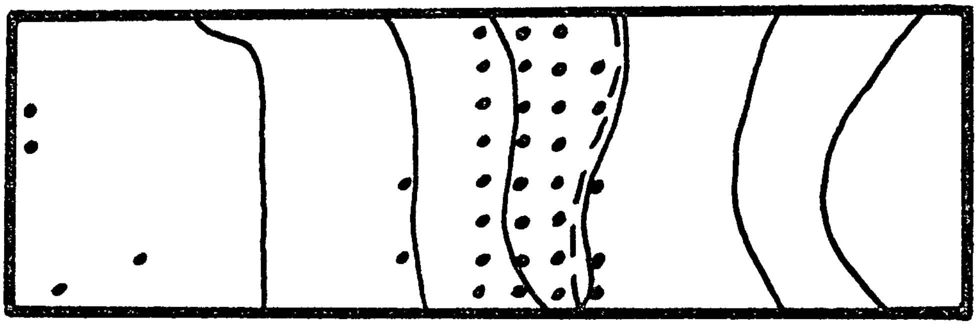

Figure 136. Distributional pattern of <u>Ulmus americana</u> specimens greater than 10 cm in diameter in the intensive study transect

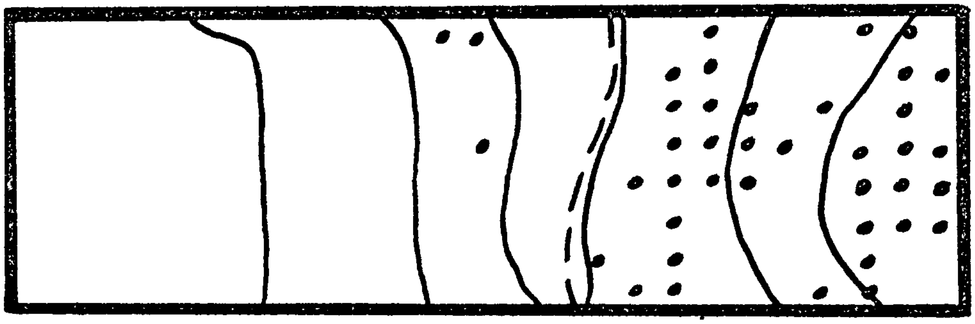

Figure 137. Distributional pattern of <u>Uvularia grandiflora</u> in the intensive study transect

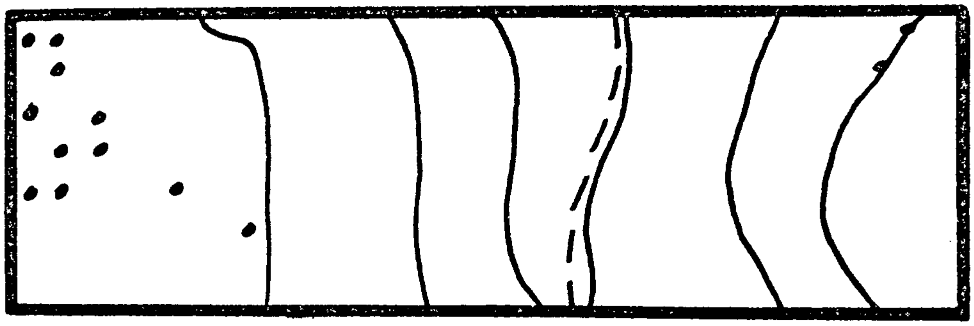

Figure 138. Distributional pattern of <u>Veronicastrum virginicum</u> in the intensive study transect

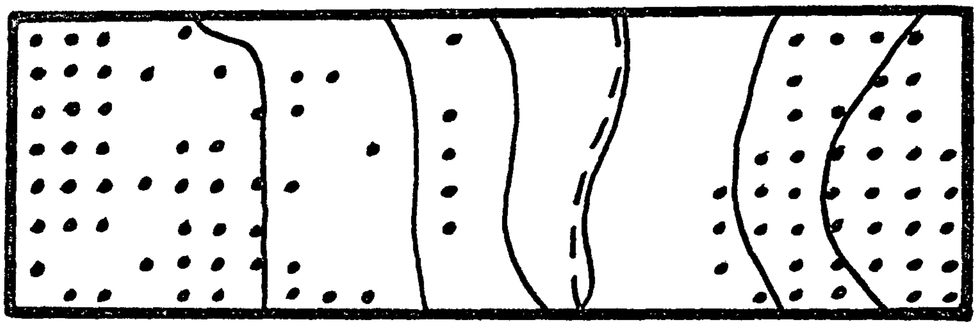

Figure 139. Distributional pattern of <u>Viburnum rafinesquianum</u> in the intensive study transect

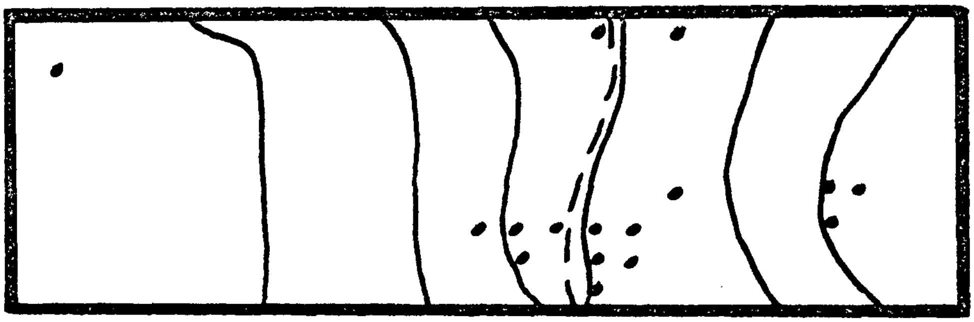

Figure 140. Distributional pattern of <u>Viola pensylvanica</u> in the intensive study transect

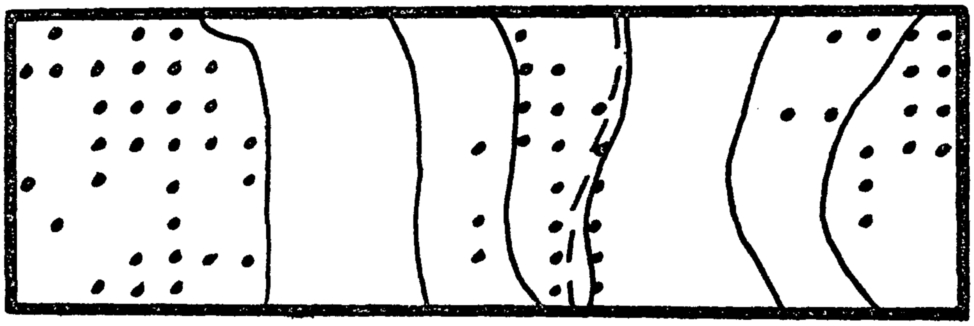

Figure 141. Distributional pattern of <u>Viola sororia</u> in the intensive study transect

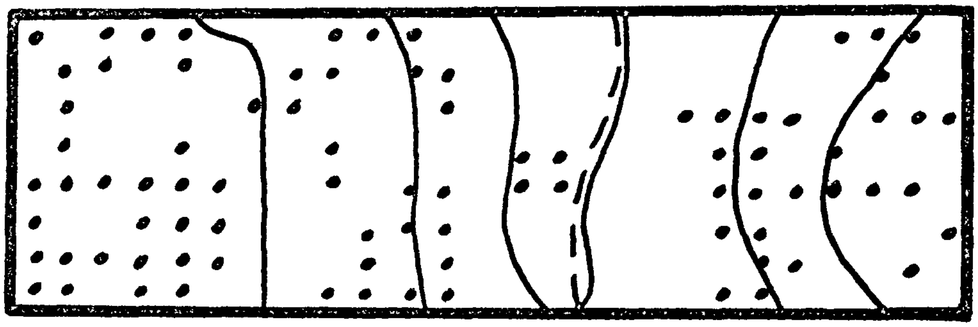

Figure 142. Distributional pattern of <u>Vitis</u> <u>riparia</u> in the intensive study transect

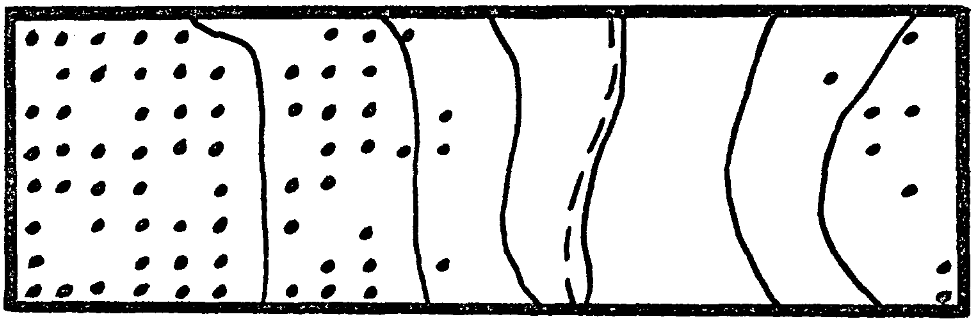

Figure 143. Distributional pattern of <u>Xanthoxylum</u> <u>americanum</u> in the intensive study transect

