Two Decades of Vegetational Change in the Ross Biological Reserve

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Abstract

The Ross Biological Reserve is a 55-acre riverside tract of forest and old fields owned by Purdue University and administered by the Department of Biological Sciences at the West Lafayette Campus. The vegetation of the Reserve was first analyzed and mapped in 1950, when 13 vegetation types were recognized, and grouped into 5 oldfield woodland, and 3 forest types. The analysis was repeated and expanded in 1960 and successional trends were described.

The present study reports and evaluates changes in the vegetation of the *Poa-Andropogon-Rubus* upland and the *Quercus-Carya* Forest for the period 1950-1971. The upland oldfield has shown rapid invasion by woody species from the adjacent forest. Tulip, black and red oak, and white ash predominate in this area. The *Quercus-Carya* forest dominates the Reserve, occupying the general south-facing slope. Full tallies were made in 1960 and 1970 of trees over 4 inches diameter breast height for a 13.2-acre area. White ash, tulip, and other species characteristic of moist sites increased in importance during the period, while the importance of species characteristic of more xeric sites, such as the hickories and some oaks, decreased or made only small gains.

Net primary above-ground productivity was measured in the *Poa-Andropogon-Rubus* and Grass-*Ambrosia* upland oldfields using harvest quadrats. Biomass accumulated during the 1971 growing season averaged 1.105 and 0.316 kilograms per square meter, respectively.

Introduction

The Ross Biological Reserve is a 55-acre tract located in Tippecanoe County, Indiana, approximately 8 miles southwest of the main campus of Purdue University in West Lafayette. This tract was acquired in 1949 by the Department of Biological Sciences of Purdue University from the Purdue Research Foundation which had administered the area as part of "The Hills" farm.

The Reserve is situated on the slope between the Wisconsin age till plain on the north and the Wabash River on the south. The difference in elevation is approximately 180 feet from the edge of the upland plateau to the river. These slopes are dissected by steep-walled ravines cut into the glacial till and outwash by a small stream, Orchis Creek, and its two main tributaries in the western half of the Reserve. The topography in the eastern half is dominated by broad, more gently sloping coves in which the *Quercus-Carya* Forest is most highly developed. Below these slopes are knolls of fine wind-blown sand and below them is a narrow strip of floodplain deposits of the Wabash. This variety of topographic features is paralleled by a wide diversity of ecological habitats and it is this concentration of habitat diversity which makes the Reserve so valuable for ecological instruction and research.

Prior to its acquisition and subsequent fencing by the Department of Biological Sciences, the land was utilized for crops, grazing and lumbering. The area is now largely undisturbed except for supervised use by ecology classes of the University. Nine master's theses have been written, based wholly or in part on research performed at the Reserve.

The present study is the third in a series concerned with the vegetation of the Reserve. The first vegegation study was performed by Kenneth Bush in 1950 (1). Bush mapped the Reserve and described 13 vegegation types as well as establishing the general pattern for further surveys to be undertaken at 10-year intervals. Ronald deLanglade (2) continued this work and enlarged upon Bush's methods.

Methods

The procedures followed in the analysis of the vegetation of the old fields and woodlands were essentially those used by Bush and deLanglade. A permanent reference grid of steel stakes driven at two chain intervals throughout the Reserve in 1948 was used to locate the sample quadrats. Two quadrats, a 5-link square (1/4000 acre) herbaceous quadrat and a 10 x 50-link (1/200 acre) woody quadrat, were used at each sampling point. The metal stake served as the southeast corner of the woody quadrat and the southwest corner of the herbaceous quadrat. Individuals were counted by species in the herbaceous quadrats. All trees under 4 inches dbh were counted and classified by species and by height in the woody quadrats and trees 4 inches dbh and over were recorded by species and diameter.

A full tally of 13.2 acres of the *Quercus-Carya* Forest type, first carried out in 1960, was repeated in this study. All trees over 4 inches dbh, from 33 two-chain square (0.4 acres) plots, were measured with a diameter tape and recorded by species and size class. Attributes of density, basal area, frequency, and importance (6) were calculated and results from the two surveys compared.