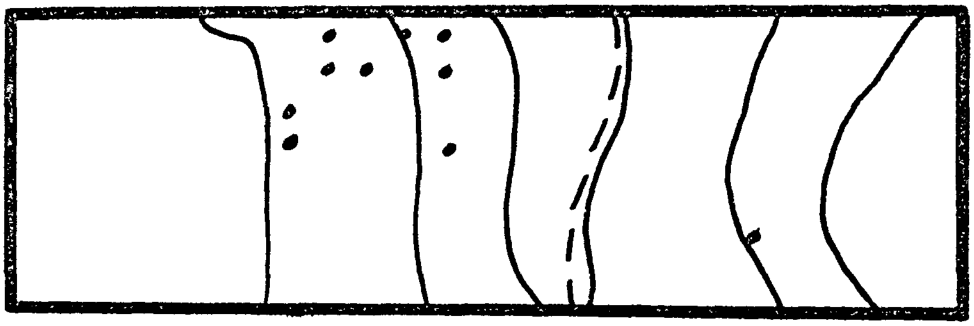

Figure 144. Distributional pattern of <u>Zizia</u> <u>aurea</u> in the intensive study transect

Ribes cynosbati. Another general group consisted of species which had a rather distinctive and limited distribution. The prairie species exhibited this type of distribution. The third general type of distribution was one which did not appear to have any order; specimens were simply scattered over the transect. This group included *Eupatorium purpureum* and *Phryma leptostachya*. Most distributional patterns appeared in between these general types.

After sorting the species into groups based on distribution, it became apparent that the communities which were determined by purely subjective field experience could not all be supported by the species presence data. The transect was classified into communities again, using the species presence maps. This classification scheme is shown in Figure 8.

The prairie opening community was classified first because its species showed the most distinctive distributional patterns. The patterns of *Amorpha canescens*, *Andropogon gerardii*, *A. scoparius*, *Lespedeza capitata*, *Melilotus albus*, and *Poa pratensis* were used. All plots which possessed three or more of these species were considered to be members of the prairie opening community.

The next community which appeared to have some basis using the distribution maps was the stream bottom community. *Arisaema atrorubens*, *Cryptotaenia canadensis*, *Glyceria striata*, *Hydrophyllum virginianum*, *Impatiens pallida*, *Pteretis pensylvanica*, *Ranunculus pensylvanica* and trees of *Ulmus americana* were used to delineate this community. Any plot with four or more of these species was placed in the stream bottom community. This community included both the lower north-facing and south-facing slope communities of the purely subjective classification. They had too few distinctive species to warrant separation by this method.

The north-facing slope had only two quite distinctive species: *Hepatica acutiloba* and *Mitella diphylla*. The north-facing slope was considered to be a distinct community based on the distribution of these two species and the pattern of some upland species, *Galium concinnum* and *Populus grandidentata*, which occur only to the slope break.

The south-facing slope was considered distinctive from the north-facing slope due to the complete absence of *Hepatica acutiloba* and *Mitella diphylla*. The area between the stream bottom community and the prairie ridge community was thus designated the south-facing slope community.

The two upland portions of the transect remained for consideration. Their borders were already set by the adjacent community lines. The two communities were very similar but an examination of the distribution maps for several species revealed some differences. *Galium aparine*, *Populus grandidentata*, *Sanguinaria canadensis*, *Thalictrum dioicum* (for the most part) and *Uvularia grandiflora* appear on the south upland and do not occur on the north upland, while *Xanthoxylum americanum* is much more frequent on the north upland. These distributional patterns seemed to warrant a separation of the uplands into two communities: the north upland community and the south upland community.

Thus, using the species distribution maps as a guide, six communities were delimited. The prairie community once again appeared to be the most distinct, followed by the stream bottom community and the north-facing slope community. The south-facing slope, north upland, and south upland communities were difficult to distinguish by species distribution.

A third method was tried in order to subdivide more objectively the transect into communities. This method involved an ordination of all 200 plots using Orloci's ordination program (Orloci, 1966). The presence data for the 127 species were transferred to IBM cards, and the program ordinated the plots using the species as attributes. Figure 145 is a computer-drawn three-dimensional plot of the 200 stands (10x10-meter plots). Due to the large number of stands, not much can be concluded from the three-dimensional plot. It does, however, seem to confirm the belief of Curtis and McIntosh (1951) that the forest vegetation of this region is best thought of as a continuum of intergrading types of vegetation. There are no distinctive groups of stands; they are almost all different.

An examination of some two-dimensional plots of the same ordination does reveal some logic to the arrangement of the 200 plots. The X-axis holds the most information concerning the relationships of the plots to each other. Less information

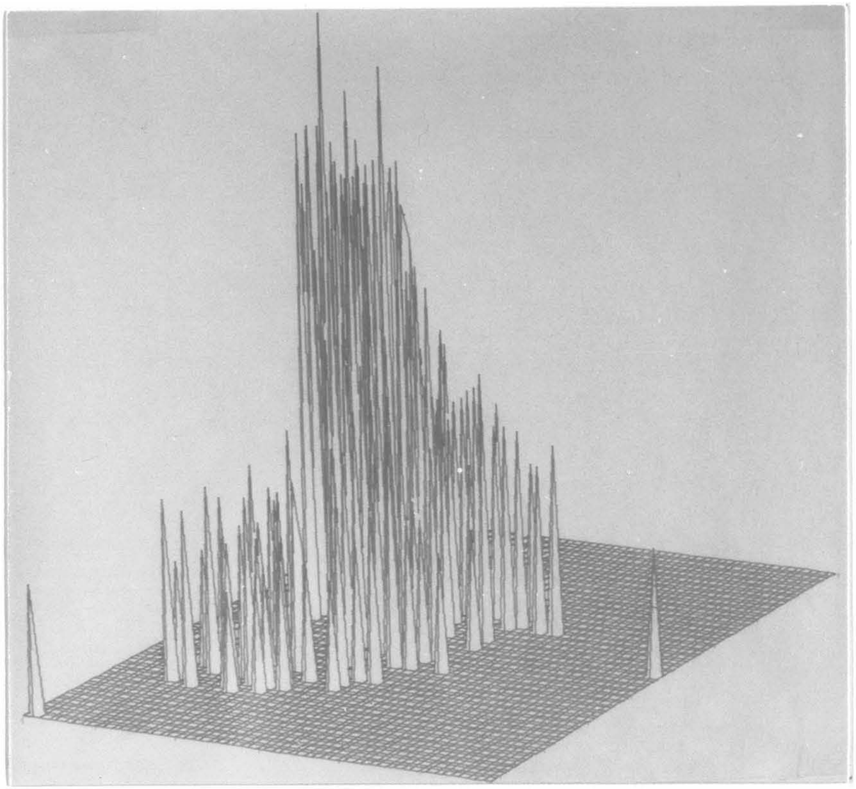

Figure 145. Computer-drawn three-dimensional plot of the Orloci ordination of the intensive study transect

is present in the Y-axis, and still less is present in the Z-axis.

Figure 146 is a plot of the X and Y coordinates. The group at the left side of the plot are the prairie stands. The group on the right are the stream bottom stands. The group in the center contains the plots of both north and south upland as well as the north-facing and south-facing slopes. Although the prairie and stream bottom plots appear as fairly distinct groups, the best term to apply to such an arrangement of stands is continuum. Based on species composition, the computer has arranged the plots in a continuum which probably corresponds to available moisture. The dry, exposed prairie opening plots occur at the extreme left while the most protected and constantly moist bottomland plots occur at the extreme right. The rest of the vegetation is indicated as intermediate in composition and probably in available moisture.

Figure 147 is a two-dimensional plot of the X and Z coordinates. Once again the prairie plots occur at the extreme left in a general group, and the stream bottom plots occur in a general group at the right. This time, however, there is a group separated at the top of the plot which corresponds to the north-facing slope community. The rest of the points correspond to the upland and south-facing slope communities.

The Y and Z coordinates of the 200 plots are plotted in Figure 148. This does not show much distinction among plots other than to group the prairie plots on the left side.