To supplement the quantitative analyses, photographs were taken from selected stakes in 1950 and repeated from the same position and direction in 1960 and 1971.

An effort was also made to determine the net annual community productivity of the two upland oldfield areas in which succession has been most rapid. Two 50 x 100 link (1/20 acre) woody harvest quadrats, one in each field, were selected. Within each of these, a 20 x 20 link (1/1000 acre) herbaceous quadrat was located. In the large woody quadrats, all above ground production of trees, shrubs and woody vines was cut and weighed in the field. To obtain ratios of wet to dry weight which could be applied to these data, one 25 foot tree (*Fraxinus americana*) was dried in the laboratory. Leaves and woody parts were dried and weighed separately. Using the ratios thus obtained, the productivity of biomass on an annual basis could be estimated for woody plants. All material from the herbaceous quadrats was weighed dry and the productivity of this layer added to that of the woody plants to obtain the desired overall productivity figures.

Results

Quantitative data were gathered for 7 of Bush's 13 vegetation types. However, results will be given and discussed for only the *Poa-Andropogon-Rubus* Upland, the larger of the two upland oldfields on which the net productivity study was carried out, and the *Quercus-Carya* Forest type.

FIGURE 1. *The* Poa-Andropogon-Rubus *Upland in 1950 (above) and 1971 (below), looking southward from the same marker stake.*

The *Poa-Andropogon-Rubus* Upland includes approximately 7.5 acres of level upland. The soil type is Russell Silt Loam, 2-6% slope. No woody quadrat data are reported from the 1950 analysis, but several small trees were present (Fig. 1) indicating that the field had already been abandoned for several years. In 1960, data were given from 18 woody quadrats. In the under 4 inches dbh size class 376 individuals were found representing 24 species. *Ulmus fulva, Fraxinus americana,* and *Acer saccharum* dominated this size class with 24, 15, and 14% of the total, respectively. Only 4 trees larger than 4 inches dbh were reported in the woody quadrats in 1960 (3).

Ten woody quadrats were used in the present study of this upland oldfield. There were 354 individuals under 4 inches dbh of 23 species. Dominance was much more evenly shared, however. Only one species, *Acer saccharum,* had more than 8% of the total (17%). Other important species in this size class were: *Prunus serotina, Rhus glabra, Malus coronaria, Fraxinus americana,* and *Carya glabra.* Some of the larger individuals found in these quadrats in 1971 were: *Liriodendron tulipifera* 11.6 and 11.0 inches dbh, *Quercus velutina* 11.3 inches and *Populus grandidentata* 10.8 and 8.7 inches.

Bush reported 9 herbaceous species in the 1950 survey of the *Poa-Andropogon-Rubus* Upland. The three dominants, for which the area was named, were *Poa compressa, Andropogon virginicus* and *Rubus flagellaris. Poa compressa* was too abundant to count but had a frequency of 35.1%. *Andropogon virginicus* had a density of 5,081 stems per acre, while that of *Rubus flagellaris* was 3,289 per acre. Their frequencies were 88.2 and 82.3%, respectively.

The number of herbaceous species increased from 9 to 32 in the first decade and dropped to 28 from 1960 to 1971. Table 1 compares the data on herbaceous species from these last two surveys. Fourteen species found in 1960 occurred in the 1971 quadrats. Fifteen species were lost during the period and 14 new species were noted. *Rubus flagellaris* declined significantly from 38,333 per acre and 89% frequency to 12,800 per acre and 50%, and *Andropogon virginicus* which was a dominant in 1950 and a minor species in 1960, was not found in the herbaceous quadrat in 1971. *Monarda fistulosa, Solidago* spp., *Potentilla simplex* and *Ambrosia elatior* also seem to be gradually disappearing from the area as shading by the developing tree canopy increases.

The net aboveground community productivity of the *Poa-Andropogon-Rubus* Upland was determined for the 1971 growing season. A site was chosen for the woody and herbaceous harvest quadrats which was representative of the field as a whole. The woody vegetation was dominated by *Prunus, Malus, Ulmus* and *Fraxinus.* Thirty-six trees were harvested representing 16 species. The live weight of these trees was 1536.5 kg. This figure, when multiplied by our wet weight to dry weight ratio of 0.65 yielded a dry weight estimate of 998.7 kg. Above-ground standing biomass of woody plants for the 50 x 100 link, 202.3m^2 quadrat (0.05 acres) was, therefore, 4.94 kg/m^2.

TABLE 1. *Density per acre and frequency for herbaceous species of the* Poa-Andropogon-Rubus *Upland.*

Species	1971 Density/acre	1971 Freq.	1960 Density/acre	1960 Freq.
Poa compressa	2,273,200	80%	525,769	100%
Daucus carota	21,200	50	11,326	61
Carex spp.	16,000	20	871	17
Rubus flagellaris	12,800	50	38,333	89
Dianthus armeria	5,200	10	1,307	6
Lespedeza sp.	4,000	30		
Desmodium spp.	3,600	50	6,098	61
Plantago	3,600	40	871	6
Rubus allegheniensis	3,200	10		
Fragaria virginiana	2,400	20	871	11
Helianthus sp.	2,400	10		
Apios americanna	2,000	10		
Convolvulus sepium	2,000	10		
Euphorbia corollata	2,000	10		
Panicum spp.	2,000	10	14,810	67
Galium spp.	2,000	10	871	11
Botrychium virginianum	1,600	20		
Oxalis sp.	1,600	20	218	6
Rosa carolina	1,600	10		
Solidago spp.	1,200	20	3,920	22
Amphicarpa bracteata	800	10		
Monarda fistulosa	800	10	30,828	50
Sanicula canadensis	800	10		
Hypericum punctatum	400	10		
Phyrma leptostachya	400	10		
Potentilla simplex	400	10	28,750	22
Smilax sp.	400	10		
Taraxacum officinale	400	10		
Draba repens			17,860	22
Lysimachia lanceolata			11,326	6
Achilles millifolium			7,841	33
Danthonia spicata			6,970	6
Andropogon virginicus			4,792	33
Cerastium spp.			2,614	22
Ambrosia elatior			1,307	17
Cirsium sp.			1,307	17
Melilotus officinalis			1,307	6
Rumex acetosella			871	17
Solanum sp.			871	11
Potentilla recta			436	6
Erigeron sp.			218	6
Mentha sp.			218	6
Specularia perfoliata			218	6

In the sample tree dried in the laboratory, the dry weight of leaves was 16.1% of the total dry weight. This percentage was applied to the estimated total dry weight of the woody material harvested, yielding a producitivity figure of 0.795 kg/m^2/year for leaves of woody plants. The remaining total weight of wood and bark was then divided by 21 years to obtain an average annual productivity estimate, for this fraction, or 0.197 kg/m^2/year. 1950 was used as the base year because it is known that very few woody invaders were established in this area at that time. The upper photograph of Figure 1 shows this clearly. This picture was made in 1950 from a stake 66 feet west of our woody harvest quadrat in this area.

It was assumed that, since below-ground plant parts were not harvested, all material clipped from the herbaceous quadrat was produced during the 1971 growing season. The total live weight of this herbaceous material was 5.96 kg. which, upon drying, reduced to 2.95 kg. Our 20 x 20 link plot had an area of 40.47m^2 (0.001 acre). Thus, the net productivity of the herbaceous layer was computed to be 0.073 kg/m^2/year.