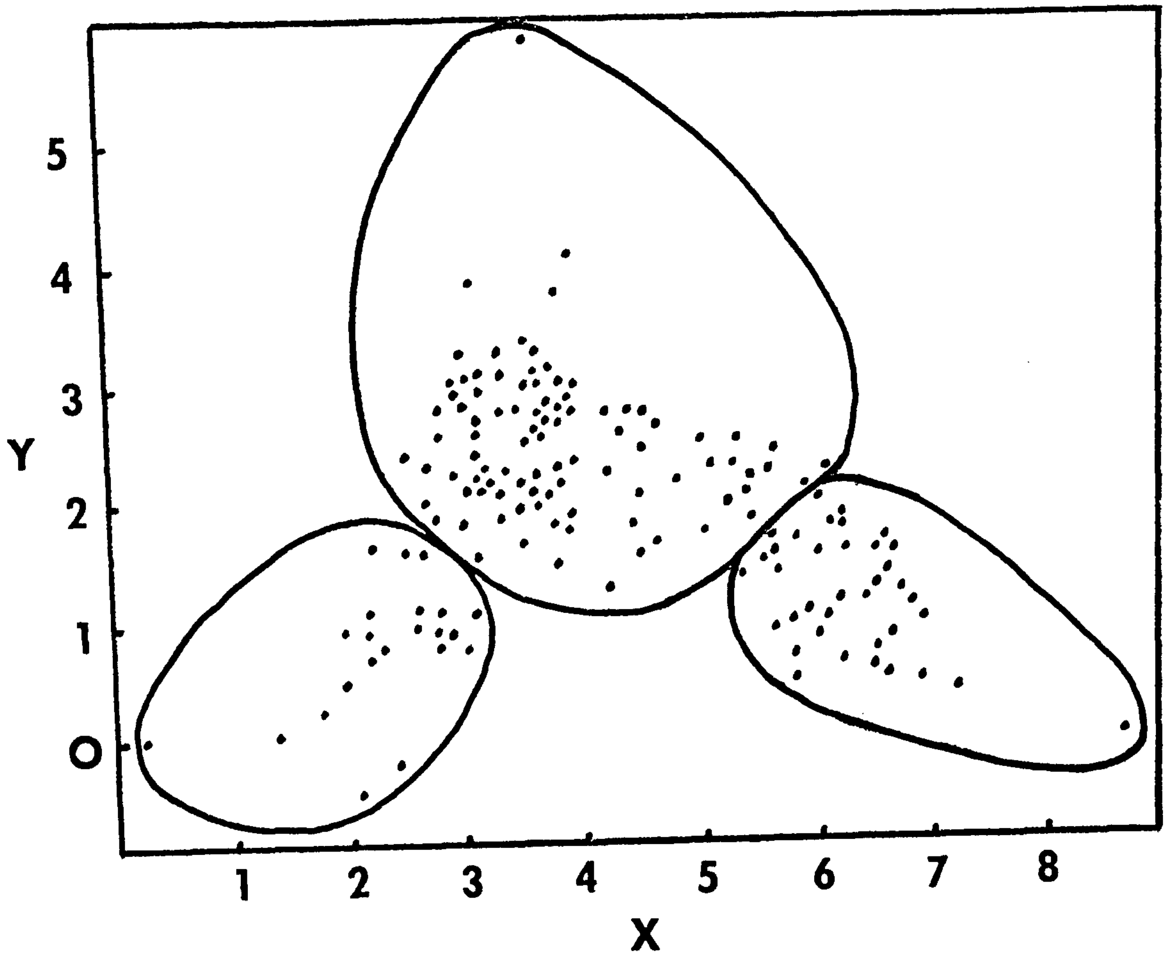

Figure 146. Two-dimensional plot of the Orloci ordination of the transect data. The group of points at the left represent prairie quadrats. The group of points at the right represent stream bottom quadrats. The group of points in the center represent all other forested quadrats in the transect

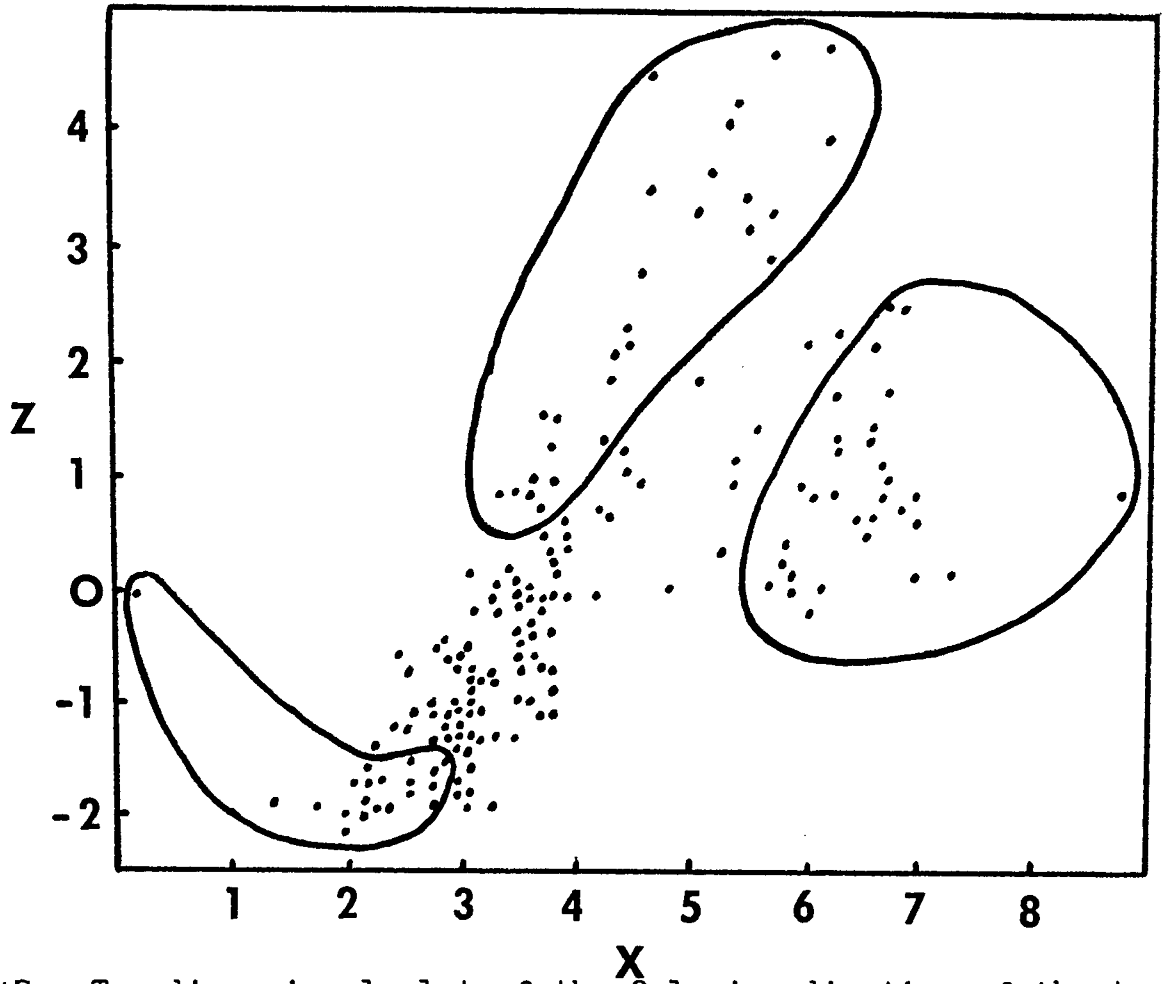

Figure 147. Two-dimensional plot of the Orloci ordination of the transect data. The group of points at the left represent prairie quadrats. The group of points in the center represent north slope quadrats. The group of points at the right represent stream bottom quadrats. The rest of the points represent forested quadrats which did not form a distinctive group

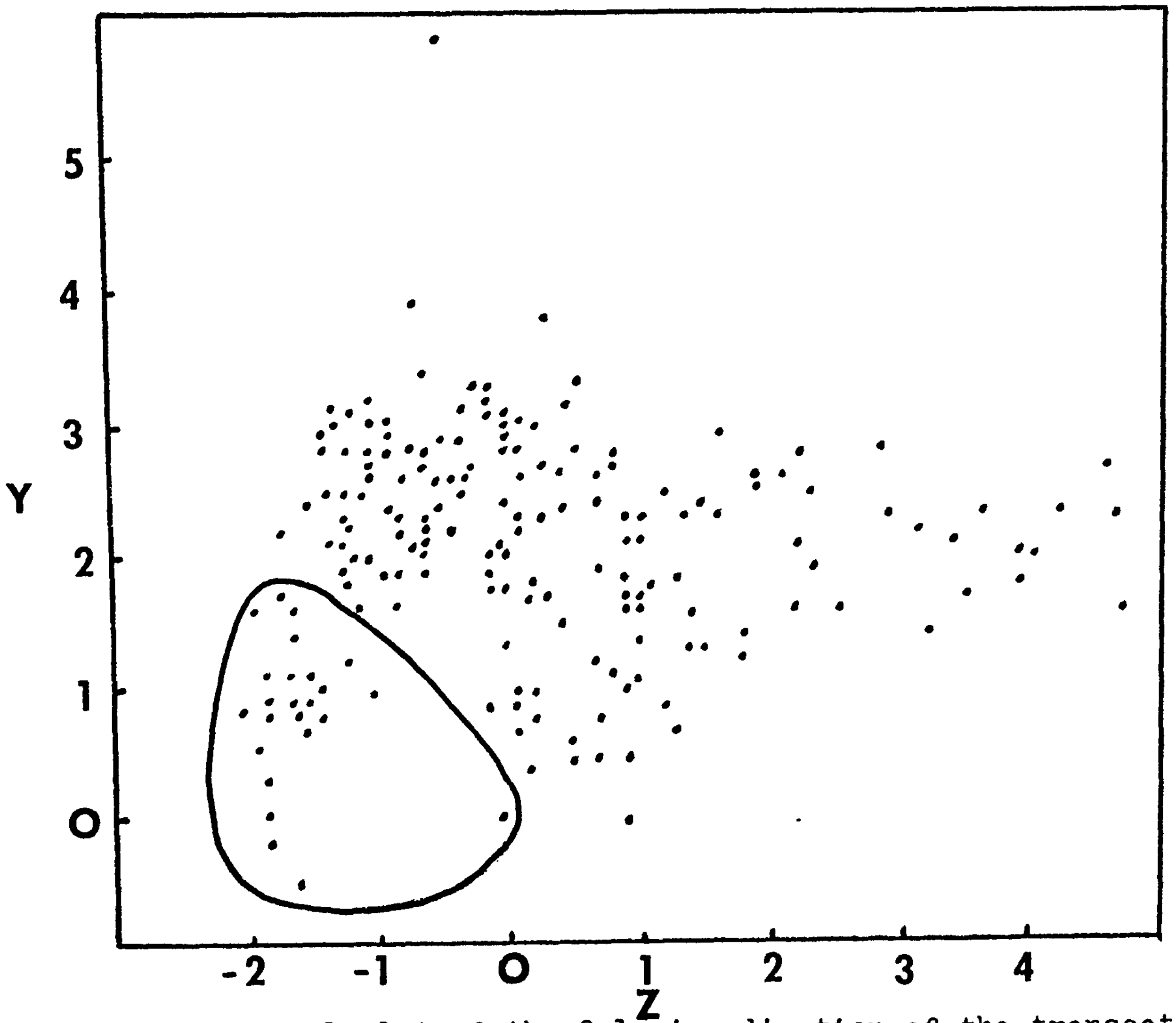

Figure 148. Two-dimensional plot of the Orloci ordination of the transect data. The group of points at the left represent prairie quadrats. The remaining points did not form distinctive groups

The main conclusion to be drawn from the Orloci ordination of presence data is that the vegetation of the transect is best described as a continuum, probably based on available moisture. The ordination confirmed the belief that the prairie should be the most distinctive community followed by the stream bottom community. The X and Z plot also picked out the north slope as being fairly distinctive with the upland and south-facing slope vegetation being indistinguishable by this method. Figure 9 shows the communities based on the Orloci ordination.

Due to the large number of species present within the transect, the cost of running the Williams and Lambert binary classification on the transect data was prohibitively high.

Of the three methods of classification used, the first was the most subjective. It took into account all aspects of the vegetation, some of which would be impossible to quantify. The second method utilized objective presence data, but it was manipulated in a subjective manner; that is, only certain indicator species were used to delineate vegetational zones. The third method was completely objective. It revealed the most realistic description of the transect as based on presence data, namely that the vegetation of the transect is a continuum of intergrading types. Still, the ordination showed that the habitats regarded as distinctive were separated from the rest to a certain degree.

Prairie Opening Study

On the shoulder position of some south and southwest-facing slopes in Woodman Hollow, small patches of tall grass prairie appear. Prairie plants are evident all along the shoulder position of the south-facing slope, but in most places they are shaded by trees. Only a few patches or prairie openings were free of trees, and four of these prairie openings were studied.

Fifty-nine species, most of which are characteristic prairie species, were found on the four openings. *Andropogon gerardii* dominated all four openings based on percentage cover. *Andropogon scoparius* was the second dominant on two openings while *Amorpha canescens* was the second dominant on the other two.

The first opening studied was the westernmost one, which had burned in April, 1970. It was roughly 10x10 meters in size. The fire removed all standing material and most of the litter, exposing the gravelly soil in most places. Stems of *Ceanothus ovatus* and *Rhus glabra* were burned to the ground, and the lower branches of junipers surrounding the opening were singed. Subjective observations were made through the summer which led to the conclusion that the plants occurring on this opening were more vigorous than the plants on the other openings. The entire opening also had a distinctly brighter green appearance, partly due to the absence of brown litter and standing stems and leaves.

The second opening was close to the first, but did not burn in 1970. It was approximately the same size as the burned opening, so it should serve as the best comparison.

The third and fourth openings were close together at the eastern edge of the preserve. Neither burned in 1970. The third was slightly larger than the first two, while the fourth was the elongate main opening about 60 meters long and 10 meters wide.

In the four openings, Andropogon gerardii had approximately the same frequency, ranging from 90 to 96% (Table 1). In contrast, on the unburned ridges the percentage cover of this species ranged from 29 to 33% while on the burned ridge the figure was 46% (Table 2). This striking difference may have been caused by the spring fire, indicating that such fires might somehow induce increased vigor in this species. Flower stem production may also be considered a measure of vigor. The flowering culms per square meter of Andropogon gerardii ranged from .4 to 2.8 on the unburned ridges while the figure was 6.0 for the burned ridge (Table 3). Once again, fire is suggested as the cause.

A somewhat similar trend may be noted in Andropogon scoparius, but it is not so striking. No other species were present in great enough quantity to draw conclusions about the influence of fire.

The prairie openings are being encroached upon by forest. Certain species will obviously disappear more rapidly than

Table 1. Frequency of occurrence of species on the four prairie openings sampled

Species	Prairie 1	Prairie 2	Prairie 3	Prairie 4
Amorpha canescens	--%	48%	47%	27%
Amphicarpa bracteata	--	1	20	--
Andropogon gerardii	96	90	95	93
Andropogon scoparius	27	33	19	64
Antennaria plantaginifolia	--	5	--	--
Apocynum androsaemifolium	28	--	--	1
Asclepias verticillata	7	3	1	5
Asclepias viridiflora	5	1	--	1
Aster azureus	1	5	2	14
Aster cordifolia	5	--	--	--
Aster ericoides	--	2	9	--
Aster laevis	21	3	4	--
Aster sericeus	3	7	15	3
Bouteloua curtipendula	14	11	11	14
Carya ovata	--	2	--	--
Carex jamesii	--	--	--	1
Carex pensylvanica	4	20	--	--
Ceanothus ovatus	25	16	25	7
Celastrus scandens	--	--	3	--
Coreopsis palmata	--	10	--	--
Cornus drummondi	--	1	--	--
Desmodium glutinosum	--	1	--	--
Desmodium illinoense	--	--	5	2
Echinacea pallida	--	--	1	43
Erigeron anuus	--	1	--	--
Eupatorium altissimum	2	--	--	--
Helianthus strummosus	--	14	9	--
Kuhnia eupatorioides	11	7	3	1
Lathyrus venosus	--	4	--	2
Lespedeza capitata	--	5	--	4
Liatris aspera	--	1	--	--
Linum sulcatum	--	--	1	1
Lithospermum canescens	14	8	15	8
Melilotus alba	--	--	7	27
Mirabilis albidus	1	--	3	2
Monarda fistulosa	--	--	1	--
Ostrya virginiana	--	13	--	--
Panicum leibergii	--	3	--	--
Parthenocissus quinquefolia	--	--	1	--

Table 1. (Continued)

Species	Prairie 1	Prairie 2	Prairie 3	Prairie 4
Petalostemum candidum	--%	42%	1%	8%
Petalostemum purpureum	31	--	24	34
Phlox pilosa	--	4	--	--
Physalis sp.	--	3	5	1
Poa pratensis	--	14	2	11
Psoralea tenuiflora	1	7	25	17
Quercus alba	--	2	--	1
Quercus rubra	--	1	--	--
Ratibida pinnata	--	2	10	--
Rhus glabra	3	13	--	--
Sisyrinchium campestre	--	--	--	3
Solidago nemoralis	--	1	4	30
Solidago rigida	4	2	--	--
Solidago ulmifolia	--	1	2	1
Sorghastrum nutans	8	2	28	23
Sporobolus asper	--	9	13	1
Vitis riparia	--	--	3	--
Viola pedatifida	--	--	1	1
Xanthoxylum americanum	--	--	2	--