Summing the productivity figures from both the woody and the herbaceous quadrats, we obtained as estimate of net annual community productivity for all aboveground plant parts of 1.065 kg/m^2/year. Lieth gives a range of net primary productivity for warm temperate mixed forests of 0.6 to 2.5 kg/m^2/year (5). Allowing for the omission of root biomass from this study, it appears that this young woodland community has been very productive during the early stages of its development. A similar upland oldfield in the Reserve, the Grass-*Ambrosia* Upland, was also sampled in 1971 using the same size quadrats and identical methods. The net aboveground community productivity of this area was, however, much lower than that of the *Poa-Andropogon-Rubus* Upland at 0.316 kg/m^2/year. This difference is probably due, in part, to a fire which occurred in the area at least 10 years before our productivity study. Another possibility is more intensive grazing prior to the fencing of the Reserve in 1949.

The *Quercus-Carya* Forest is the most extensive vegetation type in the Reserve. The soil is largely Hennepin Sandy Loam and the slope ranges from 2 to 35% (4). The 1950 analysis of the woody overstory of the forest was based on 36 woody (1/200 acre) quadrats. The dominant species in order of importance were: *Quercus borealis*, *Quercus alba*, *Carya glabra*, and *Juglans nigra*. Since grazing had been permitted in the area prior to acquisition by the Department of Biological Sciences, there was little woody reproduction present. In 1960, a similar survey of 56 quadrats recorded 1,937 woody individuals under 4 inches dbh. Four species, *Ulmus fulva*, *Acer saccharum*, *Cercis canadensis*, and *Fraxinus americana*, accounted for more than half of all woody reproduction in these quadrats.

To obtain more reliable results, a full tally of the best-developed part of the *Quercus-Carya* Forest was added in 1960. This census was repeated in the late 1970 on the same area. The results of these surveys are compared in Figure 2 for the moderate slopes and draws which make up over half of the full tally area and are considered most typical of this vegetation type. In this graph, density per acre is plotted against average basal area per tree for each of the major species. The area enclosed by each of the bars is therefore equal to the product of these two variables, average basal area per acre. It can readily be seen from this figure that significant gains in basal area per acre were made by *Fraxinus americana*, *Liriodendron tulipifera*, and *Juglans nigra* (+57.5, +32.3, and +18.0%, respectively) during the period 1960 to 1970. The largest losses were sustained by *Carya glabra*, *Fraxinus* *lanceolata,* and *Ulmus fulva* (−27.0, −36.2, and −36.3%, respectively). The loss of red elms is due mainly to Dutch elm disease.

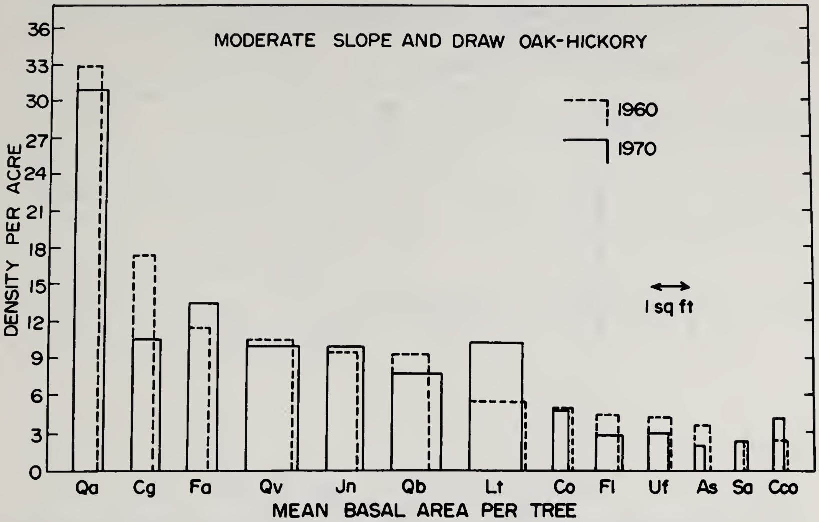

FIGURE 2. *Diagram comparing tree species of the moderate slopes and draws in the oak-hickory forest in 1960 and 1970. Abbreviations of species names from left to right are:* Qa—Quercus alba, Cg—Carya glabra, Fa—Fraxinus americana, Qv—Quercus velutina, Jn—Juglans nigra, Qb—Quercus borealis, Lt—Liriodendron tulipifera, Co—Carya ovata, Fl—Fraxinus lanceolata, Uf—Ulmus fulva, As—Acer saccharum, Sa—Sassafras albidum, and Cco—Carya cordiformis.