Table 2. Percentage cover of species on the four prairie openings sampled

Species	Prairie 1	Prairie 2	Prairie 3	Prairie 4
Amorpha canescens	-- %	9.98%	8.44%	3.45%
Amphicarpa bracteata	--	.20	.05	--
Andropogon gerardii	45.69	29.00	32.79	27.31
Andropogon scoparius	6.41	9.21	4.46	14.81
Antennaria plantaginifolia	--	.37	--	--
Apocynum androsaemifolium	3.32	--	--	.01
Asclepias verticillata	.12	.03	.01	.09
Asclepias viridiflora	.13	.01	--	.10
Aster azureus	.05	.23	.20	1.50
Aster cordifolia	.28	--	--	--
Aster ericoides	--	.10	.69	--
Aster laevis	1.56	.40	1.30	--
Aster sericeus	.14	.24	1.06	.07
Bouteloua curtipendula	.14	.11	.12	.14
Carya ovata	--	.06	--	--
Carex jamesii	--	--	--	.01
Carex pensylvanica	.10	2.43	--	--
Ceanothus ovatus	5.12	3.73	4.01	1.20
Celastrus scandens	--	--	.25	--
Coreopsis palmata	--	.56	--	--
Cornus drummondi	--	.05	--	--
Desmodium glutinosum	--	.20	--	--
Desmodium illinoense	--	--	.32	.31
Echinacea pallida	--	--	.01	2.88
Erigeron anuus	--	.01	--	--
Eupatorium altissimum	.10	--	--	--
Helianthus strummosus	--	1.41	.83	--
Kuhnia eupatorioides	.97	1.86	.16	.01
Lathyrus venosus	--	.27	--	.02
Lespedeza capitata	--	.27	.28	--
Liatris aspera	--	.15	--	--
Linum sulcatum	--	--	.01	.01
Lithospermum canescens	.77	.12	.71	.20
Melilotus alba	--	--	.42	.44
Mirabilis albidus	.01	--	.16	.25
Monarda fistulosa	--	--	.01	--
Ostrya virginiana	--	.60	--	--
Panicum leibergii	--	.32	--	--
Parthenocissus quinquefolia	--	--	.01	--

Table 2. (Continued)

Species	Prairie 1	Prairie 2	Prairie 3	Prairie 4
Petalostemum candidum	-- %	2.39%	.10%	.27%
Petalostemum purpureum	3.88	--	1.11	2.55
Phlox pilosa	--	.04	--	--
Physalis sp.	--	.03	.05	.01
Poa pratensis	--	.39	.02	2.51
Psoralea tenuiflora	.01	2.25	3.30	4.12
Quercus alba	--	.02	--	.05
Quercus rubra	--	.05	--	--
Ratibida pinnata	--	.15	1.65	--
Rhus glabra	.65	2.21	--	--
Sisyrinchium campestre	--	--	--	.22
Solidago nemoralis	--	.20	.04	2.07
Solidago rigida	1.30	.50	--	--
Solidago ulmifolia	--	.10	.20	.05
Sorghastrum nutans	1.15	.02	1.85	1.18
Sporobolus asper	--	.37	.22	.10
Vitis riparia	--	--	.71	--
Viola pedatifida	--	--	.01	.05
Xanthoxylum americanum	--	--	.21	--

Table 3. Flowering stems per square meter of species present on the four prairie ridges sampled

Species	Prairie 1	Prairie 2	Prairie 3	Prairie 4
Amorpha canescens	--	.2	.8	.7
Amphicarpa bracteata	--	.1	--	--
Andropogon gerardii	6.0	.4	2.2	2.8
Andropogon scoparius	4.2	2.1	1.8	3.2
Antennaria plantaginifolia	--	--	--	--
Apocynum androsaemifolium	.2	--	--	--
Asclepias verticillata	--	--	--	--
Asclepias viridiflora	--	--	--	--
Aster azureus	--	.2	.2	1.4
Aster cordifolia	.2	--	--	--
Aster ericoides	--	--	.1	--
Aster laevis	2.5	.7	1.3	--
Aster sericeus	.5	.5	1.7	.1
Bouteloua curtipendula	1.5	1.5	.7	1.8
Carya ovata	--	--	--	--
Carex jamesii	--	--	--	--
Carex pensylvanica	--	--	--	--
Ceanothus ovatus	--	.3	.2	--
Celastrus scandens	--	--	--	--
Coreopsis palmata	--	.1	--	--
Cornus drummondi	--	--	--	--
Desmodium glutinosum	--	--	--	--
Desmodium illinoense	--	--	--	--
Echinacea pallida	--	--	--	.4
Erigeron anuus	--	--	--	--
Eupatorium altissimum	.3	--	--	--
Helianthus strummosus	--	.3	--	--
Kuhnia eupatorioides	1.5	1.1	.2	--
Lathyrus venosus	--	--	--	--
Lespedeza capitata	--	.3	--	.3
Liatris aspera	--	.1	--	--
Linum sulcatum	--	--	.2	--
Lithospermum canescens	.5	.1	.3	.1
Melilotus alba	--	--	.4	.8
Mirabilis albidus	.1	--	.2	.2
Monarda fistulosa	--	--	--	--
Ostrya virginiana	--	--	--	--
Panicum leibergii	--	1.2	--	--
Parthenocissus quinquefolia	--	--	--	--

Table 3. (Continued)

Species	Prairie 1	Prairie 2	Prairie 3	Prairie 4
Petalostemum candidum	--	2.2	.3	.4
Petalostemum purpureum	8.5	--	2.4	4.4
Phlox pilosa	--	.1	--	--
Physalis sp.	--	--	--	--
Poa pratensis	--	2.3	.2	.7
Psoralea tenuiflora	.1	.9	2.5	1.7
Quercus alba	--	--	--	--
Quercus rubra	--	--	--	--
Ratibida pinnata	--	.1	.7	--
Rhus glabra	--	--	--	--
Sisyrinchium campestre	--	--	--	1.1
Solidago nemoralis	--	.4	--	1.1
Solidago rigida	.2	.1	--	--
Solidago ulmifolia	--	.1	.3	.1
Sorghastrum nutans	1.6	.1	1.8	1.8
Sporobolus asper	--	--	.6	.3
Vitis riparia	--	--	--	--
Viola pedatifida	--	--	--	--
Xanthoxylum americanum	--	--	--	--

others as the size of the patch decreases. *Melilotus albus* and *Echinacea pallida* were present only on the western two ridges. The frequency of occurrence for both species was much greater on the large western opening. *Aster azureus*, *A. laevis*, *Psoralea tenuiflora*, *Solidago nemoralis*, and *Sorghastrum nutans* showed a similar trend.

Kuhnia eupatorioides showed just the opposite trend, decreasing in frequency with an increase in the size of the prairie. *Ceanothus ovatus* showed a somewhat similar trend. The size of the prairie opening was directly related to the distance from the opening to the stream bottom, and it is possible that this plays some role in determining species composition.

There can be no doubt that the size of the prairie openings was decreasing at the time of this study. *Ostrya virginiana* appeared to be a particularly vigorous invader of the prairies. The only places where fruiting individuals of this species were found in 1970 was on the margin of the prairie openings. Seedlings were even able to invade at some distance from the main front of the encroaching forest. Seedlings of *Carya ovata*, *Quercus alba*, and *Q. rubra* were also present within the prairie openings.

It seems obvious that such small patches of prairie vegetation were not always present. At one time there was probably a continuous fringe of prairie where now only patches remain. Individuals of *Ceanothus ovatus* and *Amorpha canescens* growing under forest conditions on topographic positions similar to the prairie patches should be evidence enough to indicate that this was true not so long ago. Still further back in time, however, the fringe of prairie may have been connected to the rest of the upland prairie which characterized much of Iowa.

Evidence seems to indicate that the prairie openings or patches of Woodman Hollow are actually remnants of the tall grass prairie which occupied much of the upland. The original survey map (Figure 1) shows only a narrow point of forest extending into the prairie along the stream which flows through Woodman Hollow. The written comments state that the forested land extended 200 feet (61 meters) along the transect which followed the western boundary of the preserve. Now the entire western boundary of the preserve (400 meters) is forested. The property just to the west of the preserve has been separated from the preserve for a long time as evidenced by at least three different types of barbed wire fencing used along the property line. The land to the west has been pastured recently, however <u>Andropogon</u> <u>gerardii</u> and other prairie species thrive. Presumably grazing to the west kept the area in prairie since settlement times while the area now in the preserve has converted from prairie to forest. The same conversion may have taken place on the upland throughout the preserve leaving only the most exposed locations as prairie at the present time.

Another line of evidence pointing to the same conclusion concerns the growth form of the oldest trees in the preserve. Most of these occur where the steep sloping land begins. They are mainly old specimens of Quercus alba and Quercus macrocarpa. They have the low branching characteristic of open-grown trees. Many of the large lower branches have died due to shading by the younger trees which have overtopped the old trees. Figure 149 shows one of the large open-grown oaks at the western boundary of the preserve. It may be the quarter section tree marked by the original land surveyors in 1849. Daubenmire (1936) and Cottam (1949) made similar observations in Minnesota and Wisconsin, respectively. They both concluded that prairie fires at one time killed all but the fire resistant trees leaving the oaks to develop an open-grown form. Following settlement and the cessation of prairie fires, the fire-sensitive trees produced a closed forest. The same situation appears to be true of Woodman Hollow. Figure 150 shows a specimen of Ostrya virginiana with several trunks at ground level, possibly sprouts which grew when fires ceased.

Cottam (1949) discovered that the soils of the forest he studied were forest soils. He doubted that such soils could form under savanna conditions and concluded that the savanna trees were remnants of a former forest which was thinned by fires. A study of the upland soils of Woodman Hollow might reveal the same situation, but such a study was not made.

Figure 149. Photograph of a large, open-grown specimen of _Quercus_ _macrocarpa_ located at the western edge of the preserve

Figure 150. Photograph of a multiple-stemmed Ostrya virginiana. This growth form suggests that fire-sensitive species may have been killed back to ground level by occasional fires, forming a number of aerial shoots the following year

Permanent Upland Plots

The four permanent 10x10-meter plots established on the north upland of Woodman Hollow were to serve two purposes: first, to determine current species composition of the arborescent vegetation in several size classes; and second, to serve as permanent reference areas for the observation of vegetational change on the upland. Several specimens of *Acer nigrum*, *Carya cordiformis*, and *Tilia americana* were found growing among the more xeric Oak-Hickory vegetation of the upland. The presence of these species, characteristic of the north-facing slope, was taken as an indication of a possible shift of the upland vegetation away from its present composition. However, the information obtained from the study of the permanent plots did not seem to support this belief.

The composition of the permanent plots is shown in Figures 151, 152, 153, and 154. The five dominant tree species found in the plots based on basal area were *Quercus alba*, *Q. macrocarpa*, *Carya ovata*, *Quercus rubra*, and *Fraxinus pennsylvanica*. The most dominant tree species in the 400-square-meter area, *Quercus alba*, was represented by only four specimens while the fifth dominant, *Fraxinus pennsylvanica*, was represented by 12 specimens (Table 4). There was an inverse relationship between basal area and number of specimens present among the five major species. *Quercus alba* specimens were relatively large trees while *Fraxinus pennsylvanica* specimens were scarcely mature.

Figure 151. Composition of the first permanent 10x10-meter upland plot

The following is an explanation of Figures 151, 152, 153, and 154:

The location of specimens in the 10x10-meter plots is to the nearest meter

Lower case letters indicate specimens less than 25 centimeters tall

Lower case letters which are underlined indicate specimens greater than 25 centimeters tall but less than 2 meters tall

Upper case letters indicate specimens greater than 2 meters tall but less than 2.5 centimeters in diameter at 1.5 meters above the ground

Upper case letters followed by a number indicate specimens greater than 2.5 centimeters in diameter; the number indicates the diameter in centimeters

A number preceding a letter indicates the number of specimens present in a particular square meter when more than one of a particular size and species is present

The species code is as follows:

A represents *Amelanchier arborea*
B represents *Carya cordiformis*
C represents *Carya ovata*
D represents *Celtis occidentalis*
E represents *Fraxinus pennsylvanica*
F represents *Ostrya virginiana*
G represents *Populus tremuloides*
H represents *Prunus serotina*
I represents *Quercus alba*
J represents *Quercus macrocarpa*
K represents *Quercus rubra*
L represents *Tilia americana*
M represents *Ulmus americana*

				4h H		f		J38	c
			m	e b	E11				
	d		a k c			2m	2A 8m d	m	2d
H			3h H k					m	
J36	m	F G	H	c	m	m	m		
m					m	m		f	d
d m		4m	2m						d
			5m	d			m	d	C27 C30 2c
			f		d				d
	m				d	d			A6

Figure 151. Composition of the first permanent 10x10-meter upland plot. The top of the page is north

b		c	$\underline{m}$ $\underline{i}$	e m		$\underline{d}$ e	B28 b h		
k e	E			b				b	
			c e		H11 $\underline{d}$	d m	c e	m	m b
	k	c	b	$\underline{m}$		e	M	C13	j
c			J11			e	4e m		
B6	$\underline{d}$	d	m			C8	m b $\underline{d}$	c	
	c					$\underline{h}$		c	m
	K23			e $\underline{m}$		$\underline{d}$	E10 $\underline{l}$ d	j	
		$\underline{c}$ $\underline{m}$		3m	3m		$\underline{d}$		
K12			m c	K22	3m $\underline{m}$ c	$\underline{d}$ c	$\underline{c}$		

Figure 152. Composition of the second permanent 10x10-meter upland plot. The top of the page is north

	3f e	f f	C4 K3 f			b	2f k d	f	
f	c M11	f i c	4f h e i	E7 f i k	2i 2f	i	3i 2E c f	4f b	i c
	2f c	m h e f 3f	K	3i	c f	2c	2f e	2i 5f	2e b i 2f
e	c 2e	m	c				f 3m	d 2f	4f i k C4
f	f	i				i		l	c f K
	3e c K6	E8	K	I61	m c	b	f c	c	C3 d e f
	e	f	m		h	c	f	f	h C4
	c	f K8	f e				c		
f K11					d c m h		e		c e f
			c	c f	F e	e d		e	

Figure 153. Composition of the third permanent 10x10-meter upland plot. The top of the page is north

9m							e	m	e
d			2c e E	c 2m	c	e E	c	m e	2c m m i e J23
E3 e	E3			m e	E4 i	e	I44 m		e
	e	d l	I46	e E m	c	l c	k	e	c
	m	c			c			c e	e
m	e	i c e	c e e a	b c		m c E6	m		E
k	2m		E4	m		e	m	e	E3 i 2e
m c f e E4	2m E9		m	l h	e m	e f			c e
c	e					c e a m	d	2e c	e m
		m e	c E m	e	I36 m	m c 2e	m	2m e	E i m e

Figure 154. Composition of the fourth permanent 10x10-meter upland plot. The top of the page is north

Table 4. Number of arborescent individuals in each size class[a] present in the four 10x10-meter permanent plots

Species	Class 1	Class 2	Class 3	Class 4
Amelanchier arborea	2	1	1	1
Carya cordiformis	11	2	--	1
Carya ovata	50	5	4	8
Celtis occidentalis	21	18	--	--
Fraxinus pennsylvanica	54	21	8	12
Ostrya virginiana	53	9	2	--
Populus tremuloides	--	--	1	--
Prunus serotina	6	9	4	1
Quercus alba	28	1	--	4
Quercus macrocarpa	1	1	--	5
Quercus rubra	8	--	3	7
Tilia americana	3	2	--	--
Ulmus americana	80	12	2	1

[a] Class 1 consists of individuals less than 25 cm tall; class 2 consists of individuals greater than 25 cm tall but less than 2 meters tall; class 3 consists of individuals greater than 2 meters tall but less than 2.5 cm in diameter; class 4 consists of individuals greater than 2.5 cm in diameter

Table 4 shows that of the five dominants, only Carya ovata and Fraxinus pennsylvanica are represented in all four size classes. This might lead one to conclude that these two species are more successful than the Oaks and will tend to replace them. This seems unlikely, however, because all of the larger specimens of Fraxinus pennsylvanica showed insect and fungus damage. Several standing dead specimens were found. Carya ovata also failed to reach a large size in the sample area.

The other arborescent species encountered in the plots included *Amelanchier arborea* and *Ostrya virginiana*. Neither of these species is capable of dominating the area since they are understory trees rarely exceeding 10 cm in diameter.

Celtis occidentalis reached tree proportions only in the stream bottom and along the Des Moines River banks. *Populus tremuloides* dominated a portion of the northern boundary of the preserve, probably due to moisture conditions which prevail there. *Tilia americana* reached tree proportions on the north upland only near the slope breaks. Thus it seems unlikely that any of these species will tend to increase in dominance in these plots in the future.

Ulmus americana and *Prunus serotina* were each represented by only one specimen over 2.5 cm in diameter within the 400-square-meter-sample area. *Ulmus* cannot assume a position of dominance because of the effects of the Dutch Elm Disease. It is interesting to note that seedlings of *Ulmus* were the most abundant seedlings in the plots. Trees of *Prunus serotina* were affected by insects and fungi in much the same way as *Fraxinus pennsylvanica*. Specimens failed to reach a large size and several standing dead trees were present.