Figure 3 is a semilog plot of density per acre as related to size class for all trees over 4 inches dbh tallied in 1960 and 1970. The ideal curve for an all age stand would approach a straight line or a flat sigmoid shape (7). The loss of density per acre in the lower size classes may be a reflection of the damage done by grazing animals before the area was fenced in 1949.

Discussion

The *Poa-Andropogon-Rubus* Upland, in the first decade of this series, progressed from a perennial grass and forb stage to a young woodland in which *Ulmus, Fraxinus,* and *Acer* were predominant. During the period 1960 to 1971, *Poa compressa* remained dominant in the herbaceous layer while *Rubus flagellaris* declined significantly and *Andropogon virginicus* disappeared from the permanent quadrats altogether. Other species, such as *Solidago* ssp. and *Monarda fistulosa,* evidently flourished earlier in the decade but are now declining also as the woody invaders begin to form a fairly dense canopy over much of the area. As this shading progresses, other more tolerant species such as *Phyrma leptostachya, Sanicula canadensis,* and *Botrychium virginianum* are moving into the understory from the adjacent forest. *Liriodendron tulipifera,* which represented only 2% of the total number in the woody quadrats in 1960, has been more successful in invading this area since that time. In a census of the central part of the field (2.4 acres) in 1971, *Liriodendron* was the major dominant, with 42.2% density.

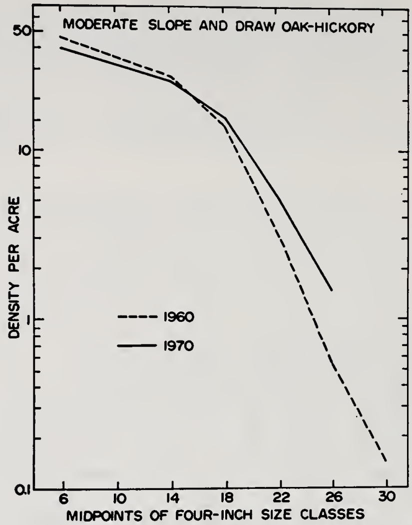

FIGURE 3. *Semilog plot of density per acre of all species, by size class, for all trees over 4 inches dbh in the moderate slopes and draws of the oak-hickory forest.*

The net above-ground community productivity of the *Poa-Andropogon-Rubus* Upland, as measured by the harvest method, shows the area to be very productive. Productivity will probably increase as community structure continues to develop and the young forest stage is approached.

The *Quercus-Carya* Forest is also in a state of transition but the changes are less pronounced and more difficult to assess. There has been an increase in the importance of several of the more mesophytic species. Among these are *Liriodendron tulipifera*, *Fraxinus americana*, and *Juglans nigra*. Conversely, the more xerophytic species, such as the oaks and hickories, have either declined (*e.g.*, *Carya glabra*) or remained essentially static in relation to other species.

The area seems to be recovering from two forms of disturbance. The small but steady increase in numbers of large trees (Fig. 2) indicates recovery from logging operations at some unknown time. The decline in numbers of smaller trees, on the other hand, indicates recovery from a disturbance affecting only young trees in the not too distant past. The most likely cause would be the grazing and browsing by domestic animals before the Reserve was fenced in 1949.

Sugar maple has not shown many indications of future importance in the *Quercus-Carya* Forest and beech is confined largely to the moist ravine slopes. However, if the trend favoring the more mesophytic species continues, it may be assumed that, in all but the very sandy, xeric sites, the forest will gradually move toward a Beech-Maple climax association.

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