Some small seedlings and one mature specimen of *Carya cordiformis* were found within the 400-square-meter area. Several other specimens of this species were found on the north upland outside the permanent plots. Although the specimens appeared vigorous, they were not common, so it seems unlikely that this species will tend to dominate the upland locations.

Thus it appears that the vegetation of the north upland of Woodman Hollow is fairly stable and will not change appreciably as long as climatic conditions remain unchanged. This disagrees with McIntosh (1957) who concluded that Oak and Hickory would eventually be replaced by Maple and Basswood on the uplands of central Wisconsin. The periodic severe droughts of central Iowa, however, have killed some <u>Acer</u> <u>nigrum</u> specimens even on sloping topography (Aikman and Smelser, 1938). Such droughts will undoubtedly occur in the future and limit the growth of mesic species on the upland. A future observation of the permanent plots will reveal any trend which might develop.

Diversity Index Values

Diversity index values were calculated to determine whether they can be of value in ascertaining the successional status of stands of forest vegetation. Margalef (1958) felt that plankton exhibited greater heterogeneity in advanced stages of succession. The same is obviously true of many types of succession involving land plants. Thus the most heterogeneous community may be thought of as the most advanced in a successional sense. Aikman and Smelser (1938) described the Maple-Basswood community as the climax forest community in central Iowa, so it should also be the most heterogeneous.

The stream bottom had the lowest diversity index value of the five sites sampled, 1.01. This is reasonable because the stream bottom is constantly disturbed by the spring floods and siltation by the Des Moines River. Few species are able to thrive under such conditions of disturbance, and succession is impeded.

The north upland had a diversity index value of 1.72. This is reasonable considering the species-poor nature of that location in relation to the south upland.

The upper south-facing slope had a diversity index value of 2.64, which was higher than expected. Although the sampling was carried out on the upper part of the south-facing slope, the high value shows that the south-facing slope is successionally closer to the north-facing slope than to the north upland. The considerable disturbance caused by soil erosion would seem to keep this location at a low successional level, but the favorable soil moisture may more than compensate for the disturbance.

The south upland and lower north-facing slope had almost identical values of 3.08 and 3.07, respectively. The south upland data was taken near the slope break which may have been one reason for the high value, but it was none the less apparent that many north-facing slope species grew on the south upland even though they were much less abundant. Acer nigrum and Tilia americana were both present on the south upland as well as the north-facing slope, indicating that the two locations may have been close to each other successionally. Thus, the Maple-Basswood community had the highest diversity index value as well as the highest successional status based on subjective considerations. This diversity index seemed to be of value in relating locations successionally to each other.

SUMMARY

1. The vegetation of a transect in the eastern portion of Woodman Hollow was classified into communities using three different methods.

   a. A purely subjective method of classification based on field experience yielded eight communities based on habitat: south upland, upper north-facing slope, lower north-facing slope, stream bottom, lower south-facing slope, upper south-facing slope, prairie opening, and north upland.

   b. A method of classification based on species distribution resulted in a classification of communities very similar to that obtained by purely subjective methods except that the lower north and lower south-facing slope habitats were not distinguishable from the stream bottom.

   c. The Orloci ordination of the transect (Orloci, 1966) demonstrated that the vegetation really consists of a continuum of types, with four distinctive types: the prairie opening, stream bottom, north-facing slope, and the combined uplands and south-facing slope.

2. The prairie openings appeared to be diminishing in size. Invasion of tree seedlings and historical evidence,

including the original land survey records, seem to indicate that the prairie openings are the last remnants of the upland prairie which have been replaced by closed forest in most of the preserve.

3. The study of the upland plots revealed that the vegetation of the north upland appears to be relatively stable and will change little if climatic conditions remain stable.

4. Diversity index values were 1.01 for the stream bottom, 1.72 for the north upland, 2.64 for the upper south-facing slope, 3.07 for the upper north-facing slope, and 3.08 for the south upland. These values suggest a successional series from stream bottom to Maple-Basswood without implying an actual sequence.

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APPENDIX

Woodman Hollow Plant List

1. Nomenclature for grasses follows Pohl (1966).

2. Nomenclature for all other vascular plants follows Fernald (1950) except for the use of lower case letters to begin all specific epithets.

Acalypha rhomboidea Raf.
Acer negundo L.
Acer nigrum Michx. f.
Acer saccharinum L.
Actaea rubra (Ait.) Willd.
Acnida tamariscina (Nutt.) Wood
Actinomeris alternifolia (L.) DC.
Adiantum pedatum L.
Agastache nepetoides (L.) Ktze.
Agrimonia gryposepala Wallr.
Agrostis alba L.
Agrostis hiemalis (Walt.) B.S.P.
Agrostis perennans (Walt.) Tuck.
Alisma triviale Pursh
Allium canadense L.
Allium tricoccum Ait.
Ambrosia artemisiifolia L.
Ambrosia trifida L.
Amelanchier arborea (Michx. f.) Fern.
Amorpha canescens Pursh
Amorpha fruticosa L.
Amphicarpa bracteata (L.) Fern.
Andropogon gerardii Vitman
Andropogon scoparius Michx.
Anemone cylindrica Gray
Anemone quinquefolia L.
Anemone virginiana L.
Anemonella thalictroides (L.) Spach
Antennaria plantaginifolia (L.) Hook.
Apios americana Medic.
Apocynum androsaemifolium L.
Apocynum cannabinum L.
Aquilegia canadensis L.
Arabis canadensis L.
Aralia nudicaulis L.

Aralia racemosa L.
Arctium minus (Hill) Bernh.
Arisaema atrorubens (Ait.) Blume
Artemisia ludoviciana Nutt.
Asarum canadense L.
Asclepias incarnata L.
Asclepias syriaca L.
Asclepias tuberosa L.
Asclepias verticillata L.
Asclepias viridiflora Raf.
Asparagus officinalis L.
Aster azureus Lindl.
Aster cordifolius L.
Aster dumosus L. var. strictior T.&G.
Aster ericoides L.
Aster laevis L.
Aster ontarionis Wieg.
Aster parviceps (Burgess) Mackenz. & Bush
Aster pilosus Willd. var. demotus Blake
Aster sericeus Vent.
Astragalus canadensis L.
Astragalus caryocarpus Ker.
Athyrium felix-femina (L.) Roth
Atriplex patula L. var. hastata (L.) Gray

Barbarea vulgaris R. Br.
Bidens comosa (Gray) Wieg.
Bidens frondosa L.
Botrychium virginianum (L.) Sw.
Bouteloua curtipendula (Michx.) Torr.
Bromus purgans L.
Bromus pubescens Muhl.

Cacalia tuberosa Nutt.
Campanula americana L.
Camptosorus rhizophyllus (L.) Link
Cardamine bulbosa (Schreb.) BSP.
Cardamine pensylvanica Muhl.
Carex albursina Sheldon
Carex convoluta Mackenz.
Carex cristatella Britt.
Carex emoryi Dew.
Carex jamesii Schwein.
Carex normalis Mackenz.
Carex oligocarpa Schkuhr
Carex pensylvanica Lam.
Carpinus caroliniana Walt.
Carya cordiformis (Wang.) K. Koch
Carya ovata (Mill.) K. Koch

Cassia fasciculata Michx.
Caulophyllum thalictroides (L.) Michx.
Ceanothus americanus L.
Ceanothus ovatus Desf.
Celastrus scandens L.
Celtis occidentalis L.
Chenopodium album L.
Chrysopsis camporum Greene
Cinna arundinacea L.
Circaea quadrisulcata (Maxim.) Franch. & Sav. var. canadensis (L.) Hara
Cirsium altissimum (L.) Spreng.
Cirsium vulgare (Savi) Tenore
Claytonia virginica L.
Clematis virginiana L.
Comandra richardsiana Fern.
Coreopsis palmata Nutt.
Cornus alternifolia L. f.
Cornus drummondi Meyer
Cornus rugosa Lam.
Corylus americana Walt.
Crataegus mollis (T.&G.) Scheele
Cryptogramma stelleri (Gmel.) Prantl
Cryptotaenia canadensis (L.) DC.
Cyperus ferruginescens Boeckl.
Cyperus filiculmis Vahl
Cyperus inflexus Muhl.
Cyperus strigosus L.
Cystopteris bulbifera (L.) Bernh.
Cystopteris ~~fragilis (L.) Bernh.~~ protrusa see Blasdell

Danthonia spicata (L.) Beauv.
Dentaria laciniata Muhl.
Desmodium canadense (L.) DC.
Desmodium cuspidatum (Muhl.) Loud.
Desmodium glutinosum (Muhl.) Wood
Desmodium illinoense Gray
Desmodium paniculatum (L.) DC.
Dicentra cucullaria (L.) Bernh.
Diervilla lonicera Mill.
Digitaria sanguinalis (L.) Scop.
Dirca palustris L.
Draba reptans (Lam.) Fern.
Dryopteris goldiana (Hook.) Gray

Echinacea pallida Nutt.
Echinochloa muricata (Beauv.) Fern
Eleocharis calva Torr.
Elymus canadensis L.

Elymus villosus Muhl.
Elymus virginicus L.
Elymus wiegandii Fern.
Epilobium glandulosum Lehm. var. adenocaulon (Haussk.) Fern.
Equisetum arvense L.
Equisetum hyemale L.
Eragrostis capillaris (L.) Nees.
Eragrostis hypnoides (Lam.) B.S.P.
Eragrostis pectinacea (Michx.) Nees.
Erigeron annuus (L.) Pers.
Erigeron canadensis L.
Erigeron philadelphicus L.
Erysimum cheiranthoides L.
Erythronium albidum Nutt.
Euonymus atropurpureus Jacq.
Eupatorium altissimum L.
Eupatorium perfoliatum L.
Eupatorium purpureum L.
Eupatorium rugosum Houtt.
Euphorbia esula L.

Festuca obtusa Biehler
Fragaria vesca L. var. americana Porter
Fragaria virginiana Duchesne
Fraxinus americana L.
Fraxinus pennsylvanica Marsh. var. subintegerrima (Vahl) Fern.

Galium aparine L.
Galium boreale L.
Galium concinnum T.&G.
Galium triflorum Michx.
Geranium maculatum L.
Geum canadense Jacq.
Glyceria striata (Lam.) Hitch.

Habenaria viridis (L.) R. Br. var. bracteata (Muhl.) Gray
Hackelia virginiana (L.) I.M. Johnston
Helianthemum bicknellii Fern.
Helianthus strumosus L.
Helopsis helianthoides (L.) Sweet
Hepatica acutiloba DC.
Hordeum jubatum L.
Hydrophyllum virginianum L.
Hystrix patula (L.) Moench.

Impatiens pallida Nutt.

Juglans cinerea L.
Juglans nigra L.

Juncus tenuis Willd.
Juniperus virginiana L.

Koeleria cristata (L.) Pers.
Kuhnia eupatorioides L.

Lactuca canadensis L.
Lactuca floridiana (L.) Gaertn.
Lactuca scariola L.
Laportea canadensis (L.) Wedd.
Lathyrus ochroleucus Hook.
Lathyrus venosus Muhl.
Lechea stricta Leggett
Leersia oryzoides (L.) Sw.
Leersia virginica Willd.
Leonurus cardiaca L.
Lepidium densiflorum Schrad.
Lespedeza capitata Michx.
Liatris aspera Michx.
Lilium michiganense Farw.
Lindernia dubia (L.) Pennell
Linum sulcatum Riddell
Liparis lilifolia (L.) Richard
Lippia lanceolata Michx. var. recognita Fern. & Grisc.
Lithospermum canescens (Michx.) Lehm.
Lobelia siphilitica L.
Lonicera dioica L.
Lycopus americanus Muhl.
Lycopus virginicus L.
Lythrum alatum Pursh

Maianthemum canadense Desf.
Medicago lupulina L.
Melilotus albus Desr.
Melilotus officinalis (L.) Lam.
Menispermum canadense L.
Mentha arvensis L.
Mimulus ringens L.
Mirabilis albida (Walt.) Heimerl
Mirabilis nyctaginea (Michx.) MacM.
Mitella diphylla L.
Monarda fistulosa L.
Morus rubra L.
Muhlenbergia cuspidata (Torr.) Rydb.
Muhlenbergia frondosa (Poir.) Fern.
Muhlenbergia mexicana (L.) Trin.
Muhlenbergia racemosa (Michx.) B.S.P.

Nepeta cataria L.

Oenothera biennis L.
Orchis spectabilis L.
Oryzopsis racemosa (J.E. Smith) Ricker.
Osmorhiza claytoni (Michx.) C.B. Clarke
Osmunda claytoniana L.
Ostrya virginiana (Mill.) K. Koch
Oxalis stricta L.
Oxalis violacea L.

Panax quinquefolius L.
Panicum capillare L.
Panicum latifolium L.
Panicum leibergii (Vasey) Scribn.
Panicum virgatum L.
Paronychia canadensis (L.) Wood
Parthenocissus quinquefolia (L.) Planch.
Pedicularis canadensis L.
Penthorum sedoides L.
Petalostemum candidum (Willd.) Michx.
Petalostemum purpureum (Vent.) Rydb.
Phleum pratense L.
Phlox divaricata L.
Phlox pilosa L.
Phryma leptostachya L.
Physalis heterophylla Nees.
Physostegia virginiana (L.) Benth.
Pilea pumila (L.) Gray
Plantago rugelii Dcne.
Poa compressa L.
Poa pratensis L.
Polygala senega L.
Polygonatum canaliculatum (Muhl.) Pursh
Polygonum aviculare L.
Polygonum coccineum Muhl.
Polygonum convolvulus L.
Polygonum pensylvanicum L.
Polygonum punctatum Ell. var. leptostachyum (Meisn.) Small
Polygonum tenue Michx.
Polypodium virginianum L.
Populus deltoides Marsh.
Populus grandidentata Michx.
Populus tremuloides Michx.
Potentilla norvegica L.
Prenanthes alba L.
Prunella vulgaris L.
Prunus americana Marsh.
Prunus mahaleb L.
Prunus serotina Ehrh.
Prunus virginiana L.

Psoralea tenuiflora Pursh
Pteretis pensylvanica (Willd.) Fern.

Quercus alba L.
Quercus macrocarpa Michx.
Quercus rubra L.

Ranunculus abortivus L.
Ranunculus pensylvanicus L. f.
Ranunculus sceleratus L.
Ranunculus septentrionalis Poir.
Ratibida pinnata (Vent.) Barnh.
Rhamnus cathartica L.
Rhus aromatica Ait.
Rhus glabra L.
Rhus radicans L.
Ribes cynosbati L.
Rorippa islandica (Oeder) Borbas
Rosa arkansana Porter
Rosa blanda Ait.
Rubus allegheniensis Porter
Rubus occidentalis L.
Rudbeckia hirta L.
Rudbeckia laciniata L.
Rumex crispus L.
Rumex maritimus L. var. fueginus (Phil.) Dusen
Rumex verticillatus L.

Salix fragilis L.
Salix nigra Marsh.
Sambucus canadensis L.
Sanguinaria canadensis L.
Sanicula gregaria Bickn.
Sanicula marilandica L.
Scirpus atrovirens Willd.
Scrophularia marilandica L.
Scutellaria lateriflora L.
Scutellaria parvula Michx. var. leonardi (Epling) Fern.
Senecio plattensis Nutt.
Setaria lutescens (Weigel) F.T. Hubb.
Setaria viridis (L.) Beauv.
Silene stellata (L.) Ait. f.
Sisyrinchium campestre Bickn.
Smilacina racemosa (L.) Desf.
Smilacina stellata (L.) Desf.
Smilax ecirrhata (Engelm.) S. Wats.
Smilax herbacea L.
Smilax tamnoides L. var. hispida (Muhl.) Fern.
Solanum americanum Mill.

Solidago altissima L.
Solidago flexicaulis L.
Solidago nemoralis Ait.
Solidago rigida L.
Solidago ulmifolia Muhl.
Sorghastrum nutans (L.) Nash
Spartina pectinata Link.
Sporobolus asper (Michx.) Kunth.
Stachys palustris L. var. nipigonensis Jennings
Staphylea trifolia L.
Symphoricarpos orbiculatus Moench

Taraxacum officinale Weber
Teuchrium canadense L.
Thalictrum dasycarpum Fisch. & Lall.
Thalictrum dioicum L.
Tilia americana L.
Tovara virginiana (L.) Raf.
Tradescantia virginiana L.
Trifolium pratense L.
Trifolium repens L.
Trillium nivale Riddell
Triosteum perfoliatum L.
Typha latifolia L.

Ulmus americana L.
Urtica dioica L.
Uvularia grandiflora Sm.

Verbascum thapsus L.
Verbena hastata L.
Verbena stricta Vent.
Verbena urticifolia L.
Vernonia fasciculata Michx.
Veronica peregrina L.
Veronicastrum virginicum (L.) Farw.
Viburnum lentago L.
Viburnum rafinesquianum Schultes
Viola pedatifida G. Don
Viola pensylvanica Michx.
Viola sororia Willd.
Vitis riparia Michx.

Woodsia obtusa ~~ilvensis (L.) R. Br.~~ [illegible]

Xanthium italicum Moretti
Xanthoxylum americanum Mill.

Zizia aurea (L.) W.D.J. Koch